# National Greenhouse Gas Inventory Report of JAPAN

**2020**

**Ministry of the Environment, Japan**
**Greenhouse Gas Inventory Office of Japan (GIO), CGER, NIES**

**Center for Global Environmental Research**

**National Institute for Environmental Studies, Japan**

## National Greenhouse Gas Inventory Report of JAPAN (2020)

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# Foreword

On the basis of Article 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Decision 2/CMP.8, all Parties to the Convention and the Kyoto Protocol are required to submit national inventories of greenhouse gas emissions and removals. Therefore, the inventories on emissions and removals of greenhouse gases and precursors are reported in the Common Reporting Format (CRF) and in this National Inventory Report, in accordance with the UNFCCC Inventory Reporting Guidelines (Decision 24/CP.19 Annex I) and Decision 2/CMP.8.

This Report presents Japan's national inventory arrangements, the estimation methods of greenhouse gas emissions and removals from sources and sinks, and the trends in emissions and removals for greenhouse gases (carbon dioxide [$CO_2$]; methane [$CH_4$]; nitrous oxide [$N_2O$]; hydrofluorocarbons [HFCs]; perfluorocarbons [PFCs]; sulfur hexafluoride [$SF_6$]; nitrogen trifluoride [$NF_3$], and indirect $CO_2$), precursors (nitrogen oxides [$NO_X$], carbon monoxide [CO], non-methane volatile organic compounds [NMVOC]), and sulfur oxides [$SO_x$]. Supplementary information under Article 7.1 of the Kyoto Protocol is presented as well.

The structure of this report is prepared in line with the structure specified in the Appendix of the UNFCCC Inventory Reporting Guidelines.

The Executive Summary focuses on the latest trends in emissions and removals of greenhouse gases in Japan. Chapter 1 deals with background information on greenhouse gas inventories, national inventory arrangements, the inventory preparation process, methodologies and data sources used, key category analysis, QA/QC plan, and results of uncertainty assessment. Chapter 2 describes the latest information on trends in emissions and removals of greenhouse gases in Japan. Chapters 3 to 7 provide the details of estimation methods for the sources and sinks described in the 2006 IPCC Guidelines. Chapter 8 comprises current status of reporting of the emissions from sources not covered by these guidelines. Chapter 9 provides the current status of reporting of indirect emissions of $CO_2$ and $N_2O$. Chapter 10 provides the explanations on improvements and recalculations (data revision, addition of new categories, etc.) made since the previous submission, and Chapters 11 through 15 provide supplementary information under Article 7.1 of the Kyoto Protocol. Annexes offer additional information to assist further understanding of Japan's inventory.

For the latest updates or changes in data, refer to the web-site (URL: www-gio.nies.go.jp) of the Greenhouse Gas Inventory Office of Japan (GIO).

April, 2020
Decarbonized Society Promotion Office
Global Environment Bureau
Ministry of the Environment

# Preface

The GHG inventory of Japan including this report represents the combined knowledge of 60 experts in a range of fields from universities, industrial bodies, regional governments, relevant government departments and agencies, and relevant research institutes, who are members of the Committee for the Greenhouse Gas Emissions Estimation Methods established by the Environment Agency (the current Ministry of the Environment) in November 1999 and held every year since.

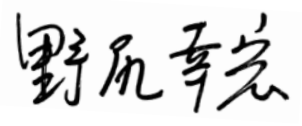
In compiling the GHG inventory, the Greenhouse Gas Inventory Office of Japan (GIO) would like to acknowledge the contribution not only of the Committee members in seeking to develop the methodology, but of other experts who provided the latest scientific knowledge, the industrial bodies and government departments and agencies that provided the data necessary for compiling the inventory. We would like to express our gratitude to the Decarbonized Society Promotion Office of the Global Environment Bureau of the Ministry of the Environment, for their support to GIO.

Upon preparation of this report, we have made further efforts to improve it through receiving feedback from many internal and external experts. We hope this report will be used widely and accurately as an index of what Japan should accomplish with regard to emission reductions under the Paris Agreement and other international obligations, and as an index that shows the extent of Japan's measures implemented against global warming.

My appreciation also extends to Ms. Akiko Tanaka who worked with us until last summer and worked hard to prepare earlier reports and provide input to the preliminary stages of the preparation of this report.

I also thank Ms. Naoko Ikeda, together with Ms. Mutsuko Fujii, Ms. Yoko Owai, and Ms. Kumiko Shiba, our assistants, who supported us with the smooth operation of GIO.

April, 2020



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# Executive Summary of the National GHG Inventory Report of Japan

## E.S.1. Background Information on the GHG Inventory

Japan reports its Greenhouse Gas (GHG) Inventory, which contains the information on emissions and removals of GHGs, including indirect GHGs and $SO_x$ in Japan for FY1990 to FY2018[1], on the basis of Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Decision 2/CMP.8.

Estimation methodologies of GHGs inventories are required to be in line with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter, *2006 IPCC Guidelines*) which was made by the Intergovernmental Panel on Climate Change (IPCC), and Japan's estimation methodologies are basically in line with these guidelines. In order to enhance transparency, consistency, comparability, completeness and accuracy of inventory, Japan also applies the *2013 Supplement to the 2006 IPCC Guidelines: Wetlands (Wetlands Guidelines)* and *the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement (2013))*.

Japan's national inventory is reported in accordance with the *UNFCCC Reporting Guidelines on Annual Inventories* (Decision 24/CP.19 Annex I, hereinafter referred to as the *UNFCCC Inventory Reporting Guidelines*) decided by the Conference of the Parties.

[1] "FY" (fiscal year), from April of the reporting year through March of the next year, is used because $CO_2$ is the primary GHGs emissions and estimated on a fiscal year basis. "CY" stands for "calendar year".

# E.S.2. Summary of National Emission and Removal Related Trends

## E.S.2.1. GHG Inventory

Total GHGs emissions[2] in FY2018 (excluding LULUCF[3], including indirect $CO_2$[4], hereafter, definition omitted) were 1,240 million tonnes (in $CO_2$ eq.). They decreased by 2.8% compared to the emissions in FY1990.

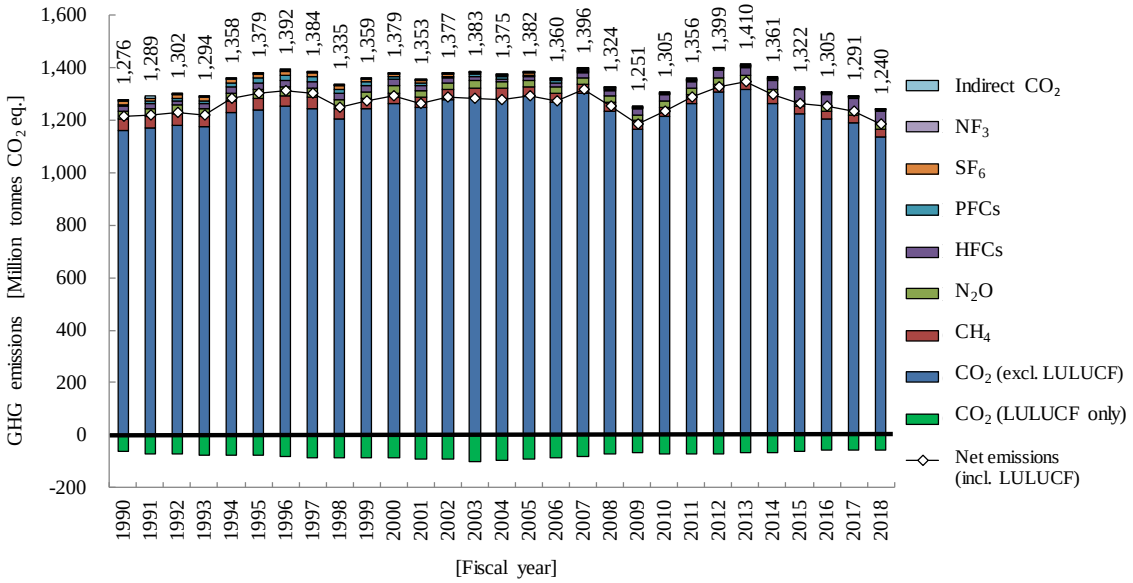


Figure 1 Trends in GHG emission and removals in Japan

[2] The sum of $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, and $NF_3$ emissions converted to $CO_2$ equivalents multiplied by their respective global warming potential (GWP). The GWP is a coefficient by means of which greenhouse gas effects of a given gas are made relative to those of an equivalent amount of $CO_2$. The coefficients are drawn from the *Fourth Assessment Report* (2007) issued by the IPCC.

[3] Abbreviation of "Land Use, Land-Use Change and Forestry"

[4] Carbon monoxide (CO), methane ($CH_4$) and non-methane volatile organic compounds (NMVOC) are oxidized in the atmosphere in the long term and converted to $CO_2$. Indirect $CO_2$ means value in $CO_2$ equivalent of these emissions. However, emissions of derived from combustion origin and biomass origin of CO, $CH_4$ and NMVOC are excluded to avoid double counting and/or by concept of carbon neutral.

## Table 1 Trends in GHGs emission and removals in Japan

| [Million tonnes $CO_2$ eq.] | GWP | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ (excl. LULUCF) *1 | 1 | 1,158.4 | 1,170.1 | 1,179.7 | 1,172.6 | 1,227.6 | 1,239.9 | 1,251.9 | 1,245.1 | 1,205.4 | 1,242.0 |
| $CO_2$ (incl. LULUCF) *1 | 1 | 1,095.9 | 1,099.5 | 1,106.1 | 1,095.9 | 1,151.1 | 1,162.5 | 1,169.8 | 1,160.7 | 1,119.6 | 1,156.0 |
| $CO_2$ (LULUCF only) | 1 | -62.5 | -70.6 | -73.6 | -76.7 | -76.4 | -77.4 | -82.0 | -84.4 | -85.8 | -86.0 |
| $CH_4$ (excl. LULUCF) | 25 | 44.4 | 43.3 | 44.1 | 40.0 | 43.4 | 41.9 | 40.7 | 40.0 | 38.1 | 38.0 |
| $CH_4$ (incl. LULUCF) | 25 | 44.5 | 43.4 | 44.2 | 40.1 | 43.5 | 42.0 | 40.8 | 40.1 | 38.2 | 38.1 |
| $N_2O$ (excl. LULUCF) | 298 | 31.9 | 31.6 | 31.8 | 31.6 | 32.9 | 33.2 | 34.3 | 35.1 | 33.5 | 27.4 |
| $N_2O$ (incl. LULUCF) | 298 | 32.1 | 31.8 | 32.0 | 31.8 | 33.1 | 33.4 | 34.5 | 35.3 | 33.7 | 27.6 |
| HFCs | HFC-134a: 1,430 etc. | 15.9 | 17.3 | 17.8 | 18.1 | 21.1 | 25.2 | 24.6 | 24.4 | 23.7 | 24.4 |
| PFCs | PFC-14: 7,390 etc. | 6.5 | 7.5 | 7.6 | 10.9 | 13.4 | 17.6 | 18.3 | 20.0 | 16.6 | 13.1 |
| $SF_6$ | 22,800 | 12.9 | 14.2 | 15.6 | 15.7 | 15.0 | 16.4 | 17.0 | 14.5 | 13.2 | 9.2 |
| $NF_3$ | 17,200 | 0.03 | 0.03 | 0.03 | 0.04 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| Indirect $CO_2$ | 1 | 5.5 | 5.3 | 5.1 | 4.8 | 4.8 | 4.7 | 4.7 | 4.6 | 4.2 | 4.2 |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | | 1,270.0 | 1,284.0 | 1,296.7 | 1,289.1 | 1,353.4 | 1,374.5 | 1,387.0 | 1,379.3 | 1,330.8 | 1,354.4 |
| Net Total (including LULUCF, excluding indirect $CO_2$) | | 1,207.8 | 1,213.7 | 1,223.4 | 1,212.7 | 1,277.3 | 1,297.4 | 1,305.3 | 1,295.2 | 1,245.2 | 1,268.6 |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | | 1,275.5 | 1,289.3 | 1,301.7 | 1,293.9 | 1,358.2 | 1,379.2 | 1,391.7 | 1,383.9 | 1,334.9 | 1,358.5 |
| Net Total (including LULUCF, including indirect $CO_2$) | | 1,213.3 | 1,219.0 | 1,228.4 | 1,217.5 | 1,282.1 | 1,302.1 | 1,310.0 | 1,299.8 | 1,249.4 | 1,272.8 |

| [Million tonnes $CO_2$ eq.] | GWP | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ (excl. LULUCF) *1 | 1 | 1,264.8 | 1,250.2 | 1,279.5 | 1,287.6 | 1,282.9 | 1,290.1 | 1,266.8 | 1,302.5 | 1,231.9 | 1,162.6 |
| $CO_2$ (incl. LULUCF) *1 | 1 | 1,176.8 | 1,161.7 | 1,189.4 | 1,187.4 | 1,186.2 | 1,198.6 | 1,180.8 | 1,221.1 | 1,160.7 | 1,095.5 |
| $CO_2$ (LULUCF only) | 1 | -88.0 | -88.6 | -90.0 | -100.3 | -96.7 | -91.5 | -86.1 | -81.5 | -71.2 | -67.2 |
| $CH_4$ (excl. LULUCF) | 25 | 38.0 | 37.1 | 36.4 | 35.0 | 36.0 | 35.8 | 35.3 | 35.5 | 35.2 | 34.3 |
| $CH_4$ (incl. LULUCF) | 25 | 38.1 | 37.2 | 36.5 | 35.1 | 36.1 | 35.9 | 35.3 | 35.6 | 35.3 | 34.4 |
| $N_2O$ (excl. LULUCF) | 298 | 29.9 | 26.3 | 25.7 | 25.6 | 25.4 | 25.0 | 24.8 | 24.2 | 23.4 | 22.7 |
| $N_2O$ (incl. LULUCF) | 298 | 30.1 | 26.5 | 25.9 | 25.8 | 25.6 | 25.2 | 25.0 | 24.4 | 23.6 | 22.9 |
| HFCs | HFC-134a: 1,430 etc. | 22.9 | 19.5 | 16.2 | 16.2 | 12.4 | 12.8 | 14.6 | 16.7 | 19.3 | 20.9 |
| PFCs | PFC-14: 7,390 etc. | 11.9 | 9.9 | 9.2 | 8.9 | 9.2 | 8.6 | 9.0 | 7.9 | 5.7 | 4.0 |
| $SF_6$ | 22,800 | 7.0 | 6.1 | 5.7 | 5.4 | 5.3 | 5.0 | 5.2 | 4.7 | 4.2 | 2.4 |
| $NF_3$ | 17,200 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 1.5 | 1.4 | 1.6 | 1.5 | 1.4 |
| Indirect $CO_2$ | 1 | 4.2 | 3.8 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 2.7 | 2.5 |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | | 1,374.8 | 1,349.3 | 1,373.2 | 1,379.1 | 1,371.7 | 1,378.8 | 1,357.2 | 1,393.2 | 1,321.2 | 1,248.4 |
| Net Total (including LULUCF, excluding indirect $CO_2$) | | 1,287.0 | 1,261.1 | 1,283.5 | 1,279.1 | 1,275.3 | 1,287.6 | 1,271.4 | 1,312.0 | 1,250.3 | 1,181.5 |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | | 1,379.0 | 1,353.1 | 1,376.7 | 1,382.5 | 1,375.0 | 1,382.0 | 1,360.3 | 1,396.2 | 1,323.9 | 1,250.9 |
| Net Total (including LULUCF, including indirect $CO_2$) | | 1,291.2 | 1,264.9 | 1,287.0 | 1,282.5 | 1,278.6 | 1,290.8 | 1,274.5 | 1,315.0 | 1,253.0 | 1,184.0 |

| [Million tonnes $CO_2$ eq.] | GWP | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Changes in emissions/removals (2018) 1990 | Changes in emissions/removals (2018) Previous year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ (excl. LULUCF) *1 | 1 | 1,214.1 | 1,264.2 | 1,305.4 | 1,314.7 | 1,263.0 | 1,222.8 | 1,203.2 | 1,187.7 | 1,135.7 | -2.0% | -4.4% |
| $CO_2$ (incl. LULUCF) *1 | 1 | 1,143.4 | 1,194.2 | 1,232.4 | 1,248.4 | 1,198.4 | 1,163.1 | 1,148.6 | 1,128.8 | 1,078.0 | -1.6% | -4.5% |
| $CO_2$ (LULUCF only) | 1 | -70.7 | -69.9 | -73.0 | -66.3 | -64.6 | -59.6 | -54.5 | -58.8 | -57.7 | -7.8% | -2.0% |
| $CH_4$ (excl. LULUCF) | 25 | 34.8 | 33.8 | 32.9 | 32.5 | 31.9 | 31.1 | 30.7 | 30.2 | 29.9 | -32.8% | -1.3% |
| $CH_4$ (incl. LULUCF) | 25 | 34.9 | 33.9 | 33.0 | 32.6 | 32.0 | 31.1 | 30.8 | 30.3 | 29.9 | -32.8% | -1.3% |
| $N_2O$ (excl. LULUCF) | 298 | 22.2 | 21.8 | 21.5 | 21.5 | 21.1 | 20.7 | 20.2 | 20.4 | 20.0 | -37.3% | -2.0% |
| $N_2O$ (incl. LULUCF) | 298 | 22.4 | 22.0 | 21.7 | 21.7 | 21.3 | 20.9 | 20.4 | 20.6 | 20.2 | -37.1% | -2.0% |
| HFCs | HFC-134a: 1,430 etc. | 23.3 | 26.1 | 29.4 | 32.1 | 35.8 | 39.3 | 42.6 | 44.9 | 47.0 | 194.9% | 4.7% |
| PFCs | PFC-14: 7,390 etc. | 4.2 | 3.8 | 3.4 | 3.3 | 3.4 | 3.3 | 3.4 | 3.5 | 3.5 | -46.7% | -0.7% |
| $SF_6$ | 22,800 | 2.4 | 2.2 | 2.2 | 2.1 | 2.0 | 2.1 | 2.2 | 2.1 | 2.0 | -84.1% | -1.3% |
| $NF_3$ | 17,200 | 1.5 | 1.8 | 1.5 | 1.6 | 1.1 | 0.6 | 0.6 | 0.4 | 0.3 | 766.3% | -37.2% |
| Indirect $CO_2$ | 1 | 2.4 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | -62.4% | -0.7% |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | | 1,302.5 | 1,353.6 | 1,396.3 | 1,407.8 | 1,358.3 | 1,319.8 | 1,302.8 | 1,289.2 | 1,238.3 | -2.5% | -3.9% |
| Net Total (including LULUCF, excluding indirect $CO_2$) | | 1,232.1 | 1,283.9 | 1,323.6 | 1,341.8 | 1,294.0 | 1,260.4 | 1,248.6 | 1,230.7 | 1,181.0 | -2.2% | -4.0% |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | | 1,305.0 | 1,355.9 | 1,398.6 | 1,410.1 | 1,360.5 | 1,322.0 | 1,305.0 | 1,291.3 | 1,240.4 | -2.8% | -3.9% |
| Net Total (including LULUCF, including indirect $CO_2$) | | 1,234.5 | 1,286.3 | 1,325.8 | 1,344.0 | 1,296.2 | 1,262.6 | 1,250.7 | 1,232.8 | 1,183.0 | -2.5% | -4.0% |

*1 Excluding indirect $CO_2$

*2 LULUCF: Land Use, Land-Use Change and Forestry

### E.S.2.2. KP-LULUCF Activities

In accordance with the decision 2/CMP.8 in paragraph 4 adopted by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP8), Japan reports afforestation/reforestation (AR), deforestation (D), forest management (FM), cropland management (CM), grazing land management (GM), and revegetation (RV) as LULUCF activities under article 3, paragraphs 3 and 4 of the Kyoto Protocol for the second commitment period[5]. The breakdown of emissions and removals for each activity is shown in Table 2. For detailed information, see Chapter 11.

Table 2 Accounting summary for activities under articles 3.3 and 3.4 of the Kyoto Protocol
(CRF Accounting table)

| GREENHOUSE GAS SOURCE AND SINK ACTIVITIES | Base Year (1990) | NET EMISSIONS/REMOVALS | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| | (kt $CO_2$ eq) | | | | | | |
| A. Article 3.3 activities | | | | | | | |
| A.1. Afforestation/reforestation | | -1558 | -1563 | -1562 | -1562 | -1536 | -1442 |
| Excluded emissions from natural disturbances | | NA | NA | NA | NA | NA | NA |
| Excluded subsequent removals from land subject to natural disturbances | | NA | NA | NA | NA | NA | NA |
| A.2. Deforestation | | 2049 | 2055 | 2274 | 2275 | 1611 | 1605 |
| B. Article 3.4 activities | | | | | | | |
| B.1. Forest management | | | | | | | |
| Net emissions/removals | | -51149 | -51449 | -49216 | -46650 | -46469 | -45361 |
| Excluded emissions from natural disturbances | | NA | NA | NA | NA | NA | NA |
| Excluded subsequent removals from land subject to natural disturbances | | NA | NA | NA | NA | NA | NA |
| Any debits from newly established forest (CEF-ne) | | NA | NA | NA | NA | NA | NA |
| Forest management reference level (FMRL) | | 0 | 0 | 0 | 0 | 0 | 0 |
| Technical corrections to FMRL | | 1069 | 1252 | 1404 | 1544 | 1687 | 1821 |
| Forest management cap | | | | | | | |
| B.2. Cropland management | 10265 | 3693 | 4476 | 4413 | 4917 | 4139 | 3721 |
| B.3. Grazing land management | 840 | -190 | 9 | -70 | -118 | -127 | -209 |
| B.4. Revegetation | -82 | -1228 | -1247 | -1267 | -1285 | -1308 | -1322 |
| B.5. Wetland drainage and rewetting (not elected) | NA | NA | NA | NA | NA | NA | NA |

* The total values and results of summing up each element are not always the same because of the difference in display digit.

[5] The emissions/removals occurring from Kyoto Protocol Article 3.3. and 3.4 activities correspond to a part of the LULUCF emission/removals reported under the Convention. Detailed information on LULUCF under the Convention can be found in chapter 6 of this report, and the same for KP-LULUCF activities can be found in chapter 11.

# E.S.3. Overview of Source and Sink Category Emission Estimates and Trends

## E.S.3.1. GHG Inventory

The breakdown of GHGs emissions and removals in FY2018 by sector[6] shows that the energy (excluding indirect $CO_2$) accounts for 87.5% of total GHGs emissions. It is followed by the industrial processes and product use sector (excluding indirect $CO_2$) (8.1%), the agriculture sector (2.7%), the waste sector (1.6%), and indirect $CO_2$ emissions (0.2%).

Removals by the LULUCF in FY2018 were equivalent to 4.6% of total GHGs emissions.

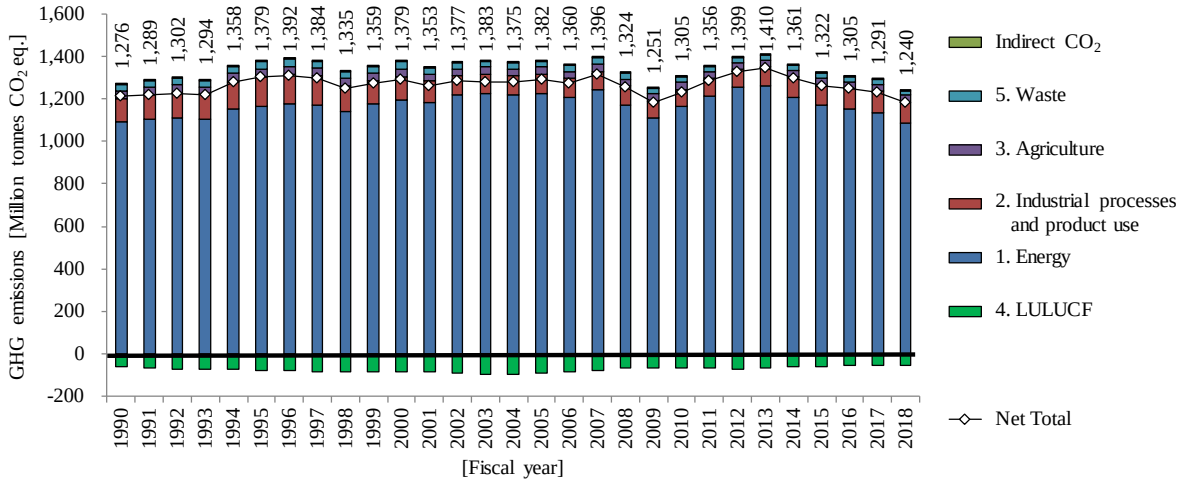


Figure 2 Trends in GHGs emissions and removals in each sector

[6] As indicated in the *2006 IPCC Guidelines* and the CRF.

Table 3 Trends in GHGs emissions and removals in each sector

| [Million tonnes $CO_2$ eq.] | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Energy[*1] | 1,091.9 | 1,102.2 | 1,110.6 | 1,104.5 | 1,155.3 | 1,167.4 | 1,178.2 | 1,173.4 | 1,139.4 | 1,176.0 |
| 2. Industrial processes and product use[*1] | 110.9 | 115.4 | 117.3 | 119.4 | 127.0 | 137.1 | 139.3 | 136.3 | 123.6 | 110.9 |
| 3. Agriculture | 37.4 | 36.7 | 37.9 | 34.7 | 38.3 | 37.0 | 36.2 | 35.9 | 34.5 | 34.7 |
| 4. LULUCF[*2] | -62.2 | -70.3 | -73.3 | -76.4 | -76.1 | -77.1 | -81.7 | -84.1 | -85.5 | -85.7 |
| 5. Waste | 29.7 | 29.7 | 30.9 | 30.4 | 32.9 | 33.1 | 33.3 | 33.7 | 33.3 | 32.7 |
| Indirect $CO_2$ | 5.5 | 5.3 | 5.1 | 4.8 | 4.8 | 4.7 | 4.7 | 4.6 | 4.2 | 4.2 |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | 1,270.0 | 1,284.0 | 1,296.7 | 1,289.1 | 1,353.4 | 1,374.5 | 1,387.0 | 1,379.3 | 1,330.8 | 1,354.4 |
| Net Total (including LULUCF, excluding indirect $CO_2$) | 1,207.8 | 1,213.7 | 1,223.4 | 1,212.7 | 1,277.3 | 1,297.4 | 1,305.3 | 1,295.2 | 1,245.2 | 1,268.6 |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | 1,275.5 | 1,289.3 | 1,301.7 | 1,293.9 | 1,358.2 | 1,379.2 | 1,391.7 | 1,383.9 | 1,334.9 | 1,358.5 |
| Net Total (including LULUCF, including indirect $CO_2$) | 1,213.3 | 1,219.0 | 1,228.4 | 1,217.5 | 1,282.1 | 1,302.1 | 1,310.0 | 1,299.8 | 1,249.4 | 1,272.8 |

| [Million tonnes $CO_2$ eq.] | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Energy[*1] | 1,198.0 | 1,185.7 | 1,217.4 | 1,226.1 | 1,221.8 | 1,228.5 | 1,205.7 | 1,241.8 | 1,174.2 | 1,112.6 |
| 2. Industrial processes and product use[*1] | 109.0 | 98.0 | 91.1 | 89.7 | 86.3 | 87.4 | 90.2 | 89.3 | 84.9 | 77.5 |
| 3. Agriculture | 35.3 | 34.8 | 35.0 | 34.0 | 35.1 | 35.2 | 35.0 | 36.1 | 35.5 | 34.8 |
| 4. LULUCF[*2] | -87.8 | -88.3 | -89.7 | -100.0 | -96.4 | -91.2 | -85.8 | -81.2 | -70.9 | -66.9 |
| 5. Waste | 32.5 | 30.8 | 29.7 | 29.4 | 28.5 | 27.7 | 26.3 | 26.0 | 26.6 | 23.5 |
| Indirect $CO_2$ | 4.2 | 3.8 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 2.7 | 2.5 |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | 1,374.8 | 1,349.3 | 1,373.2 | 1,379.1 | 1,371.7 | 1,378.8 | 1,357.2 | 1,393.2 | 1,321.2 | 1,248.4 |
| Net Total (including LULUCF, excluding indirect $CO_2$) | 1,287.0 | 1,261.1 | 1,283.5 | 1,279.1 | 1,275.3 | 1,287.6 | 1,271.4 | 1,312.0 | 1,250.3 | 1,181.5 |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | 1,379.0 | 1,353.1 | 1,376.7 | 1,382.5 | 1,375.0 | 1,382.0 | 1,360.3 | 1,396.2 | 1,323.9 | 1,250.9 |
| Net Total (including LULUCF, including indirect $CO_2$) | 1,291.2 | 1,264.9 | 1,287.0 | 1,282.5 | 1,278.6 | 1,290.8 | 1,274.5 | 1,315.0 | 1,253.0 | 1,184.0 |

| [Million tonnes $CO_2$ eq.] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Energy[*1] | 1,162.6 | 1,213.3 | 1,253.7 | 1,261.1 | 1,210.5 | 1,171.6 | 1,152.7 | 1,137.0 | 1,085.7 |
| 2. Industrial processes and product use[*1] | 80.7 | 82.7 | 85.2 | 89.5 | 92.1 | 93.2 | 96.2 | 99.0 | 100.1 |
| 3. Agriculture | 35.9 | 35.3 | 34.8 | 34.8 | 34.2 | 33.6 | 33.5 | 33.4 | 33.3 |
| 4. LULUCF[*2] | -70.4 | -69.7 | -72.7 | -66.0 | -64.3 | -59.4 | -54.3 | -58.5 | -57.4 |
| 5. Waste | 23.3 | 22.4 | 22.7 | 22.4 | 21.5 | 21.3 | 20.4 | 19.9 | 19.3 |
| Indirect $CO_2$ | 2.4 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | 1,302.5 | 1,353.6 | 1,396.3 | 1,407.8 | 1,358.3 | 1,319.8 | 1,302.8 | 1,289.2 | 1,238.3 |
| Net Total (including LULUCF, excluding indirect $CO_2$) | 1,232.1 | 1,283.9 | 1,323.6 | 1,341.8 | 1,294.0 | 1,260.4 | 1,248.6 | 1,230.7 | 1,181.0 |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | 1,305.0 | 1,355.9 | 1,398.6 | 1,410.1 | 1,360.5 | 1,322.0 | 1,305.0 | 1,291.3 | 1,240.4 |
| Net Total (including LULUCF, including indirect $CO_2$) | 1,234.5 | 1,286.3 | 1,325.8 | 1,344.0 | 1,296.2 | 1,262.6 | 1,250.7 | 1,232.8 | 1,183.0 |

*1 Excluding indirect $CO_2$

*2 LULUCF: Land Use, Land-Use Change and Forestry

### E.S.3.2. KP-LULUCF Activities

See section 2.2 of this executive summary.

# Chapter 1. Introduction

## 1.1. Background Information on Japan's Greenhouse Gas Inventory and Climate Change

Japan hereby reports its greenhouse gas (GHG) inventory, which contains information on emissions and removals of GHGs, including precursors (nitrogen oxides [$NO_X$], carbon monoxide [CO], non-methane volatile organic compounds [NMVOC]), and sulfur oxides ($SO_x$) in Japan from FY1990 to FY2018[1], on the basis of Article 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Decision 2/CMP.8.

Estimation methodologies for the GHG inventories are required to be in line with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 IPCC Guidelines*), which was prepared by the Intergovernmental Panel on Climate Change (IPCC), and Japan's estimation methodologies are basically in line with these guidelines. In order to enhance transparency, consistency, comparability, completeness, and accuracy of the inventory, Japan also applies the *2013 Supplement to the 2006 IPCC Guidelines: Wetlands (Wetlands Guidelines)* and *the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement (2013))*.

Japan's national inventory is reported in accordance with the *UNFCCC Reporting Guidelines on Annual Greenhouse Gas Inventories* (Decision 24/CP.19 Annex I, hereinafter referred to as the *UNFCCC Inventory Reporting Guidelines*) decided by the Conference of the Parties.

## 1.2. Description of Japan's National Inventory Arrangements

### 1.2.1. Institutional, Legal and Procedural Arrangements

#### 1.2.1.1. Institutional and legal Arrangement for the Inventory Preparation

The government of Japan is to calculate the emissions and removals of GHGs for Japan and disclose the results every year, in accordance with Article 7 of Chapter 1 "General Provisions", the Act on Promotion of Global Warming Countermeasures,[2] which determines the domestic measures for the UNFCCC and Kyoto Protocol. The Ministry of the Environment (MOE), with the cooperation of relevant ministries, agencies and organizations, prepares Japan's national inventory and compiles supplementary information required under Decision 2/CMP.8, etc., which is annually submitted in accordance with the UNFCCC and the Kyoto Protocol.

The MOE assumes overall responsibilities for the national inventory and organizes the Committee for the Greenhouse Gas Emission Estimation Methods (Committee) in order to integrate the latest scientific knowledge into the inventory and to modify it to meet international requirements. The estimation of GHG emissions and removals are then carried out by taking the decisions of the Committee into consideration. Substantial activities, such as the estimation of emissions and removals and the preparation of the Common Reporting Format (CRF) tables and National Inventory Report (NIR), are done by the Greenhouse Gas Inventory Office of Japan (GIO), which belongs to the Center for Global Environmental Research of the National Institute for Environmental Studies. The relevant ministries, agencies and organizations provide the GIO with the appropriate data (e.g., activity data, emission

[1] "FY (fiscal year)" is used because the major part of $CO_2$ emission estimate is on the fiscal year basis (April to March).
[2] Enacted in October 1998. The latest amendment was made on May 27, 2016.

factors, and GHG emissions and removals) through compiling various statistics and providing relevant information on supplementary information required under Decision 2/CMP.8, etc. The relevant ministries and agencies check the inventories (i.e., CRF, NIR), including the spreadsheets that are actually utilized for the estimation (Japan National Greenhouse gas Inventory files, hereinafter referred to as "JNGI files"), as a part of the Quality Control (QC) activities.

The checked inventories are determined as Japan's official GHG emission/removal values. The inventories are then published and submitted to the UNFCCC Secretariat.

Figure 1-1 shows the overall institutional arrangement for Japan's inventory preparation. More detailed information on the roles and responsibilities of relevant ministries, agencies and organizations in the inventory preparation process is described below.

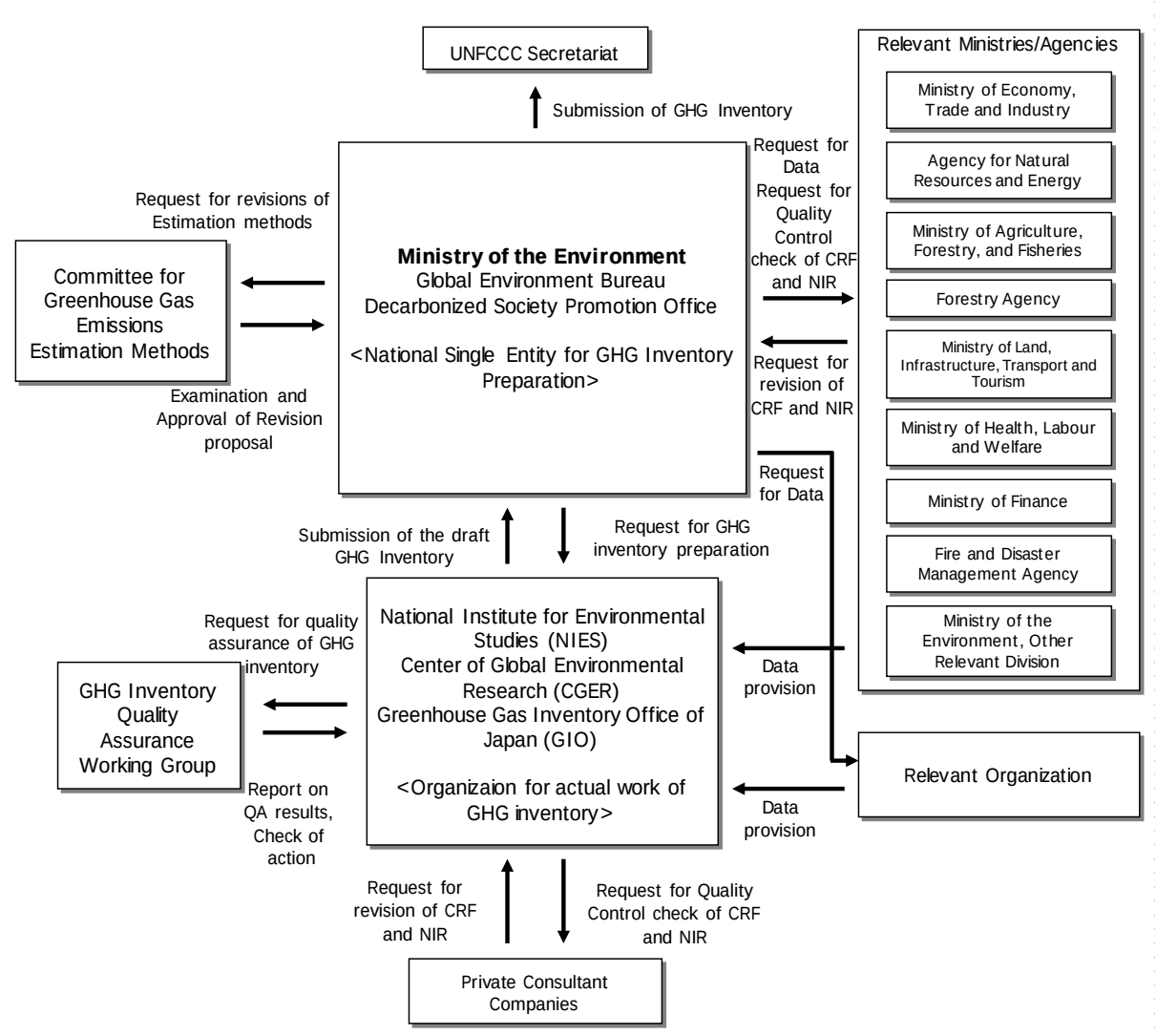


Figure 1-1 Japan's institutional arrangement for the national inventory preparation

#### 1.2.1.2. Roles and responsibilities of each entity involved in the inventory preparation process

The following are the agencies involved in the inventory compilation process, and the roles of those agencies.

***1) Ministry of the Environment (Decarbonized Society Promotion Office, Global Environment Bureau)***

- The single national agency responsible for preparing Japan's inventory, which was designated pursuant to the UNFCCC Inventory Reporting Guidelines and the Kyoto Protocol Article 5.1.
- It is responsible for editing and submitting the inventory.
- It coordinates the Quality Assurance and Quality Control (QA/QC) activities for the inventory.
- It checks and approves the QA/QC plan.
- It checks and approves the inventory improvement plan.

***2) Greenhouse Gas Inventory Office of Japan (GIO), Center for Global Environmental Research, National Institute for Environmental Studies***

- Performs the actual work of inventory compilation. Responsible for inventory calculations, editing, and the archiving and management of all data.
- Prepares the revised draft of the QA/QC plan.
- Prepares the draft of the inventory improvement plan.

***3) Relevant Ministries/Agencies***

The relevant ministries and agencies have the following roles and responsibilities regarding inventory compilation.

- Preparation and provision of data such as activity data and emission factors required for the preparation of the inventory.
- Confirmation of data provided for the preparation of the inventory.
- Confirmation of the inventory (CRF, NIR, JNGI files, and other information) prepared by the GIO (Category-specific QC).
- (When necessary), responding to questions from expert review teams (ERTs) about the statistics controlled by relevant ministries and agencies, or about certain data they have prepared, and preparing comments on draft reviews.
- (When necessary), responding to in-country review by ERTs.

***4) Relevant Organizations***

Relevant organizations have the following roles and responsibilities regarding inventory compilation.

- Preparation and provision of data such as activity data and emission factors required for the preparation of the inventory.
- Confirmation of data provided for the preparation of the inventory.

- (When necessary), responding to questions from ERTs about the statistics controlled by relevant organizations, or about certain data they have prepared, and preparing comments on draft review reports.

### *5) Committee for the Greenhouse Gas Emissions Estimation Methods*

The Committee for the Greenhouse Gas Emissions Estimation Methods (the Committee) is a committee created and run by the MOE. Its role is to consider the methods for calculating inventory emissions and removals, and consider the selection of parameters such as activity data (AD) and emission factors (EFs). Under the Committee, the inventory working group (WG) that examines cross-cutting issues, and breakout groups that consider sector-specific issues (Breakout group on Energy and Industrial Processes, Breakout group on Transport, Breakout group on F-gases [HFCs, PFCs, $SF_6$, and $NF_3$], Breakout group on Agriculture, Breakout group on Waste, Breakout group on LULUCF and Breakout group on NMVOC) are set up. The inventory WG and the breakout groups comprise experts in various fields, and consider suggestions for inventory improvements.

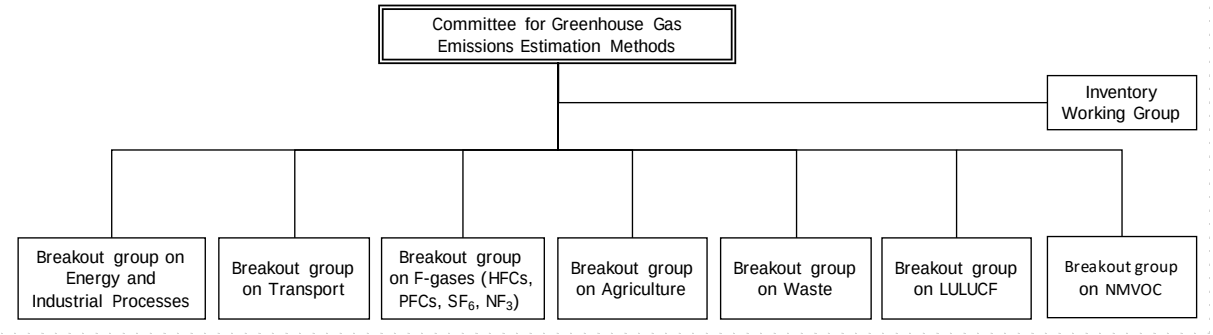


Figure 1-2 Structure of the Committee for the Greenhouse Gas Emissions Estimation Methods

### *6) Private Consulting Companies*

Private consultant companies that are contracted by the MOE to perform tasks related to inventory compilation play the following roles in inventory compilation based on their contracts.

- Quality Control (QC) of the inventory (CRF, NIR, JNGI files) compiled by the MOE and the GIO.
- (When necessary), providing support for responding to questions from ERTs and for preparing comments on draft reviews.
- (When necessary), providing support for responding to in-country review by ERTs.

### *7) GHG Inventory Quality Assurance Working Group (QAWG)*

The GHG Inventory Quality Assurance Working Group (the QAWG) is an organization for QA activities, and comprises experts who are not directly involved in inventory compilation. Its role is to assure inventory quality and to identify places that need improvement by conducting detailed reviews of each emission source and sink in the inventory.

## 1.2.1.3. Response for UNFCCC inventory review

The convention inventory and Kyoto Protocol supplementary information on sinks that Japan submits

each year are to be reviewed by an ERTs pursuant to UNFCCC inventory review guidelines (Decision 13/CP.20 Annex), Kyoto Protocol Article 8, Decision 22/CMP.1, and other requirements. Specifically, rigorous checks are performed from perspectives including: whether emissions and removals are accurately and completely estimated and reported, or whether transparent explanations are provided for estimation methods, or whether QA/QC activities and uncertainty assessments are performed appropriately in accordance with the designated guidelines[3].

In view of the fact that ensuring the transparency of the inventory is a matter of importance, since Japan does not have a reduction commitment under the second commitment period of the Kyoto Protocol, the system shown in Figure 1-3 is used for responding to reviews.

[Basic structure]

The MOE (Decarbonized Society Promotion Office, Global Environment Bureau), which in Japan is responsible for editing and submitting the inventory, is assigned to be the agency with overall control (responsibility) for review response, while the GIO performs the actual work, such as preparing source materials and communicating with the UNFCCC Secretariat. The relevant ministries and agencies, relevant organizations, and private consultant companies[4] that are involved in inventory compilation cooperate with review response through activities including providing relevant information, support for source material preparation, and QC implementation.

[3] UNFCCC Inventory Reporting Guidelines, *2006 IPCC Guidelines*, and the *KP Supplement (2013)*

[4] Private consultant companies cooperate in correspondence of the reviews based on the operating agreement with MOE.

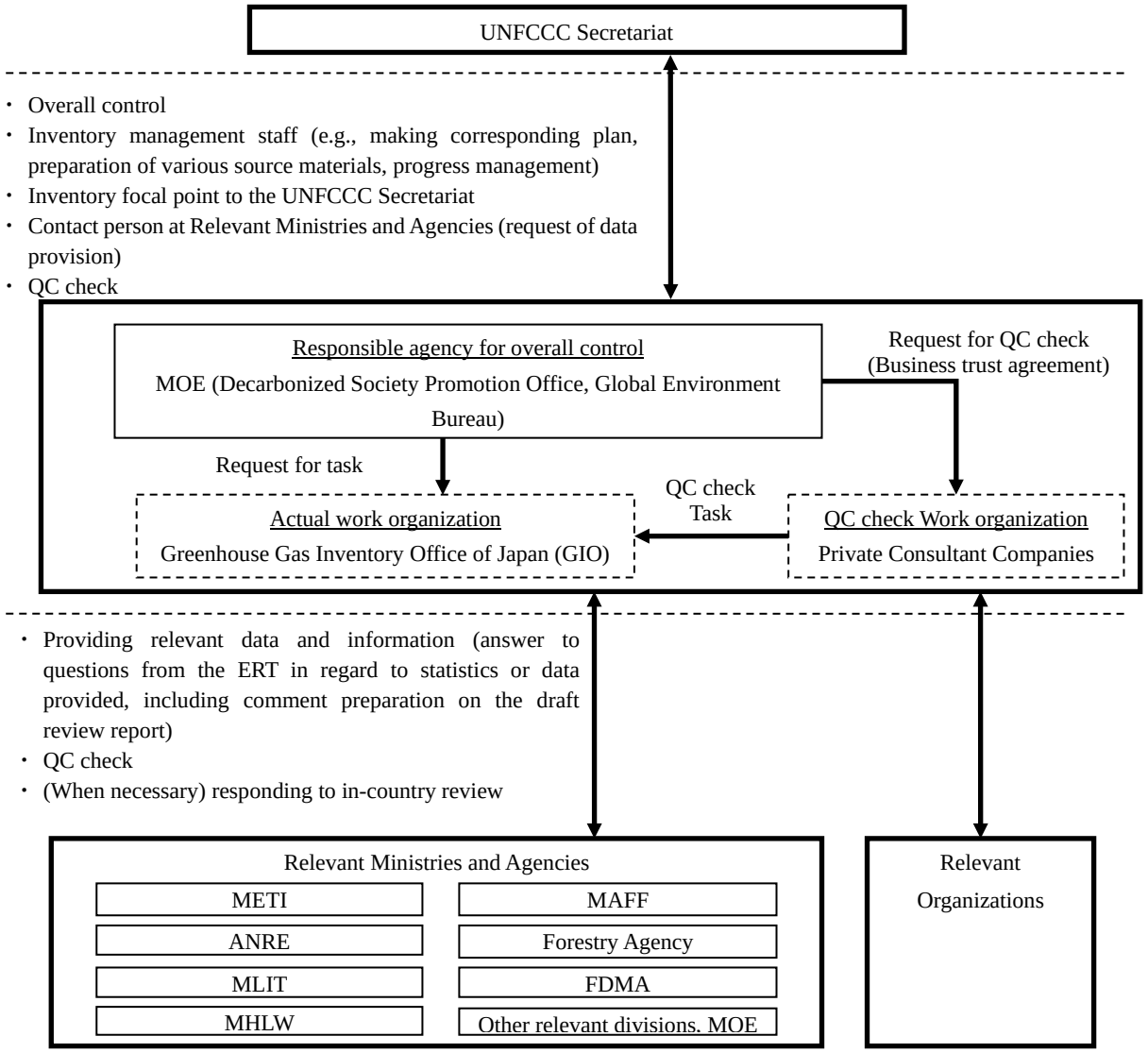


Figure 1-3 Basic structure of Japan's national system corresponding to inventory review

### 1.2.2. Overview of Inventory Planning, Preparation and Management

MOE (Decarbonized Society Promotion Office, Global Environment Bureau) is the single national agency responsible for preparing Japan's inventory, and the GIO performs the actual work of inventory compilation. Relevant ministries and organizations are also involved in the preparation of the inventory, mainly by preparing AD, EFs, and other data needed for inventory compilation. Private consulting companies are contracted by MOE to perform tasks related to QC of the inventory, mainly prepared by MOE and GIO.

The Committee, run by MOE, considers the methods, AD and EFs used. Under the Committee, the inventory WG that examines crosscutting issues, and breakout groups that consider sector-specific problems (Breakout group on Energy and Industrial Processes, Breakout group on Transport, Breakout group on F-gases, Breakout group on Agriculture, Breakout group on Waste, Breakout group on LULUCF and Breakout group on NMVOC) are set up.

The emissions and removals are prepared in accordance with the Inventory Reporting Guidelines (See

sectoral chapters for details). The key category analysis is performed in accordance with the *2006 IPCC Guidelines*, and both Approach 1 and 2 are applied (See section 1.5 for results). No additional key categories were identified using the qualitative approach. Key categories have been identified for activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol following the guidance on establishing the relationship between the activities under the Kyoto Protocol and the associated key categories in the UNFCCC inventory. The key category analysis is used to prioritize inventory improvements. The uncertainty analysis is carried out in accordance with the *2006 IPCC Guidelines*, and Approach 1 is applied (See section 1.6 for results).

QC procedures are used in the inventory and are documented as part of the QA/QC plan (See section 1.2.3 for details). As part of inventory QA, detailed reviews (expert peer reviews) are regularly performed by experts not directly involved in inventory compilation for each emission source and sink.

Japan has a centralized archiving system, which includes the archiving of disaggregated EFs and AD, and documentation on how these factors and data have been generated and aggregated for the preparation of the inventory. The archived information also includes internal documentation on QA/QC procedures, UNFCCC review and QA peer review, and documentation on annual key categories identification and planned inventory improvements. The archiving system is run by GIO and is comprised of electronic and paper versions of documents.

### 1.2.3. Quality Assurance, Quality Control and Verification Plan

#### 1.2.3.1. QA/QC Procedures Applied

When compiling the inventory in Japan, inventory quality is controlled by performing QC activities (such as checking the correctness of calculations and archiving of documents) at each step in accordance with *2006 IPCC Guidelines*. In Japan, the QC activities relating to inventory compilation performed by personnel belonging to agencies involved in inventory compilation—that is, the MOE (including the GIO and private consultant companies), relevant ministries and agencies—are considered to be QC. External reviews by experts who are outside the inventory compilation system are considered to be QA. They assess data quality from the perspectives of scientific knowledge and data availability with respect to current calculation methods. Table 1-1 sketches Japan's QA/QC activities.

Table 1-1 Summary of Japan's QA/QC activity

| | Implementing entity | Main contents of activity |
|---|---|---|
| QC (Quality Control) | Ministry of the Environment (Decarbonized Society Promotion Office, Global Environment Bureau) | ・Coordinating QA/QC activities for inventory preparation<br>・Checking and approving the QA/QC plan<br>・Checking and approving the inventory improvement plan |
| | Greenhouse Gas Inventory Office of Japan, Center for Global Environmental Research, National Institute for Environmental Studies (GIO) | ・Conducting general QC check<br>・Archiving QA/QC activity records and relevant data and documents<br>・Developing inventory improvement plan<br>・Revising QA/QC plan |
| | Relevant Ministry and Agencies | ・Checking data necessary for inventory preparation<br>・Checking JNGI files and inventory prepared by GIO (Category-specific QC) |
| | Committee for the Greenhouse Gas Emissions Estimation Methods | ・Discussing and assessing estimation methods, EFs, and AD (Category-specific QC) |
| | Private Consultant Companies | ・Checking JNGI files and inventory prepared by GIO (Category-specific QC) |
| QA (Quality Assurance) | Inventory Quality Assurance Working Group (QAWG) | ・Conducting expert peer review of inventory |

### 1.2.3.1.a. QC activity

#### *a) General QC procedures*

In accordance with Table 6.1, Chapter 6, Vol.1 of the *2006 IPCC Guidelines*, general QC procedures include the general items to be confirmed which are related to the calculation, data processing, completeness, and documentation applicable to all emission source and sink categories. General QC procedures are implemented by each inventory compiler.

Following are the QC activities conducted by GIO's sectoral experts (SEs), who perform the work of compiling the emissions/removals estimation files for each category, the CRF transition files and NIR; the National Inventory compiler (NIC), who integrates the information from the individual SEs and compiles the inventory; and the data providers, who provide the AD and other data used to calculate emissions and removals.

#### *1) Sectoral expert (SE)*

SEs perform mainly the following QC activities.

- Checking for transcription errors in data entry and referencing
- Checking to ensure that emissions are accurately estimated
- Checking to see that parameters and emission units are accurately recorded, and that proper conversion factors are used
- Checking the conformity of databases and/or files
- Checking the consistency of data from one category to another
- Checking the accuracy of inventory data behavior from one processing step to the next
- Checking completeness
- Checking time series consistency
- Checking trends
- Conducting comparisons with past estimated values
- Checking that uncertainties in emissions and removals are accurately estimated and calculated

- Carrying out reviews of internal documentation
- Checking that the assumptions and criteria for selecting AD and EFs are documented

***2) National inventory compiler (NIC)***

The NIC performs mainly the following QC activities.

- Confirming that CRF Reporter data provided by SEs are imported without omission
- Confirming that the information needed for the documentation box is properly entered
- Confirming that the reasons for "NE" and "IE" are correctly entered
- Confirming that the key category analysis results are correctly outputted
- Confirming that the reasons for recalculations are provided for all categories
- Confirming that emissions and removals are correctly aggregated
- Confirming that data are corrected after the coordination with the relevant ministries and agencies

***b) QC procedure for source and sink each category***

The following category-specific QC activities are performed in Japan:

***1) QC by private consultant companies (External QC)***

QC on the estimation files and CRF and NIR drafts prepared by the GIO, are performed by mutual checks of estimation results with private consultant companies, through the use of estimation files like those of the GIO, and confirming the data entered into estimation files for each source and sink category and the equations for calculating emissions and removal.

***2) QC through coordination with the relevant ministries and agencies (External QC)***

The relevant ministries and agencies are sent the sets of files for estimation, CRF, NIR, and the drafts of documents for domestic release showing estimated values for emissions and removals. Through this, category-specific QC is implemented for the content of categories relevant to each ministry or agency.

***3) Committee for the Greenhouse Gas Emissions Estimation Methods***

Since the Committee considers and selects the methodologies, AD and parameters including EFs, which are actually applied to the estimation of emissions/removals from each category, it also implements category-specific QC activities.

***c) QC activities of the documentation and archiving of inventory information***

GIO promptly implements QC activities of the documentation and archiving of inventory information, after the inventory submission to the UNFCCC.

### 1.2.3.1.b. QA activity

QA refers to assessment of inventory quality by third units that are not directly involved in inventory compilation. In Japan, the expert peer review is held by the GHG Inventory Quality Assurance Working Group (QAWG) as a QA activity, to assure inventory quality.

***a) GHG Inventory Quality Assurance Working Group (QAWG)***

***1) Summary***

The QAWG performs detailed reviews by experts (expert peer reviews) not directly involved in

inventory compilation for each emission source and sink in order to assure inventory quality and to identify places that need improvement.

The secretariat for the QAWG is established within the GIO. The secretariat and the MOE determine the sectors/categories to be reviewed by the QAWG. The experts for the QAWG are selected by taking the following requirements into account.

<Requirements for QAWG review experts>

a. No direct involvement in the inventory preparation process for estimating emissions/ removals from the sectors/categories to be reviewed (i.e., no involvement in the Committee, the data creation and the data provision for those sectors/categories)
b. No specific interests related to the inventory and the capability to judge objectively without being affected by any specific organizations and/or stakeholders
c. Sufficient skills, knowledge and experiences to assure the quality of the inventory

***2) Scope of review***

The QAWG performs reviews mainly in the following areas. The results are utilized for the preparation of the inventory for the next submission.

- Confirming the soundness of estimation methods, AD, EFs, and other items.
- Confirming the soundness of content reported in the CRF and NIR.

***3) Activities in FY2019***

The Industrial Processes and Product Use sector was reviewed by two experts in FY2019, and the schedule was as follows.

Table 1-2 Schedule for the review by the QAWG in FY2019

| Schedule | Matter |
|---|---|
| Mid-April 2019 | Selection of experts |
| Late May | Visiting and briefing of the experts by secretariat |
| June to August | Review by the experts (The detailed review of the GHG inventory, the listing of questionable points and issues, and proposals for improvement) |
| September 18 | Holding of the QAWG meeting |
| October, and January 2020 | Bringing up of suggestions from the QAWG to the Committee and relevant breakout groups in the Committee for discussion |
| March to April | Summarizing QAWG activities and results in the inventory<br>Reporting to QAWG experts on how their comments were considered/addressed<br>Checking of results of consideration and modifications by QAWG experts |

It was confirmed by the QAWG that the inventory for the Industrial Processes and Product Use sector was generally valid. Although this QAWG did not identify any new issues for discussion by the relevant breakout group in the Committee, the QAWG identified insufficient explanations in the NIR. These findings lead to the improvement of the quality of the NIR.

The MOE and the secretariat will annually determine the sectors/categories reviewed by the QAWG, and the entire GHG inventory will be covered over the course of several years.

### 1.2.3.2. QA/QC Plan

The QA/QC Plan is an internal document that documents, among other things, the specifics of all QA/QC activities in all processes from the start of inventory compilation to the final report, the compilation schedule, and the apportionment of all involved entities' roles. It organizes and systematizes

the QA/QC activities of inventory compilation and clarifies what each entity involved in compilation is supposed to do. Additionally, it is prepared for the purpose of guaranteeing the implementation of QA/QC activities.

The QA/QC Plan's scope includes the processes of preparing, reporting, and reviewing the inventory under the UNFCCC, and the supplementary information on sinks under Kyoto Protocol Articles 3.3 and 3.4, as stipulated in Decision 2/CMP.8.

#### 1.2.3.3. Verification Activities

Confirmation such as the following have been undertaken in the Breakout groups of the Committee for the Greenhouse Gas Emission Estimation Methods: checking the appropriateness of EFs which were established based on actual measurements in the past, against new measurements, or checking the appropriateness of applying specific EFs based on models, to the national inventory. Additionally, the inventory emissions are checked against entity-based emission data reported under the Mandatory GHG Accounting and Reporting System - a system that aims to reduce emissions from entities by requiring them to estimate and understand the amount of GHG emissions originating from their own activities. This mutual verification activity is to avoid any possible large omission of emissions.

#### 1.2.3.4. Treatment of Confidential Information

Part of the AD and EFs, other parameters, and emissions obtained from ministries or the private sector correspond to confidential information. These are listed and archived. At the stage of obtaining and archiving data, and in the QC process, data is protected by using a password, and confidential files are distinguished from others, together with restricted access. When sending data to relevant ministries for checks, confidential data are sent only to the ministry which provided the data. At the stage of UN reporting, a minimum level of aggregation with other sub-categories is performed, and the notation key "C" (confidential) is used.

### 1.2.4. Changes in the National Inventory Arrangements since the Previous Annual GHG Inventory Submission

In line with paragraph 50 (J) of the UNFCCC Inventory Reporting Guidelines and paragraph 21 of the annex to decision 15/CMP.1, Japan reports the changes in its national inventory arrangements from the previous inventory submission.

## 1.3. Inventory Preparation, and Data Collection, Processing and Storage

### 1.3.1. Annual cycle of inventory preparation

Table 1-3 shows the annual cycle of inventory preparation. The inventory preparation cycle is set in conjunction with Japan's fiscal year calendar (starting April 1 and ending March 31 of the next year) In Japan, in advance of the estimation of national inventory submitted to the UNFCCC (submission deadline: April 15), preliminary figures are estimated and published as a document for an official announcement (In preliminary figures, only GHG emissions excluding removals are published.).

Table 1-3 Annual cycle of the inventory preparation

*Inventory preparation in fiscal yaer "n"

| | Process | Relevant Entities | Calender Year n+1 | | | | | | | | CY n+2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fiscal Year n+1 | | | | | | | | | | | FY n+2 |
| | | | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr |
| 1 | Holding the meeting of the QAWG | MOE, GIO | → | → | → | → | | | | | | | | |
| 2 | Discussion on the inventory improvement | MOE, GIO | | → | → | → | → | | | | | | | |
| 3 | Holding the meeting of the Committee | MOE, (GIO, Private consultant) | | → | → | → | → | → | → | → | → | | | |
| 4 | Collection of data for the national inventory | MOE, GIO, Relevant Ministries/Agencies, Relevant organization, Private consultant | | | | | | | | → | → | → | → | |
| 5 | Preparation of a draft of CRF | GIO, Private consultant | | | | | | | | | → | → | → | |
| 6 | Preparation of a draft of NIR | GIO, Private consultant | | | | | | | | | → | → | → | |
| 7 | Implementation of the exterior QC and the coordination with the relevant ministries and agencies | MOE, GIO, Relevant Ministries/Agencies, Private consultant | | | | | | | | | | → | → | → |
| 8 | Correction of the drafts of CRF and NIR | MOE, GIO, Private consultant | | | | | | | | | | | → | → |
| 9 | Submission and official announcement of the national inventory | MOE, GIO | | | | | | | | | | | | ★ |

### 1.3.2. Process of the inventory preparation

#### *1) Holding the meeting of the Greenhouse Gas Inventory Quality Assurance Working Group (QAWG) (Step 1)*

The QAWG, which is composed of experts who are not directly involved in nor related to the inventory preparation process, is organized in order to conduct peer review and assure the inventory's quality and to find possible improvements.

This QAWG reviews the appropriateness of the estimation methodologies, AD, EFs, and the contents of the CRF and NIR. The GIO utilizes the items identified for improvement by the QAWG in discussions on the inventory estimation methods and in subsequent inventory preparation.

#### *2) Discussion on inventory improvement (Step 2)*

The MOE and the GIO identify the items that need to be addressed by the Committee, based on the results of the previous inventory review of the UNFCCC, the recommendations of the QAWG, the items needing improvement as identified at former Committee meetings, and any other items requiring revision, as determined during previous inventory preparations. The schedule for the expert evaluation (step 3) is developed by taking the above-mentioned information into account.

#### *3) Holding meetings of the Committee for the Greenhouse Gas Emission Estimation Methods [evaluation and examination of estimation methods by experts] (Step 3)*

The MOE holds meetings of the Committee, in which estimation methodologies for an annual inventory and the issues that require technical reviews are discussed by experts with different scientific backgrounds.

#### *4) Collection of data for the national inventory (Step 4)*

The data required for preparing the national inventory and the supplementary information required under Decision 2/CMP.8 are collected.

#### *5) Preparation of a draft of the CRF [including the implementation of the key category analysis and the uncertainty assessment] (Step 5)*

The data input and estimation of emissions and removals are carried out simultaneously by utilizing JNGI files, which have interconnecting links based on the calculation formulas for emissions and removals. Subsequently, the key category analysis and the uncertainty assessment are also carried out.

***6) Preparation of a draft of NIR (Step 6)***

The GIO identifies the points that need to be revised in the NIR or that require an additional description by taking the discussion at step 2 into account. The organization of the NIR is generally the same every year, but if large modifications such as changes in chapters are envisaged, this is proposed to the MOE and approval is sought. The GIO prepares the new NIR draft by updating the data and by adding and revising descriptions.

***7) Implementation of the external QC and the coordination with the relevant ministries and agencies (Step 7)***

As a QC activity, the selected private consulting companies check the JNGI files and the initial draft of the CRF (the $0^{th}$ draft) prepared by the GIO (external QC). The companies not only check the input data and the calculation formulas in the files but also check the estimations by calculating the amount of GHG emissions and removals by utilizing the same files. Because of this crosscheck, any possible data input and emission estimation mistakes are avoided. They also check the content and descriptions of the initial draft of the NIR (the $0^{th}$ draft) prepared by the GIO. JNGI files, draft CRF and draft NIR, which have been checked by the private consulting companies, are regarded as the primary drafts of inventories.

Subsequently, the GIO sends out the primary drafts of the inventories and official announcements as electronic computer files to the MOE and the relevant ministries and agencies and asks them to check the contents of the primary drafts. The data, which are estimated based on confidential data, are only sent out for confirmation to the ministries and/or agencies that provided the confidential data.

For some sources/sinks, emissions/removals are estimated by entities other than GIO, and the QC implemented in these entities are checked.

***8) Correction of the drafts of CRF and NIR (Step 8)***

When revisions are requested as a result of the check of the primary drafts of the inventories and official announcements by the relevant ministries and agencies (step 7), the MOE, GIO, and relevant ministries and/or agencies that submit requests for revision then coordinate the details of any revision, revise the primary drafts, and prepare the secondary drafts. The secondary drafts are sent out again to the relevant ministries and/or agencies for conclusive confirmation. If there is no additional request for revision, the secondary drafts are considered the final versions.

***9) Submission and official announcement of the national inventory (Step 9)***

The completed inventory is submitted to the UNFCCC Secretariat. At the same time of the submission, information on the estimated GHG emissions and removals are officially announced and published on the MOE's website (http://www.env.go.jp/) with additional relevant information. The inventory is also published on the GIO's website (http://www-gio.nies.go.jp/).

### 1.3.3. Documentation and Archiving of Inventory Information

In Japan, the information needed for inventory compilation is documented and as a rule archived by the agency which compiles the inventory (GIO).

The main files (all JNGI files, NIR word files, and CRFs) needed for inventory compilation is electronically archived at MOE as well.

#### 1.3.3.1. Documentation of information

The GIO documents all the inventory-related information in electronic or printed form and archives it. Examples of information that must be archived follow.

- The inventory related files submitted every year to the UNFCCC Secretariat
- Published materials for preliminary and finalized data
- Statistical data and provided data (including data providers, time period when provided, and other related information) used in compiling the inventory
- Information on the discussion process and discussion results related to the selection of AD, estimation methods, EFs, and other items (relevant source materials for the discussion process by the Committee for the Greenhouse Gas Emissions Estimation Methods)
- Records of communications with related entities in the inventory compilation process
- Information on inventory recalculations (such as reasons for recalculations, and when performed)
- QA/QC Plan and records of QA/QC activities conducted, including holding the QAWG
- Comments by experts on the inventory
- In relation to UNFCCC inventory reviews, review reports and records of questions and answers with ERTs

#### 1.3.3.2. Archiving of information

***1) Archiving electronic information***

***i) Inventory-related electronic information***

- Each year's JNGI files and CRF- and NIR-related files have file names with the year when the estimation was performed, and files are saved in folders prescribed for each year.
- Electronic files of statistical data, provided data, etc. used to prepare the inventory's emissions/removals estimates and other related data are given file names, etc. with the date on which the data were obtained and the data provider, and saved in prescribed folders.
- Source materials in electronic form (files in Word, PDF, or other format) used when considering emissions/removals estimation methods are labeled with the source material title and the date the file was obtained (and if necessary, the file provider), and saved in prescribed folders.
- If the exchange of information on the inventory has been conducted by email, the email files are saved in prescribed folders.

***ii) Backup and risk management of electronic information***

- The server, hosted by the Center for Global Environmental Research of the National Institute for Environmental Studies (in which GIO is included), and where inventory-related information is stored, is automatically backed up to another location every day.
- Once a year, after submission of the annual inventory to the UNFCCC Secretariat, all inventory-related electronic information is saved to CD-ROMs and other electronic media and archived.

***2) Archiving printed form***

- Books of statistics, data and source materials in printed form that have been provided, and other source materials in printed form that have been used in inventory emissions/removals estimates are filed in a prescribed storage location.

#### 1.3.3.3. QC activity for documentation and archiving of inventory information

Immediately after the inventory is submitted to the UNFCCC Secretariat, the GIO carries out QC activities related to the documentation and archive of inventory information.

## 1.4. Brief General Description of Methodologies and Data Sources Used (including tiers used)

The methodology used in estimation of GHG emissions or removals is basically in accordance with the *2006 IPCC Guidelines*. The country-specific methodologies are also used for some source/sink categories in order to more accurately reflect the actual emission status in Japan.

The results of the actual measurements or estimates based on research conducted in Japan are used to determine the EFs (country-specific emissions factors). The default values given in the *2006 IPCC Guidelines* are used for some categories, emissions of which are assumed to be quite low (e.g., "1.B.2.a.ii fugitive emissions from fuel (oil and natural gas" ($CO_2$ and $CH_4$))) etc.

### 1.4.1. Collection Process of Activity Data

When the AD needed for calculations are available from sources such as publications and the internet, the necessary data are gathered from these media. Data that are not released in publications, the internet, or in other media, and unpublished data that are used when compiling the inventory are obtained by the MOE or the GIO by requesting them from the relevant ministries and agencies and the relevant organizations which control those data. The main relevant ministries, agencies, and relevant organizations, and their statistics and data are as shown in Table 1-4.

Table 1-4 Main relevant ministries, agencies, and the relevant organizations, and their statistics and data

| Ministries/Agencies/Organizations | | Major data or statistics |
|---|---|---|
| Relevant Ministries/ Agencies | MOE | Research of Air Pollutant Emissions from Stationary Sources/ Waste Treatment in Japan/ Report of the research on the state of wide-range movement and cyclical use of wastes (the volume on cyclical use)/ Survey of Industrial Waste Treatment Facilities |
| | METI | General Energy Statistics / Yearbook of Chemical Industry Statistics / Yearbook of Ceramics and Building Materials Statistics/ Amount of nitric acid production/ Documents of Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub -Group, Industrial Structure Council |
| | MLIT | Statistical Yearbook of Motor Vehicle Fuel Consumption / Land Use Status Survey |
| | MAFF | Livestock Statistics / Statistics of Arable and Planted Land Area / Yearbook of Fertilizer Statistics (Pocket Edition)/ Forest Status Survey/ National Forest Resources Database |
| Relevant Organizations | Federation of Electric Power Companies | Amount of Fuel Used by Pressurized Fluidized Bed Boilers |
| | Japan Coal Energy Center | Coal Production/ History of Coal Policy |
| | Japan Cement Association | Amount of clinker production / Cement Handbook |
| | Japan Iron and Steel Federation | Emissions from Coke Oven Covers, Desulfurization Towers, and Desulfurization Recycling Towers |
| | Japan Paper Association | Amount of final disposal of industrial waste / Amount of RPF incineration |

### 1.4.2. Selection Process of Emission Factors and Estimation Methods

Calculation methods for Japan's emission and removal amounts are determined by having the Committee explore calculation methods suited to Japan's situation for all the activity categories necessary for calculating Japan's greenhouse gas emission and removal amounts, based on the *2006 IPCC Guidelines*.

### 1.4.3. Improvement Process of Estimations for Emissions and Removal

In Japan, improvements in the calculation methods are considered in accordance with necessity whenever an inventory item requiring improvement is identified because of, for example, a UNFCCC review or an observation by the QAWG, progress in international negotiations such as the creation of new guidelines, progress or changes in scientific research or in the compilation of statistics, or the acquisition of new information by the system for calculating, reporting, and publishing GHG emissions. Proposals for improving the estimation of emissions and removals are considered by scientific research or the Committee, and the results are incorporated into the inventory. Figure 1-4 is a diagram of the inventory improvement process.

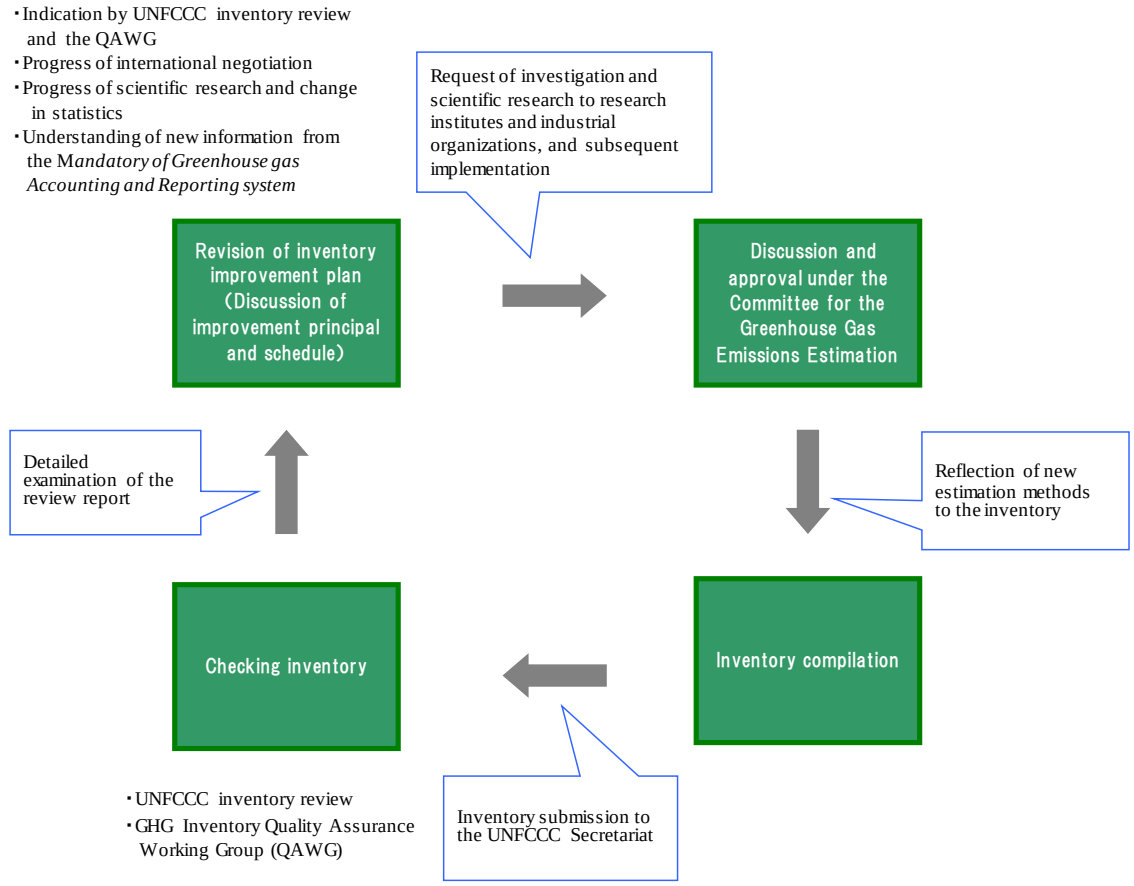


Figure 1-4 Diagram of the inventory improvement process

## 1.5. Brief Description of Key Categories

Key category analysis was carried out in accordance with the *2006 IPCC Guidelines* and the *KP Supplement (2013)* (Approach 1 and Approach 2 level/trend assessment).

### 1.5.1. GHG Inventory

In FY2018, 46 sources and sinks were identified as Japan's key categories (Table 1-5). For the base year of the UNFCCC (FY1990), 40 sources and sinks were identified as key categories (Table 1-6). More detailed information is described in Annex 1.

Table 1-5 Japan's key categories in FY2018

| | Category Code | A IPCC Code | B IPCC Category | | C GHGs | Ap1-L | Ap1-T | Ap2-L | Ap2-T |
|---|---|---|---|---|---|---|---|---|---|
| #1 | A-02 | 1.A.1. | Energy Industries | Solid Fuels | CO2 | #1 | #1 | #1 | #1 |
| #2 | A-16 | 1.A.3. | Transport | b. Road Transportation | CO2 | #2 | #18 | #3 | |
| #3 | A-08 | 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | #3 | #7 | #2 | #14 |
| #4 | A-03 | 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | #4 | #4 | #6 | #10 |
| #5 | A-25 | 1.A.4. | Other Sectors | Liquid Fuels | CO2 | #5 | #5 | #5 | #8 |
| #6 | A-01 | 1.A.1. | Energy Industries | Liquid Fuels | CO2 | #6 | #2 | #9 | #3 |
| #7 | D-01 | 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | #7 | #10 | #4 | #9 |
| #8 | A-07 | 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | #8 | #3 | #11 | #4 |
| #9 | A-27 | 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | #9 | #8 | #24 | #22 |
| #10 | B-26 | 2.F | Product uses as substitutes for ODS | 1. Refrigeration and Air conditioning | HFCs | #10 | #6 | #10 | #5 |
| #11 | A-09 | 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | #11 | #9 | #29 | #24 |
| #12 | B-01 | 2.A | Mineral Product | 1. Cement Production | CO2 | #12 | #12 | #23 | #25 |
| #13 | C-04 | 3.C | Rice Cultivation | | CH4 | #13 | | #28 | |
| #14 | A-22 | 1.A.3. | Transport | d. Domestic Navigation | CO2 | #14 | | | |
| #15 | A-13 | 1.A.3. | Transport | a. Domestic Aviation | CO2 | #15 | #22 | | |
| #16 | E-04 | 5.C | Incineration and Open Burning of Waste | | CO2 | #16 | | #14 | |
| #17 | A-10 | 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | #17 | #20 | #13 | #17 |
| #18 | A-28 | 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | #18 | | #15 | |
| #19 | C-01 | 3.A | Enteric Fermentation | | CH4 | #19 | | #12 | #26 |
| #20 | A-26 | 1.A.4. | Other Sectors | Solid Fuels | CO2 | #20 | #15 | | #28 |
| #21 | B-15 | 2.C | Metal Production | 1 Iron and Steel Production | CO2 | #21 | | | |
| #22 | C-03 | 3.B | Manure Management | | N2O | | | #8 | |
| #23 | C-05 | 3.D | Agricultural Soils | 1. Direct Emissions | N2O | | | #27 | |
| #24 | D-03 | 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | | #17 | #18 | #7 |
| #25 | E-01 | 5.A | Solid Waste Disposal | | CH4 | | #16 | | #13 |
| #26 | B-27 | 2.F | Product uses as substitutes for ODS | 2. Foam Blowing Agents | HFCs | | #25 | #19 | #12 |
| #27 | B-06 | 2.B | Chemical Industry | Other products except Anmonia | CO2 | | | #16 | #27 |
| #28 | B-21 | 2.D | Non-energy Products from Fuels and Solvent Use | | CO2 | | | #20 | #30 |
| #29 | A-06 | 1.A.1. | Energy Industries | | N2O | | | | #29 |
| #30 | D-15 | 4.G | Harvested Wood Products | | CO2 | | | | #23 |
| #31 | E-08 | 5.D | Wastewater Treatment and Discharge | | N2O | | | #31 | |
| #32 | B-23 | 2.E | Electronics Industry | | PFCs | | | #17 | #31 |
| #33 | C-06 | 3.D | Agricultural Soils | 2. Indirect Emissions | N2O | | | #7 | #18 |
| #34 | Ind-02 | | Indirect CO2 | from IPPU sector | Ind CO2 | | | #30 | #16 |
| #35 | B-31 | 2.F | Product uses as substitutes for ODS | 5. Solvents | PFCs | | #24 | | |
| #36 | A-18 | 1.A.3. | Transport | b. Road Transportation | N2O | | | #26 | #15 |
| #37 | E-06 | 5.C | Incineration and Open Burning of Waste | | N2O | | | #22 | |
| #38 | D-12 | 4.E | Settlements | 2. Land converted to Settlements | CO2 | | #26 | | #21 |
| #39 | B-34 | 2.G | Other Product Manufacture and Use | | SF6 | | #13 | #21 | #2 |
| #40 | D-02 | 4.A | Forest Land | 2. Land converted to Forest Land | CO2 | | #19 | | #19 |
| #41 | A-32 | 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CH4 | | #21 | | #6 |
| #42 | B-24 | 2.E | Electronics Industry | | SF6 | | | #25 | |
| #43 | B-09 | 2.B | Chemical Industry | 4. Caprolactam, Glyoxal and Glyoxylic Acid Production | N2O | | | | #11 |
| #44 | B-10 | 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | HFCs | | #11 | | |
| #45 | B-08 | 2.B | Chemical Industry | 3. Adipic Acid Production | N2O | | #14 | | #20 |
| #46 | B-12 | 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | SF6 | | #23 | | |

Note1: Ap1-L: Approach 1-Level Assessment, Ap1-T: Approach 1-Trend Assessment,
Ap2-L: Approach 2-Level Assessment, Ap2-T: Approach 2-Trend Assessment
Note2: Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table 1-6 Japan's key categories in FY1990

| | A IPCC Code | B IPCC Category | | C GHGs | Ap1-L | Ap2-L |
|---|---|---|---|---|---|---|
| #1 | 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | #1 | #1 |
| #2 | 1.A.3. | Transport | b. Road Transportation | CO2 | #2 | #3 |
| #3 | 1.A.1. | Energy Industries | Liquid Fuels | CO2 | #3 | #4 |
| #4 | 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | #4 | #6 |
| #5 | 1.A.4. | Other Sectors | Liquid Fuels | CO2 | #5 | #8 |
| #6 | 1.A.1. | Energy Industries | Solid Fuels | CO2 | #6 | #7 |
| #7 | 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | #7 | #19 |
| #8 | 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | #8 | #2 |
| #9 | 2.A | Mineral Product | 1. Cement Production | CO2 | #9 | #21 |
| #10 | 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | #10 | |
| #11 | 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | HFCs | #11 | |
| #12 | 1.A.3. | Transport | d. Domestic Navigation | CO2 | #12 | |
| #13 | 3.C | Rice Cultivation | | CH4 | #13 | #32 |
| #14 | 5.C | Incineration and Open Burning of Waste | | CO2 | #14 | #17 |
| #15 | 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | #15 | |
| #16 | 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | #16 | #9 |
| #17 | 5.A | Solid Waste Disposal | | CH4 | #17 | #15 |
| #18 | 3.A | Enteric Fermentation | | CH4 | #18 | #14 |
| #19 | 2.G | Other Product Manufacture and Use | | SF6 | #19 | #5 |
| #20 | 2.C | Metal Production | 1 Iron and Steel Production | CO2 | #20 | |
| #21 | 2.B | Chemical Industry | 3. Adipic Acid Production | N2O | #21 | |
| #22 | 1.A.3. | Transport | a. Domestic Aviation | CO2 | #22 | |
| #23 | 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | #23 | #22 |
| #24 | 4.A | Forest Land | 2. Land converted to Forest Land | CO2 | #24 | #30 |
| #25 | 2.A | Mineral Product | 2. Lime Production | CO2 | #25 | |
| #26 | 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CH4 | #26 | #12 |
| #27 | 3.D | Agricultural Soils | 1. Direct Emissions | N2O | #27 | #24 |
| #28 | | Indirect CO2 | from IPPU sector | Ind CO2 | | #16 |
| #29 | 4.E | Settlements | 2. Land converted to Settlements | CO2 | | #29 |
| #30 | 3.B | Manure Management | | N2O | | #11 |
| #31 | 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | | #31 |
| #32 | 2.B | Chemical Industry | Other products except Anmonia | CO2 | | #18 |
| #33 | 1.A.3. | Transport | b. Road Transportation | N2O | | #13 |
| #34 | 3.D | Agricultural Soils | 2. Indirect Emissions | N2O | | #10 |
| #35 | 5.D | Wastewater Treatment and Discharge | | N2O | | #28 |
| #36 | 2.D | Non-energy Products from Fuels and Solvent Use | | CO2 | | #27 |
| #37 | 2.B | Chemical Industry | 4. Caprolactam, Glyoxal and Glyoxylic Acid Production | N2O | | #20 |
| #38 | 2.E | Electronics Industry | | PFCs | | #25 |
| #39 | 5.C | Incineration and Open Burning of Waste | | N2O | | #26 |
| #40 | 2.E | Electronics Industry | | SF6 | | #23 |

Note1: Ap1-L: Approach 1-Level Assessment, Ap2-L: Approach 2-Level Assessment
Note2: Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

### 1.5.2. KP-LULUCF Activity

As a result of analysis implemented in accordance with the *2006 IPCC Guidelines* and the *KP Supplement (2013)*, "Afforestation/Reforestation", "Deforestation", "Forest management", "Cropland management", and "Revegetation" activities ($CO_2$) were identified as key categories for Japan's KP-LULUCF activities in FY2018. More detailed information is described in section 11.8.1 of chapter 11.

## 1.6. General Uncertainty Assessment, including Data on the Overall Uncertainty for the

## Inventory Totals

### 1.6.1. GHG Inventory

Total net GHG emissions in Japan for FY2018 were approximately 1,183 million tonnes ($CO_2$ equivalents). The total net emissions uncertainties calculated by approach 1 (propagation of error) were -4% to +2% and the uncertainties introduced into the trend in the total emissions were -5% to +3%. More detailed information on the uncertainty assessment is described in Annex 2.

Table 1-7 Uncertainty of Japan's total net emissions

| A | B | C | D | G-1990 | | G-2018 | | I | J | |
|---|---|---|---|---|---|---|---|---|---|---|
| Category | GHGs | 1990 emissions / removals | 2018 emissions / removals | Combined uncertainty in 1990 | | Combined uncertainty in 2018 | | Inventory trend in national emissions for 2018 increase with respect to 1990 | Uncertainty introduced into the trend in total national emissions | |
| | | kt-$CO_2$ eq. | kt-$CO_2$ eq. | (-) % | (+) % | (-) % | (+) % | % | (-) % | (+) % |
| 1A. Fuel Combustion ($CO_2$) | $CO_2$ | 1,078,839 | 1,077,487 | -5% | +2% | -4% | +2% | -0.1% | -4.9% | +2.6% |
| 1A. Fuel Combustion (Stationary:$CH_4$,$N_2O$) | $CH_4$, $N_2O$ | 3,916 | 5,281 | -23% | +29% | -25% | +28% | 34.9% | 0.0% | +0.0% |
| 1A. Fuel Combustion (Transport:$CH_4$,$N_2O$) | $CH_4$, $N_2O$ | 4,031 | 1,796 | -32% | +92% | -30% | +87% | -55.4% | 0.0% | +0.0% |
| 1B. Fugitive Emissions from Fuels | $CO_2$, $CH_4$, $N_2O$ | 5,165 | 1,155 | -40% | +80% | -23% | +39% | -77.6% | 0.0% | +0.0% |
| 2. IPPU ($CO_2$,$CH_4$,$N_2O$) | $CO_2$, $CH_4$, $N_2O$ | 75,591 | 47,305 | -4% | +4% | -5% | +5% | -37.4% | -0.1% | +0.1% |
| 2. IPPU (HFCs,PFCs,$SF_6$,$NF_3$) | HFCs, PFCs, $SF_6$, $NF_3$ | 35,354 | 52,800 | -7% | +36% | -7% | +8% | 49.3% | -0.5% | +0.5% |
| 3. Agriculture | $CO_2$, $CH_4$, $N_2O$ | 37,413 | 33,252 | -10% | +25% | -9% | +21% | -11.1% | 0.0% | +0.0% |
| 4. LULUCF | $CO_2$, $CH_4$, $N_2O$ | -62,219 | -57,390 | -16% | +16% | -13% | +13% | -7.8% | -0.4% | +0.4% |
| 5. Waste | $CO_2$, $CH_4$, $N_2O$ | 29,732 | 19,267 | -10% | +11% | -12% | +12% | -35.2% | -0.2% | +0.2% |
| Indirect $CO_2$ | Ind $CO_2$ | 5,482 | 2,063 | -28% | +50% | -27% | +48% | -62.4% | 0.0% | +0.0% |
| Total Net Emissions | | 1,213,304 | 1,183,016 | -4.5% | +2.3% | -3.7% | +2.1% | -2.5% | -4.9% | +2.6% |

### 1.6.2. KP-LULUCF Activity

Japan's net removals in FY2018 were 43.0 million tonnes ($CO_2$ equivalents) and the uncertainty was 15%. More detailed information on the uncertainty assessment is described in section 11.5.1.8 of chapter 11.

Table 1-8 Uncertainty of Japan's KP-LULUCF activities

| Greenhouse gas source and sink activities | GHGs | Emissions/Removals [kt $CO_2$eq.] | Emissions/Removals Uncertainty [%] | | Emissions/Removals Uncertainty as % of net removals [%] | |
|---|---|---|---|---|---|---|
| | | | (-)[%] | (+)[%] | (-)[%] | (+)[%] |
| Article 3.3 activities Afforestation and Reforestation | $CO_2$, $N_2O$, $CH_4$ | -1,442 | -35% | 35% | -1% | 1% |
| Article 3.3 activities Deforestation | $CO_2$, $N_2O$, $CH_4$ | 1,605 | -23% | 23% | -1% | 1% |
| Article 3.4 activities Forest management | $CO_2$, $N_2O$, $CH_4$ | -45,361 | -14% | 14% | -15% | 15% |
| Article 3.4 activities Cropland management | $CO_2$, $N_2O$, $CH_4$ | 3,721 | -40% | 40% | -3% | 3% |
| Article 3.4 activities Grazing land management | $CO_2$, $N_2O$, $CH_4$ | -209 | -22% | 22% | 0% | 0% |
| Article 3.4 activities Revegetation | $CO_2$, $N_2O$, $CH_4$ | -1,322 | -33% | 33% | -1% | 1% |
| Total | | -43,008 | -15% | 15% | | |

## 1.7. General Assessment of the Completeness

In this inventory report, emissions from some categories are not estimated and reported as "NE".

Source categories reported as NE in this year's report include those whose emissions are thought to be very small, those whose emissions are unknown, and those for which emission estimation methods have not been developed. For these categories, further investigation on their emission possibility and the development of estimation methodologies will be carried out in accordance with Japan's QA/QC plan. See Annex 5 for a list of not-estimated emission source categories.

- ***Impacts of the Great East Japan Earthquake***

  In order to check impacts of the Great East Japan Earthquake, which occurred on March 11, 2011, on completeness, accuracy and consistency of AD, we carried out investigations by questionnaires and hearing to all of the relevant ministries, agencies and organizations which are responsible for management of statistics used in estimation of GHG emissions and removals. As a result, we confirmed that the impacts of the Great East Japan Earthquake on the statistics, including missing data in them, were insignificant in the total emissions and removals. Since the inventory was prepared after experts' assessment and review of estimation methodologies, etc. taking into account the investigation results, completeness, accuracy and consistency of the inventory are considered to be assured. However, for some statistical data, investigation and checks on the data continued since the impacts of the earthquake on the data were still insufficient. Based on the ongoing investigation results, GHG emissions from wastes and refuses due to disaster are reported in Chapter 7 (waste sector).

## *References*

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. IPCC, *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, 2014.
3. IPCC, *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*, 2014.
4. UNFCCC, *Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention*, Decision 24/CP.19, FCCC/CP/2013/10/Add.3, 2014.
5. UNFCCC, *Guidelines for the Preparation of the Information Required under Article 7 of the Kyoto Protocol*, Decision 15/CMP.1, FCCC/KP/CMP/2005/8/Add.2, 2005.
6. UNFCCC, *Guidelines for Review under Article 8 of the Kyoto Protocol*, Decision 22/CMP.1, FCCC/KP/CMP/2005/8/Add.3, 2005.
7. UNFCCC, *Implications of the Implementation of Decisions 2/CMP.7 to 5/CMP.7 on the Previous Decisions on Methodological Issues Related to the Kyoto Protocol, including those relating to Articles 5, 7 and 8 of the Kyoto Protocol*, Decision 2/CMP.8, FCCC/KP/CMP/2012/13/Add.1, 2013.

# Chapter 2. Trends in GHG Emissions and Removals

## 2.1. Description and Interpretation of Emission and Removal Trends for Aggregate GHGs

### 2.1.1. Overview of GHGs Emissions and Removals

Total GHG emissions in FY2018[1,2] (excluding LULUCF[3], including indirect $CO_2$[4], hereafter, definition omitted) were 1,240 million tonnes (in $CO_2$ eq.). They decreased by 2.8% compared to the emissions in FY1990.

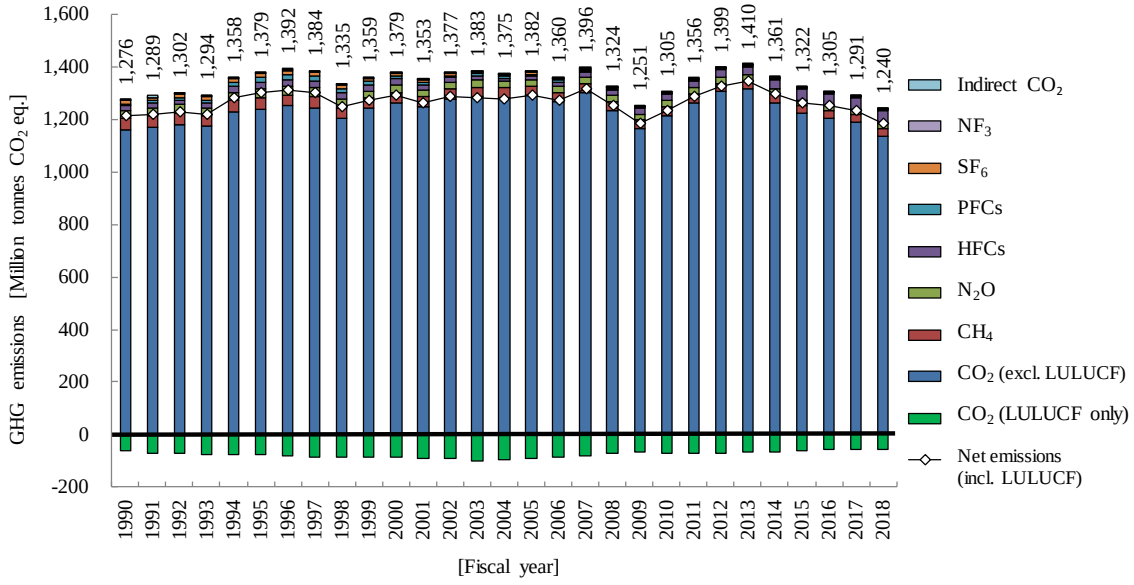


Figure 2-1 Trends in GHG emissions and removals in Japan

$CO_2$ emissions in FY2018 were 1,136 million tonnes (excluding LULUCF, excluding indirect $CO_2$, hereafter, definition omitted), accounting for 91.6% of total GHG emissions. They decreased by 2.0% since FY1990 and decreased by 4.4% compared to the previous year. $CO_2$ removals[5] in FY2018 were 57.7 million tonnes, which were equivalent to 4.6% of total GHG emissions. They decreased by 7.8% since FY1990 and decreased by 2.0% compared to the previous year.

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1 Fiscal year (FY), from April of the reporting year through March of the next year, is used because $CO_2$ is the primary GHGs emissions and estimated on a fiscal year basis. "CY" stands for calendar year.

2 The sum of $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, and $NF_3$ emissions converted to $CO_2$ equivalents, multiplied by their respective global warming potential (GWP). The GWP is a coefficient by means of which greenhouse gas effects of a given gas are made relative to those of an equivalent amount of $CO_2$. The coefficients are drawn from the *Fourth Assessment Report* (2007) issued by the Intergovernmental Panel on Climate Change (IPCC).

3 Abbreviation of "Land Use, Land-Use Change and Forestry"

4 Carbon monoxide (CO), methane ($CH_4$) and non-methane volatile organic compounds (NMVOC) are oxidized in the atmosphere in the long term and converted to $CO_2$. Indirect $CO_2$ means the $CO_2$ equivalent value of these emissions. However, emissions derived from combustion-origin and biomass-origin CO, $CH_4$, and NMVOC are excluded to avoid double counting and/or by the concept of carbon neutrality.

5 Since the inventory to be submitted under the UNFCCC reports all GHG emissions and removals from the LULUCF sector, these values do not correspond to emissions and removals under the Kyoto Protocol.

## Table 2-1 Trends in GHG emissions and removals in Japan

| [Million tonnes $CO_2$ eq.] | GWP | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ (excl. LULUCF) *1 | 1 | 1,158.4 | 1,170.1 | 1,179.7 | 1,172.6 | 1,227.6 | 1,239.9 | 1,251.9 | 1,245.1 | 1,205.4 | 1,242.0 |
| $CO_2$ (incl. LULUCF) *1 | 1 | 1,095.9 | 1,099.5 | 1,106.1 | 1,095.9 | 1,151.1 | 1,162.5 | 1,169.8 | 1,160.7 | 1,119.6 | 1,156.0 |
| $CO_2$ (LULUCF only) | 1 | -62.5 | -70.6 | -73.6 | -76.7 | -76.4 | -77.4 | -82.0 | -84.4 | -85.8 | -86.0 |
| $CH_4$ (excl. LULUCF) | 25 | 44.4 | 43.3 | 44.1 | 40.0 | 43.4 | 41.9 | 40.7 | 40.0 | 38.1 | 38.0 |
| $CH_4$ (incl. LULUCF) | 25 | 44.5 | 43.4 | 44.2 | 40.1 | 43.5 | 42.0 | 40.8 | 40.1 | 38.2 | 38.1 |
| $N_2O$ (excl. LULUCF) | 298 | 31.9 | 31.6 | 31.8 | 31.6 | 32.9 | 33.2 | 34.3 | 35.1 | 33.5 | 27.4 |
| $N_2O$ (incl. LULUCF) | 298 | 32.1 | 31.8 | 32.0 | 31.8 | 33.1 | 33.4 | 34.5 | 35.3 | 33.7 | 27.6 |
| HFCs | HFC-134a: 1,430 etc. | 15.9 | 17.3 | 17.8 | 18.1 | 21.1 | 25.2 | 24.6 | 24.4 | 23.7 | 24.4 |
| PFCs | PFC-14: 7,390 etc. | 6.5 | 7.5 | 7.6 | 10.9 | 13.4 | 17.6 | 18.3 | 20.0 | 16.6 | 13.1 |
| $SF_6$ | 22,800 | 12.9 | 14.2 | 15.6 | 15.7 | 15.0 | 16.4 | 17.0 | 14.5 | 13.2 | 9.2 |
| $NF_3$ | 17,200 | 0.03 | 0.03 | 0.03 | 0.04 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| Indirect $CO_2$ | 1 | 5.5 | 5.3 | 5.1 | 4.8 | 4.8 | 4.7 | 4.7 | 4.6 | 4.2 | 4.2 |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | | 1,270.0 | 1,284.0 | 1,296.7 | 1,289.1 | 1,353.4 | 1,374.5 | 1,387.0 | 1,379.3 | 1,330.8 | 1,354.4 |
| Net Total (including LULUCF, excluding indirect $CO_2$) | | 1,207.8 | 1,213.7 | 1,223.4 | 1,212.7 | 1,277.3 | 1,297.4 | 1,305.3 | 1,295.2 | 1,245.2 | 1,268.6 |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | | 1,275.5 | 1,289.3 | 1,301.7 | 1,293.9 | 1,358.2 | 1,379.2 | 1,391.7 | 1,383.9 | 1,334.9 | 1,358.5 |
| Net Total (including LULUCF, including indirect $CO_2$) | | 1,213.3 | 1,219.0 | 1,228.4 | 1,217.5 | 1,282.1 | 1,302.1 | 1,310.0 | 1,299.8 | 1,249.4 | 1,272.8 |

| [Million tonnes $CO_2$ eq.] | GWP | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ (excl. LULUCF) *1 | 1 | 1,264.8 | 1,250.2 | 1,279.5 | 1,287.6 | 1,282.9 | 1,290.1 | 1,266.8 | 1,302.5 | 1,231.9 | 1,162.6 |
| $CO_2$ (incl. LULUCF) *1 | 1 | 1,176.8 | 1,161.7 | 1,189.4 | 1,187.4 | 1,186.2 | 1,198.6 | 1,180.8 | 1,221.1 | 1,160.7 | 1,095.5 |
| $CO_2$ (LULUCF only) | 1 | -88.0 | -88.6 | -90.0 | -100.3 | -96.7 | -91.5 | -86.1 | -81.5 | -71.2 | -67.2 |
| $CH_4$ (excl. LULUCF) | 25 | 38.0 | 37.1 | 36.4 | 35.0 | 36.0 | 35.8 | 35.3 | 35.5 | 35.2 | 34.3 |
| $CH_4$ (incl. LULUCF) | 25 | 38.1 | 37.2 | 36.5 | 35.1 | 36.1 | 35.9 | 35.3 | 35.6 | 35.3 | 34.4 |
| $N_2O$ (excl. LULUCF) | 298 | 29.9 | 26.3 | 25.7 | 25.6 | 25.4 | 25.0 | 24.8 | 24.2 | 23.4 | 22.7 |
| $N_2O$ (incl. LULUCF) | 298 | 30.1 | 26.5 | 25.9 | 25.8 | 25.6 | 25.2 | 25.0 | 24.4 | 23.6 | 22.9 |
| HFCs | HFC-134a: 1,430 etc. | 22.9 | 19.5 | 16.2 | 16.2 | 12.4 | 12.8 | 14.6 | 16.7 | 19.3 | 20.9 |
| PFCs | PFC-14: 7,390 etc. | 11.9 | 9.9 | 9.2 | 8.9 | 9.2 | 8.6 | 9.0 | 7.9 | 5.7 | 4.0 |
| $SF_6$ | 22,800 | 7.0 | 6.1 | 5.7 | 5.4 | 5.3 | 5.0 | 5.2 | 4.7 | 4.2 | 2.4 |
| $NF_3$ | 17,200 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 1.5 | 1.4 | 1.6 | 1.5 | 1.4 |
| Indirect $CO_2$ | 1 | 4.2 | 3.8 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 2.7 | 2.5 |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | | 1,374.8 | 1,349.3 | 1,373.2 | 1,379.1 | 1,371.7 | 1,378.8 | 1,357.2 | 1,393.2 | 1,321.2 | 1,248.4 |
| Net Total (including LULUCF, excluding indirect $CO_2$) | | 1,287.0 | 1,261.1 | 1,283.5 | 1,279.1 | 1,275.3 | 1,287.6 | 1,271.4 | 1,312.0 | 1,250.3 | 1,181.5 |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | | 1,379.0 | 1,353.1 | 1,376.7 | 1,382.5 | 1,375.0 | 1,382.0 | 1,360.3 | 1,396.2 | 1,323.9 | 1,250.9 |
| Net Total (including LULUCF, including indirect $CO_2$) | | 1,291.2 | 1,264.9 | 1,287.0 | 1,282.5 | 1,278.6 | 1,290.8 | 1,274.5 | 1,315.0 | 1,253.0 | 1,184.0 |

| [Million tonnes $CO_2$ eq.] | GWP | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Changes in emissions/removals (2018) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | 1990 | Previous year |
| $CO_2$ (excl. LULUCF) *1 | 1 | 1,214.1 | 1,264.2 | 1,305.4 | 1,314.7 | 1,263.0 | 1,222.8 | 1,203.2 | 1,187.7 | 1,135.7 | -2.0% | -4.4% |
| $CO_2$ (incl. LULUCF) *1 | 1 | 1,143.4 | 1,194.2 | 1,232.4 | 1,248.4 | 1,198.4 | 1,163.1 | 1,148.6 | 1,128.8 | 1,078.0 | -1.6% | -4.5% |
| $CO_2$ (LULUCF only) | 1 | -70.7 | -69.9 | -73.0 | -66.3 | -64.6 | -59.6 | -54.5 | -58.8 | -57.7 | -7.8% | -2.0% |
| $CH_4$ (excl. LULUCF) | 25 | 34.8 | 33.8 | 32.9 | 32.5 | 31.9 | 31.1 | 30.7 | 30.2 | 29.9 | -32.8% | -1.3% |
| $CH_4$ (incl. LULUCF) | 25 | 34.9 | 33.9 | 33.0 | 32.6 | 32.0 | 31.1 | 30.8 | 30.3 | 29.9 | -32.8% | -1.3% |
| $N_2O$ (excl. LULUCF) | 298 | 22.2 | 21.8 | 21.5 | 21.5 | 21.1 | 20.7 | 20.2 | 20.4 | 20.0 | -37.3% | -2.0% |
| $N_2O$ (incl. LULUCF) | 298 | 22.4 | 22.0 | 21.7 | 21.7 | 21.3 | 20.9 | 20.4 | 20.6 | 20.2 | -37.1% | -2.0% |
| HFCs | HFC-134a: 1,430 etc. | 23.3 | 26.1 | 29.4 | 32.1 | 35.8 | 39.3 | 42.6 | 44.9 | 47.0 | 194.9% | 4.7% |
| PFCs | PFC-14: 7,390 etc. | 4.2 | 3.8 | 3.4 | 3.3 | 3.4 | 3.3 | 3.4 | 3.5 | 3.5 | -46.7% | -0.7% |
| $SF_6$ | 22,800 | 2.4 | 2.2 | 2.2 | 2.1 | 2.0 | 2.1 | 2.2 | 2.1 | 2.0 | -84.1% | -1.3% |
| $NF_3$ | 17,200 | 1.5 | 1.8 | 1.5 | 1.6 | 1.1 | 0.6 | 0.6 | 0.4 | 0.3 | 766.3% | -37.2% |
| Indirect $CO_2$ | 1 | 2.4 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | -62.4% | -0.7% |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | | 1,302.5 | 1,353.6 | 1,396.3 | 1,407.8 | 1,358.3 | 1,319.8 | 1,302.8 | 1,289.2 | 1,238.3 | -2.5% | -3.9% |
| Net Total (including LULUCF, excluding indirect $CO_2$) | | 1,232.1 | 1,283.9 | 1,323.6 | 1,341.8 | 1,294.0 | 1,260.4 | 1,248.6 | 1,230.7 | 1,181.0 | -2.2% | -4.0% |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | | 1,305.0 | 1,355.9 | 1,398.6 | 1,410.1 | 1,360.5 | 1,322.0 | 1,305.0 | 1,291.3 | 1,240.4 | -2.8% | -3.9% |
| Net Total (including LULUCF, including indirect $CO_2$) | | 1,234.5 | 1,286.3 | 1,325.8 | 1,344.0 | 1,296.2 | 1,262.6 | 1,250.7 | 1,232.8 | 1,183.0 | -2.5% | -4.0% |

*1 Excluding indirect $CO_2$

*2 LULUCF: Land Use, Land-Use Change and Forestry

$CH_4$ emissions in FY2018 (excluding LULUCF) were 29.9 million tonnes (in $CO_2$ eq.), accounting for 2.4% of total GHG emissions. They decreased by 32.8% since FY1990 and by 1.3% compared to the previous year. $N_2O$ emissions in FY2018 (excluding LULUCF) were 20.0 million tonnes (in $CO_2$ eq.), accounting for 1.6% of total GHG emissions. They decreased by 37.3% since FY1990 and decreased by 2.0% compared to the previous year.

HFC emissions in CY2018 were 47.0 million tonnes (in $CO_2$ eq.), accounting for 3.8% of total GHG emissions. They increased by 194.9% since CY1990 and by 4.7% compared to the previous year. PFC emissions in CY2018 were 3.5 million tonnes (in $CO_2$ eq.), accounting for 0.3% of total GHG emissions. They decreased by 46.7% since CY1990 and decreased by 0.7% compared to the previous year. $SF_6$ emissions in CY2018 were 2.0 million tonnes (in $CO_2$ eq.), accounting for 0.2% of total GHG emissions. They decreased by 84.1% since CY1990 and 1.3% compared to the previous year. $NF_3$ emissions in CY2018 were 0.3 million tonnes (in $CO_2$ eq.), accounting for 0.02% of total GHG emissions. They increased 766.3% since CY1990 and decreased by 37.2% compared to the previous year.

Indirect $CO_2$ emissions in FY2018 were 2.1 million tonnes (in $CO_2$ eq.), accounting for 0.2% of total GHG emissions. They decreased by 62.4% since FY1990 and decreased by 0.7% compared to the previous year.

### 2.1.2. $CO_2$

$CO_2$ emissions in FY2018 were 1,136 million tonnes, accounting for 91.6% of total GHG emissions. They decreased by 2.0% since FY1990 and decreased by 4.4% compared to the previous year.

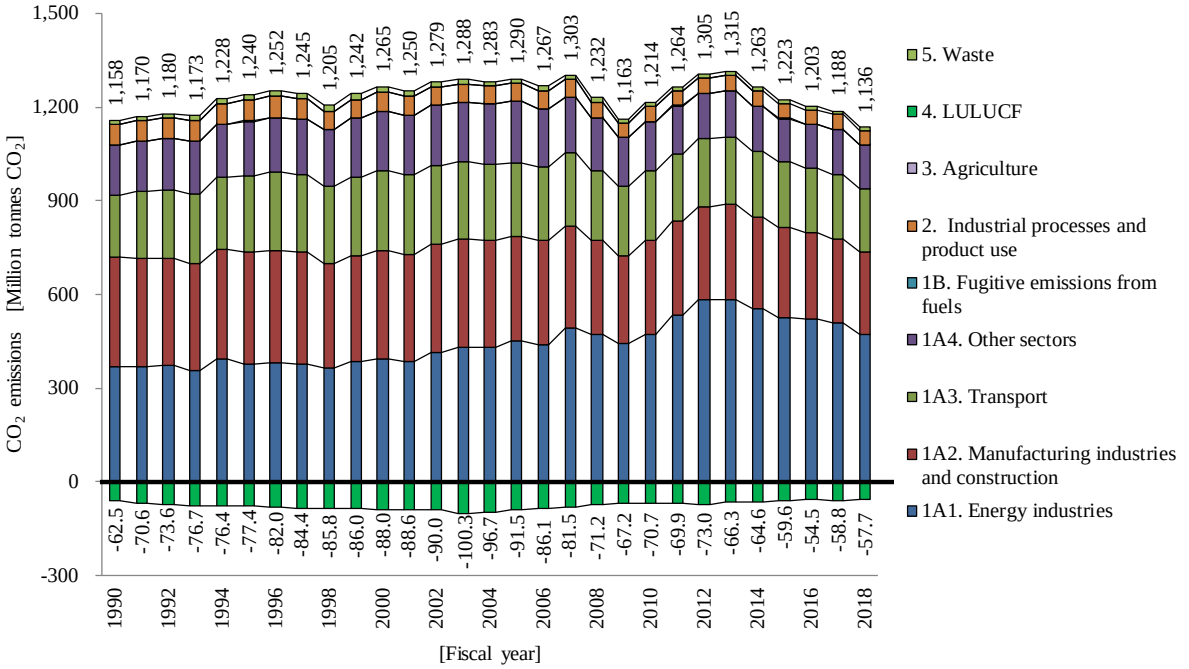


Figure 2-2 Trends in $CO_2$ emissions

The breakdown of $CO_2$ emissions in FY2018 shows that fuel combustion accounts for 94.9% and is followed by industrial processes and product use (4.1%) and waste sectors (1.0%). As for the breakdown of $CO_2$ emissions within the fuel combustion category, energy industries accounts for 41.6% and is

followed by manufacturing industries and construction at 23.1%, transport at 17.9%, and other sectors[6] at 12.3%. The main driving factor for the decrease in $CO_2$ emissions compared to the previous year is the decrease in $CO_2$ emissions from the energy industries sector.

By looking at the changes in emissions by sector, emissions from fuel combustion in the energy industries increased by 28.2% since FY1990 and decreased by 7.1% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increased solid fuel consumption for electricity power generation. Emissions from manufacturing industries and construction decreased by 24.8% since FY1990 and decreased by 2.6% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption for the other sub-sector (machinery manufacturing, etc). Emissions from transport increased by 1.0% compared to FY1990 and decreased by 1.2% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increase in emissions from domestic aviation, compensating for the decrease in emissions from domestic navigation. Emissions from other sectors decreased by 12.8% since FY1990 and decreased by 3.6% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption for the commercial/institutional sub-sector.

$CO_2$ removals in FY2018 were 57.7 million tonnes, which were equivalent to 4.6% of total GHG emissions. They decreased by 7.8% since FY1990 and decreased by 2.0% compared to the previous year.

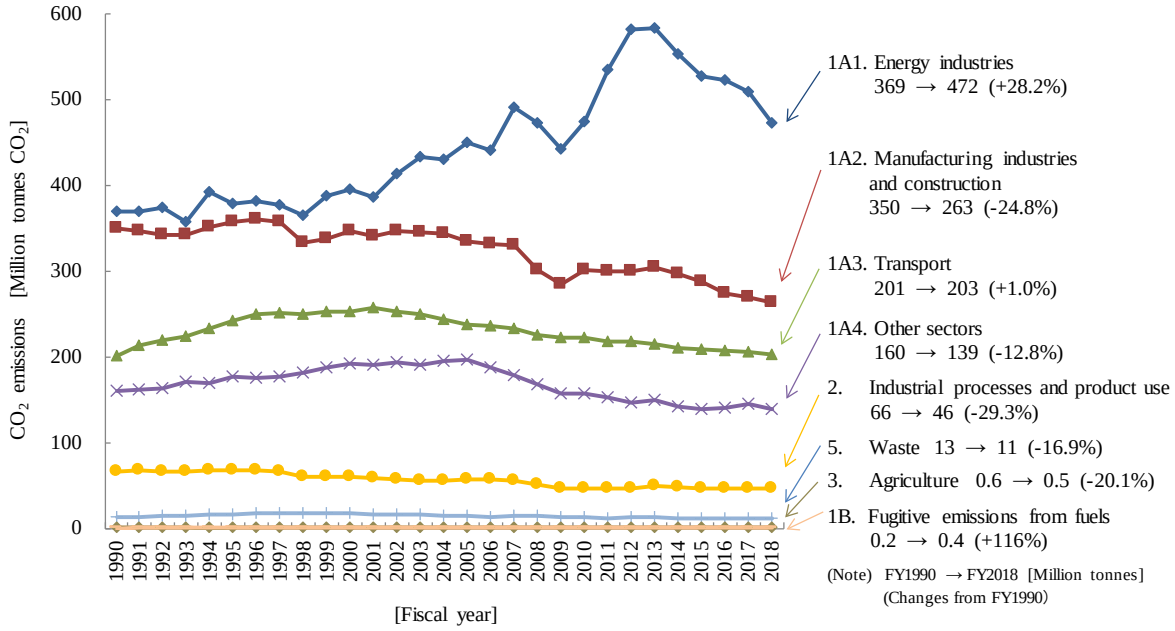


Figure 2-3 Trends in $CO_2$ emissions in each sector

Note: Figures in brackets indicate relative increase or decrease to the FY1990 values

[6] It covers emissions from commercial/institutional, residential and agriculture/forestry/fishing.

Table 2-2 Trends in $CO_2$ emissions and removals in each sector

[Thousand tonnes $CO_2$]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A. Fuel combustion | 1,078,839 | 1,154,876 | 1,186,033 | 1,218,052 | 1,103,125 | 1,153,259 | 1,204,244 | 1,244,716 | 1,252,248 | 1,201,718 | 1,162,992 | 1,144,294 | 1,128,427 | 1,077,487 |
| 1A1. Energy industries | 368,529 | 378,904 | 395,495 | 449,661 | 441,432 | 473,849 | 534,792 | 581,482 | 583,367 | 552,884 | 527,321 | 522,736 | 508,760 | 472,488 |
| Public electricity and heat production | 303,055 | 317,587 | 330,118 | 378,044 | 373,133 | 404,240 | 468,952 | 516,377 | 521,751 | 493,352 | 468,475 | 469,005 | 456,772 | 418,339 |
| Petroleum refining | 36,397 | 41,085 | 46,978 | 50,888 | 47,184 | 47,715 | 44,478 | 43,298 | 42,939 | 41,103 | 41,664 | 35,883 | 35,147 | 36,211 |
| Manufacture of solid fuels and other energy industries | 29,077 | 20,232 | 18,399 | 20,728 | 21,115 | 21,894 | 21,361 | 21,807 | 18,677 | 18,429 | 17,182 | 17,849 | 16,840 | 17,938 |
| 1A2. Manufacturing industries and construction | 349,703 | 357,556 | 346,635 | 334,189 | 283,829 | 300,375 | 299,343 | 299,008 | 304,121 | 296,553 | 287,513 | 273,647 | 269,847 | 262,837 |
| Iron and steel | 150,689 | 143,096 | 152,113 | 154,175 | 135,644 | 153,172 | 148,896 | 151,309 | 157,569 | 155,124 | 148,897 | 142,785 | 139,784 | 136,047 |
| Non-ferrous metals | 8,428 | 7,380 | 6,332 | 5,705 | 4,066 | 3,999 | 3,871 | 4,037 | 3,778 | 3,673 | 3,282 | 3,556 | 3,172 | 3,114 |
| Chemicals | 58,039 | 64,239 | 59,022 | 54,488 | 48,956 | 49,188 | 48,484 | 46,108 | 47,287 | 45,499 | 44,571 | 41,084 | 41,841 | 40,638 |
| Pulp, paper and print | 27,105 | 31,427 | 31,679 | 29,738 | 23,425 | 22,592 | 23,266 | 23,761 | 23,778 | 22,848 | 23,248 | 20,802 | 20,466 | 20,229 |
| Food processing, beverages and tobacco | 7,649 | 10,132 | 11,511 | 12,217 | 9,906 | 9,925 | 10,900 | 10,653 | 9,901 | 9,668 | 8,669 | 8,678 | 8,163 | 8,188 |
| Non-metallic minerals | 43,620 | 46,453 | 40,150 | 35,482 | 29,281 | 28,775 | 28,681 | 28,962 | 29,865 | 29,059 | 28,134 | 27,207 | 27,005 | 26,677 |
| Other | 54,173 | 54,828 | 45,828 | 42,385 | 32,551 | 32,725 | 35,246 | 34,178 | 31,943 | 30,682 | 30,712 | 29,535 | 29,416 | 27,946 |
| 1A3. Transport | 200,986 | 241,993 | 252,656 | 237,777 | 221,488 | 221,969 | 217,138 | 218,004 | 215,115 | 210,131 | 208,853 | 206,949 | 205,394 | 202,914 |
| Domestic aviation | 7,162 | 10,278 | 10,677 | 10,799 | 9,781 | 9,193 | 9,001 | 9,524 | 10,149 | 10,173 | 10,067 | 10,187 | 10,399 | 10,536 |
| Road transportation | 179,213 | 216,223 | 226,256 | 213,317 | 200,656 | 201,457 | 197,148 | 197,158 | 193,437 | 188,521 | 187,641 | 185,709 | 184,024 | 181,333 |
| Railways | 935 | 822 | 711 | 647 | 590 | 574 | 554 | 554 | 540 | 524 | 523 | 499 | 499 | 499 |
| Domestic navigation | 13,675 | 14,669 | 15,012 | 13,014 | 10,462 | 10,745 | 10,434 | 10,769 | 10,989 | 10,912 | 10,622 | 10,555 | 10,472 | 10,546 |
| 1A4. Other sectors | 159,621 | 176,423 | 191,246 | 196,425 | 156,376 | 157,066 | 152,972 | 146,222 | 149,645 | 142,151 | 139,305 | 140,962 | 144,425 | 139,247 |
| Commercial/institutional | 79,184 | 88,256 | 98,693 | 106,091 | 75,808 | 75,023 | 73,925 | 67,332 | 74,462 | 69,509 | 67,726 | 68,071 | 69,487 | 71,725 |
| Residential | 58,167 | 67,477 | 72,226 | 70,395 | 61,351 | 64,217 | 62,541 | 62,626 | 60,319 | 58,014 | 55,392 | 55,712 | 59,260 | 52,152 |
| Agriculture/forestry/fishing | 22,270 | 20,690 | 20,326 | 19,939 | 19,217 | 17,826 | 16,505 | 16,264 | 14,863 | 14,628 | 16,188 | 17,179 | 15,678 | 15,370 |
| 1A5. Other | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 1B. Fugitive emissions from fuels | 192 | 521 | 512 | 508 | 501 | 475 | 477 | 490 | 438 | 449 | 425 | 457 | 436 | 414 |
| 1C. $CO_2$ transport and storage | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO |
| 2. Industrial processes and product use | 65,620 | 67,458 | 60,214 | 56,476 | 46,056 | 47,105 | 46,946 | 46,995 | 48,758 | 48,153 | 46,772 | 46,359 | 46,994 | 46,389 |
| 3. Agriculture | 609 | 359 | 443 | 411 | 390 | 403 | 415 | 520 | 578 | 551 | 459 | 446 | 486 | 486 |
| 4. LULUCF | -62,537 | -77,382 | -88,049 | -91,471 | -67,158 | -70,710 | -69,923 | -72,985 | -66,285 | -64,621 | -59,636 | -54,536 | -58,825 | -57,655 |
| 5. Waste | 13,132 | 16,714 | 17,644 | 14,609 | 12,575 | 12,827 | 12,073 | 12,711 | 12,681 | 12,179 | 12,133 | 11,611 | 11,318 | 10,912 |
| Total (including LULUCF) | 1,095,855 | 1,162,546 | 1,176,796 | 1,198,585 | 1,095,489 | 1,143,358 | 1,194,232 | 1,232,448 | 1,248,418 | 1,198,429 | 1,163,145 | 1,148,632 | 1,128,837 | 1,078,033 |
| Total (excluding LULUCF) | 1,158,391 | 1,239,928 | 1,264,844 | 1,290,056 | 1,162,648 | 1,214,069 | 1,264,155 | 1,305,433 | 1,314,703 | 1,263,050 | 1,222,781 | 1,203,167 | 1,187,661 | 1,135,688 |

*1 Excluding indirect $CO_2$

*2 LULUCF: Land Use, Land-Use Change and Forestry

$CO_2$ emissions per capita in FY2018 were 8.98 tonnes. They decreased by 4.2% since FY1990 and decreased by 4.2% compared to the previous year.

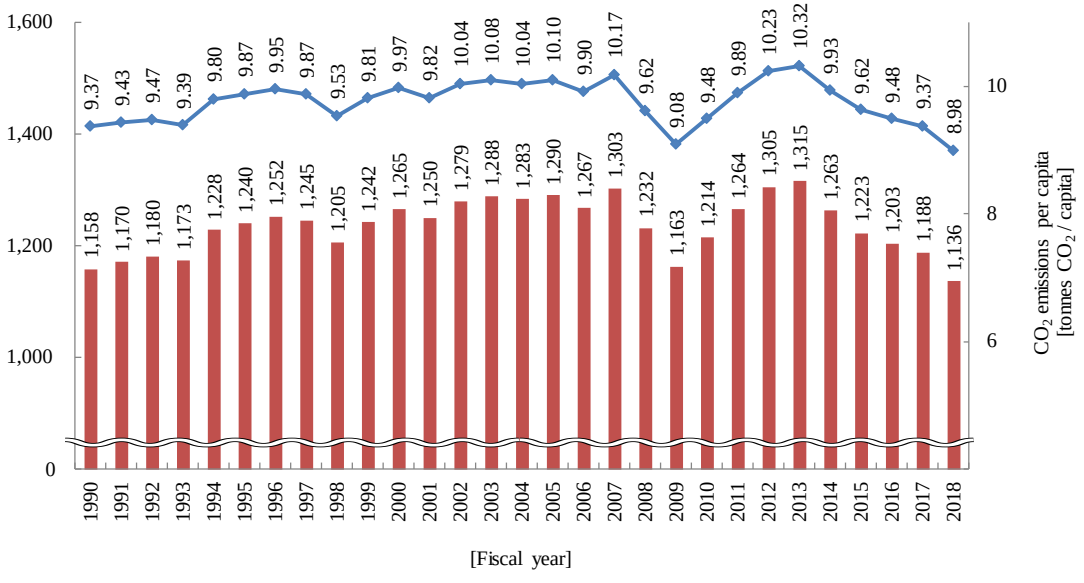


Figure 2-4 Trends in total $CO_2$ emissions and $CO_2$ emissions per capita

Reference of population data: Ministry of Internal Affairs and Communications, Statistics Bureau, Population Census and Annual Report of Population Estimates

$CO_2$ emissions per unit of GDP (million yen) in FY2018 were 2.13 tonnes. They decreased by 24.4% since FY1990 and 4.7% compared to the previous year.

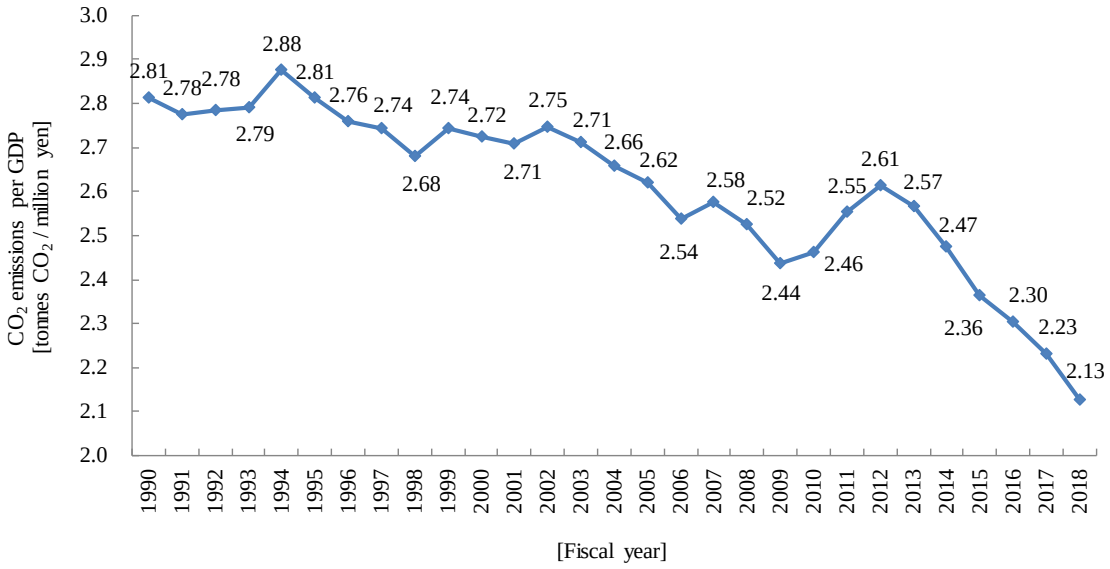


Figure 2-5 Trends in $CO_2$ emissions per unit of GDP

Reference of GDP data: Cabinet Office, Government of Japan, *Annual Report on National Accounts*

### 2.1.3. $CH_4$

$CH_4$ emissions in FY2018 were 29.9 million tonnes (in $CO_2$ eq., including LULUCF), accounting for 2.4% of total GHG emissions. They decreased by 32.8% since FY1990 and by 1.3% compared to the previous year. Their decrease since FY1990 is mainly a result of a 63.1% decrease in emissions from the waste sector (solid waste disposal).

The breakdown of the FY2018 emissions showed that the largest source was rice cultivation accounting for 45%. It is followed by enteric fermentation (25%) and solid waste disposal (10%).

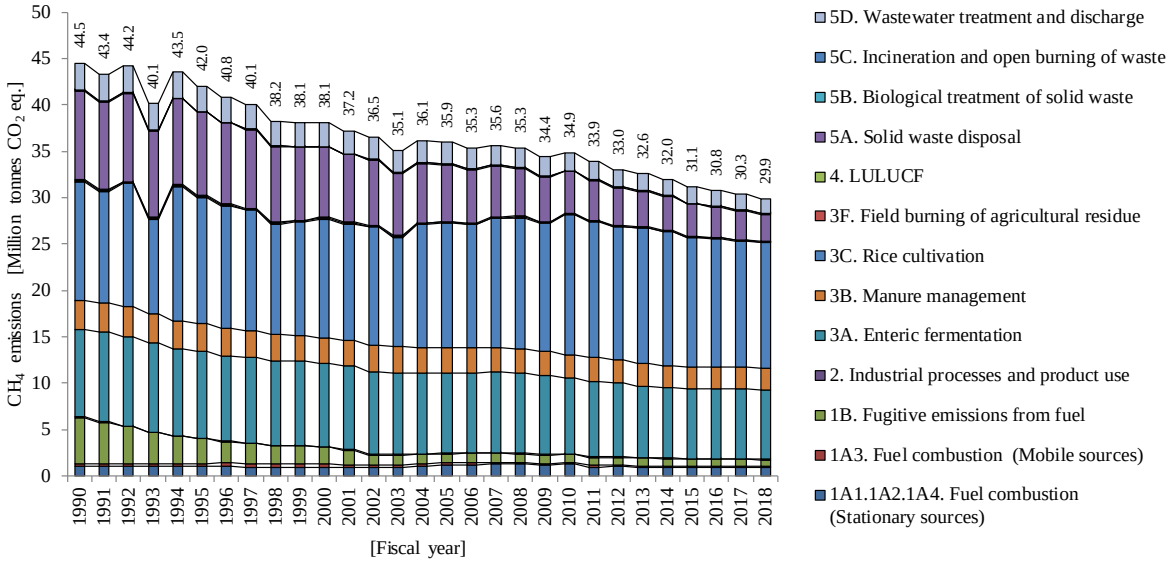


Figure 2-6 Trends in $CH_4$ emissions

Table 2-3 Trends in $CH_4$ emissions

[Thousand tonnes $CO_2$ eq.]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A. Fuel combustion | 1,350 | 1,381 | 1,276 | 1,434 | 1,366 | 1,437 | 1,147 | 1,166 | 1,112 | 1,099 | 1,052 | 1,050 | 1,043 | 1,014 |
| 1A1. Energy industries | 459 | 400 | 263 | 249 | 258 | 270 | 290 | 300 | 239 | 225 | 214 | 222 | 208 | 200 |
| 1A2. Manufacturing industries and construction | 360 | 378 | 371 | 442 | 499 | 538 | 439 | 465 | 496 | 519 | 496 | 487 | 489 | 492 |
| 1A3. Transport | 291 | 309 | 312 | 247 | 184 | 174 | 166 | 160 | 151 | 143 | 137 | 133 | 128 | 125 |
| 1A4. Other sectors | 239 | 294 | 330 | 496 | 426 | 455 | 252 | 241 | 225 | 211 | 205 | 207 | 218 | 198 |
| 1B. Fugitive emissions from fuels | 4,973 | 2,647 | 1,836 | 976 | 916 | 885 | 867 | 851 | 816 | 806 | 788 | 794 | 800 | 741 |
| 1B1. Solid fuels | 4,760 | 2,394 | 1,563 | 655 | 577 | 564 | 552 | 545 | 533 | 538 | 521 | 510 | 521 | 479 |
| 1B2. Oil and natural gas and other emissions | 213 | 253 | 273 | 322 | 339 | 321 | 315 | 305 | 283 | 268 | 267 | 284 | 280 | 262 |
| 2. Industrial processes and product use | 61 | 58 | 54 | 54 | 51 | 54 | 54 | 46 | 46 | 43 | 48 | 43 | 43 | 40 |
| 3. Agriculture | 25,441 | 26,022 | 24,615 | 24,898 | 24,991 | 25,829 | 25,415 | 24,815 | 24,781 | 24,415 | 23,871 | 23,776 | 23,510 | 23,413 |
| 3A. Enteric fermentation | 9,423 | 9,318 | 8,966 | 8,651 | 8,480 | 8,202 | 8,154 | 7,953 | 7,737 | 7,543 | 7,534 | 7,481 | 7,494 | 7,466 |
| 3B. Manure management | 3,121 | 2,988 | 2,804 | 2,717 | 2,573 | 2,513 | 2,508 | 2,465 | 2,406 | 2,364 | 2,362 | 2,321 | 2,324 | 2,324 |
| 3C. Rice cultivation | 12,771 | 13,605 | 12,749 | 13,445 | 13,863 | 15,041 | 14,680 | 14,325 | 14,565 | 14,437 | 13,908 | 13,907 | 13,627 | 13,561 |
| 3F. Field burning of agricultural residue | 127 | 111 | 96 | 86 | 76 | 74 | 73 | 71 | 72 | 70 | 67 | 67 | 64 | 63 |
| 4. LULUCF | 99 | 96 | 91 | 90 | 88 | 81 | 82 | 77 | 78 | 97 | 80 | 74 | 95 | 74 |
| 5. Waste | 12,594 | 11,818 | 10,201 | 8,483 | 6,951 | 6,579 | 6,293 | 6,026 | 5,778 | 5,524 | 5,306 | 5,073 | 4,841 | 4,646 |
| 5A. Solid waste disposal | 9,570 | 8,985 | 7,570 | 6,090 | 4,835 | 4,521 | 4,272 | 4,058 | 3,855 | 3,635 | 3,444 | 3,247 | 3,093 | 2,930 |
| 5B. Biological treatment of solid waste | 54 | 53 | 54 | 95 | 106 | 93 | 102 | 101 | 100 | 100 | 102 | 103 | 90 | 89 |
| 5C. Incineration and open burning of waste | 28 | 29 | 21 | 18 | 13 | 12 | 11 | 11 | 12 | 10 | 10 | 9 | 10 | 10 |
| 5D. Wastewater treatment and discharge | 2,942 | 2,750 | 2,556 | 2,280 | 1,997 | 1,954 | 1,908 | 1,855 | 1,811 | 1,779 | 1,749 | 1,714 | 1,648 | 1,617 |
| Total (including LULUCF) | 44,518 | 42,022 | 38,073 | 35,936 | 34,364 | 34,865 | 33,858 | 32,981 | 32,612 | 31,984 | 31,145 | 30,810 | 30,333 | 29,929 |
| Total (excluding LULUCF) | 44,418 | 41,926 | 37,982 | 35,845 | 34,277 | 34,784 | 33,776 | 32,904 | 32,533 | 31,887 | 31,065 | 30,736 | 30,237 | 29,855 |

* LULUCF: Land Use, Land-Use Change and Forestry

### 2.1.4. $N_2O$

$N_2O$ emissions in FY2018 were 20.2 million tonnes (in $CO_2$ eq., including LULUCF), accounting for 1.6% of total GHG emissions. They decreased by 37.1% since FY1990 and decreased by 2.0% compared to the previous year. Their decrease since FY1990 is mainly a result of a 94.7% decrease in emissions from industrial processes and product use (e.g. adipic acid production in the chemical industry). There is a sharp decline in emissions from the industrial processes and product use from FY1998 to 1999, as $N_2O$ abatement equipment came on stream in the adipic acid production plant in March 1999. However, the $N_2O$ emissions increased in FY2000 because of a decrease in the equipment's operation rate due to mechanical failure; the emissions decreased again in FY2001 with the resumption of normal operation.

Breakdown of the FY2018 emissions showed that the largest source was agricultural soils accounting for 27%. It is followed by fuel combustion (stationary sources) (22%) and manure management (19%).

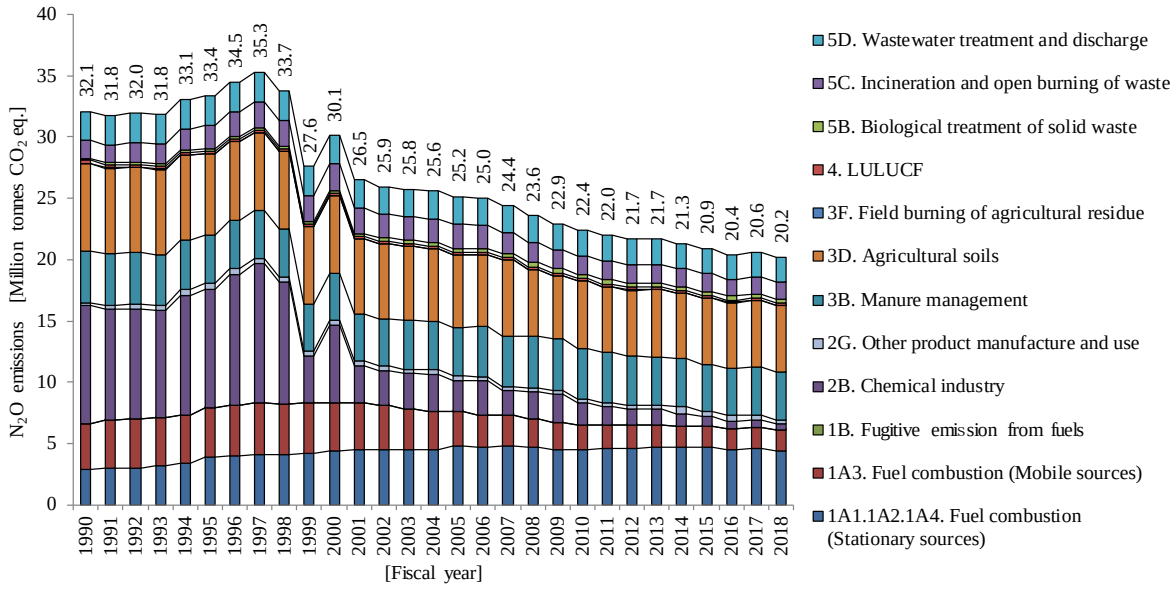


Figure 2-7 Trends in $N_2O$ emissions

Table 2-4 Trends in $N_2O$ emissions

[Thousand tonnes $CO_2$ eq.]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A. Fuel combustion | 6,597 | 7,941 | 8,341 | 7,559 | 6,690 | 6,503 | 6,517 | 6,497 | 6,529 | 6,420 | 6,377 | 6,151 | 6,299 | 6,063 |
| 1A1. Energy industries | 889 | 1,353 | 1,613 | 2,117 | 2,084 | 2,072 | 2,267 | 2,290 | 2,358 | 2,346 | 2,348 | 2,183 | 2,338 | 2,166 |
| 1A2. Manufacturing industries and construction | 1,259 | 1,705 | 1,878 | 1,867 | 1,762 | 1,723 | 1,720 | 1,738 | 1,761 | 1,721 | 1,723 | 1,650 | 1,643 | 1,600 |
| 1A3. Transport | 3,739 | 4,104 | 3,997 | 2,817 | 2,187 | 2,052 | 1,950 | 1,874 | 1,803 | 1,745 | 1,716 | 1,691 | 1,680 | 1,671 |
| 1A4. Other sectors | 709 | 778 | 852 | 757 | 656 | 656 | 580 | 595 | 606 | 608 | 590 | 626 | 638 | 625 |
| 1B. Fugitive emissions from fuels | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 2. Industrial processes and product use | 9,911 | 10,114 | 6,720 | 2,926 | 2,619 | 2,088 | 1,777 | 1,600 | 1,618 | 1,606 | 1,199 | 1,105 | 1,020 | 876 |
| 2B. Chemical industry | 9,620 | 9,665 | 6,348 | 2,558 | 2,360 | 1,813 | 1,507 | 1,293 | 1,259 | 979 | 798 | 676 | 599 | 506 |
| 2G. Other product manufacture and use | 291 | 449 | 371 | 368 | 259 | 275 | 270 | 308 | 359 | 627 | 402 | 429 | 420 | 370 |
| 3. Agriculture | 11,362 | 10,598 | 10,207 | 9,915 | 9,416 | 9,666 | 9,507 | 9,442 | 9,398 | 9,274 | 9,295 | 9,258 | 9,385 | 9,353 |
| 3B. Manure management | 4,208 | 3,983 | 3,850 | 3,994 | 4,218 | 4,136 | 4,093 | 4,024 | 3,927 | 3,865 | 3,849 | 3,847 | 3,926 | 3,922 |
| 3D. Agricultural soils | 7,115 | 6,580 | 6,327 | 5,894 | 5,175 | 5,506 | 5,391 | 5,397 | 5,448 | 5,388 | 5,426 | 5,390 | 5,440 | 5,412 |
| 3F. Field burning of agricultural residue | 39 | 34 | 30 | 26 | 23 | 23 | 22 | 22 | 22 | 22 | 21 | 21 | 20 | 20 |
| 4. LULUCF | 219 | 209 | 199 | 190 | 184 | 182 | 182 | 183 | 183 | 186 | 185 | 185 | 189 | 190 |
| 5. Waste | 4,006 | 4,525 | 4,638 | 4,563 | 4,018 | 3,939 | 3,989 | 3,931 | 3,952 | 3,801 | 3,865 | 3,683 | 3,714 | 3,708 |
| 5B. Biological treatment of solid waste | 181 | 179 | 181 | 319 | 354 | 309 | 342 | 338 | 335 | 333 | 340 | 343 | 298 | 296 |
| 5C. Incineration and open burning of waste | 1,438 | 1,908 | 2,156 | 1,963 | 1,570 | 1,515 | 1,518 | 1,523 | 1,535 | 1,423 | 1,498 | 1,312 | 1,423 | 1,429 |
| 5D. Wastewater treatment and discharge | 2,387 | 2,439 | 2,301 | 2,280 | 2,094 | 2,115 | 2,129 | 2,069 | 2,082 | 2,045 | 2,027 | 2,028 | 1,992 | 1,983 |
| Total (including LULUCF) | 32,095 | 33,388 | 30,105 | 25,152 | 22,927 | 22,377 | 21,971 | 21,654 | 21,679 | 21,287 | 20,922 | 20,381 | 20,607 | 20,190 |
| Total (excluding LULUCF) | 31,876 | 33,179 | 29,906 | 24,963 | 22,743 | 22,195 | 21,790 | 21,471 | 21,496 | 21,101 | 20,737 | 20,196 | 20,418 | 20,000 |

* LULUCF: Land Use, Land-Use Change and Forestry

### 2.1.5. HFCs

HFC emissions in CY2018[7] were 47.0 million tonnes (in $CO_2$ eq.), accounting for 3.8% of total GHG emissions. They increased by 194.9% since CY1990, and by 4.7% compared to the previous year. Their increase since CY1990 is mainly a result of an increase in emissions from refrigeration and air conditioning (+43.2 million tonnes $CO_2$ eq.) substituting for HCFC (an ozone depleting substance), despite a decrease in emissions of HFC-23 (-99.9%) produced as a by-product of HCFC-22 production due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures. (Act No.53, 1988)

The breakdown of the CY2018 emissions showed that the largest source was refrigerants of refrigeration and air conditioning equipment accounting for 92%. It is followed by foam blowing agents (6%).

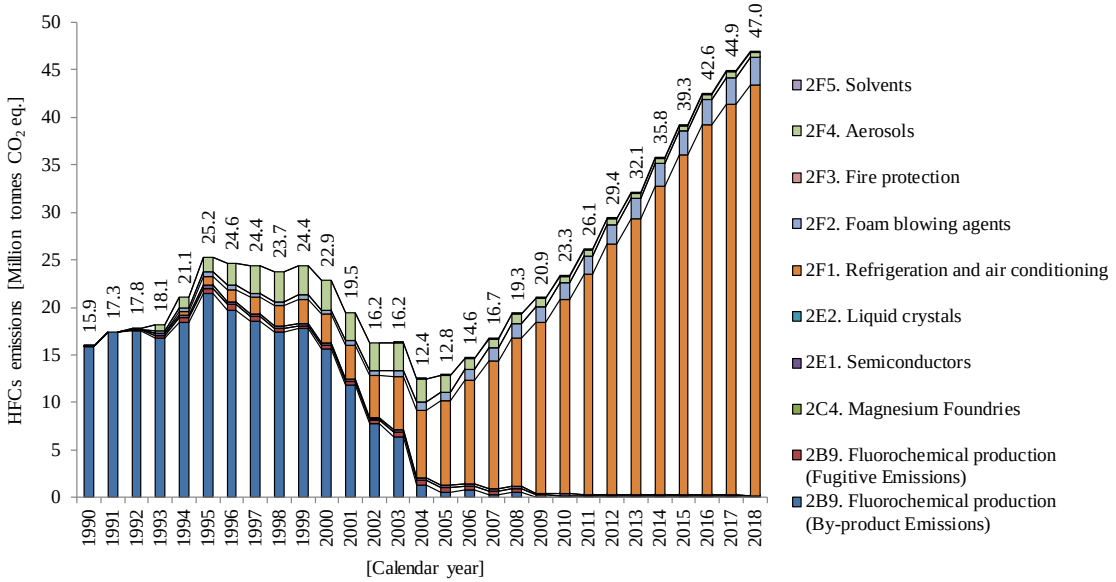


Figure 2-8 Trends in HFC emissions

Table 2-5 Trends in HFC emissions

[Thousand tonnes $CO_2$ eq.]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2B9. Fluorochemical production | 15,930 | 22,019 | 15,984 | 1,035 | 284 | 181 | 168 | 138 | 147 | 124 | 113 | 172 | 133 | 100 |
| By-product Emissions | 15,929 | 21,460 | 15,688 | 586 | 50 | 53 | 16 | 18 | 16 | 24 | 30 | 24 | 38 | 12 |
| Fugitive Emissions | 2 | 559 | 296 | 449 | 234 | 128 | 151 | 120 | 131 | 101 | 83 | 149 | 95 | 88 |
| 2C4. Magnesium production | NO | NO | NO | NO | NO | NO | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 2E. Electronics industry | 1 | 271 | 285 | 227 | 152 | 168 | 145 | 124 | 112 | 115 | 115 | 119 | 125 | 113 |
| 2E1. Semiconductors | 1 | 271 | 283 | 224 | 150 | 165 | 142 | 122 | 109 | 113 | 113 | 117 | 123 | 113 |
| 2E2. Liquid crystals | 0.001 | 0.3 | 2 | 3 | 2 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 0.4 |
| 2F. Product uses as substitutes for ODS | 1 | 2,923 | 6,583 | 11,522 | 20,498 | 22,966 | 25,791 | 29,097 | 31,844 | 35,543 | 39,034 | 42,282 | 44,631 | 46,772 |
| 2F1. Refrigeration and air conditioning | NO | 925 | 2,977 | 8,876 | 17,998 | 20,482 | 23,139 | 26,353 | 29,007 | 32,535 | 35,875 | 38,905 | 41,104 | 43,179 |
| 2F2. Foam blowing agents | 1 | 497 | 484 | 937 | 1,608 | 1,749 | 1,923 | 2,081 | 2,229 | 2,373 | 2,484 | 2,651 | 2,801 | 2,922 |
| 2F3. Fire protection | NO | NO | 5 | 7 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 10 | 10 | 10 |
| 2F4. Aerosols | NO | 1,502 | 3,117 | 1,695 | 845 | 666 | 634 | 561 | 489 | 503 | 540 | 587 | 600 | 544 |
| 2F5. Solvents | NO | NO | NO | 6 | 39 | 60 | 86 | 94 | 109 | 122 | 126 | 130 | 116 | 117 |
| Total | 15,932 | 25,213 | 22,852 | 12,784 | 20,934 | 23,315 | 26,105 | 29,361 | 32,104 | 35,783 | 39,263 | 42,575 | 44,891 | 46,988 |

[7] Emissions of HFCs, PFCs, $SF_6$, and $NF_3$ are estimated on a calendar year (CY) basis.

### 2.1.6. PFCs

PFC emissions in CY2018 were 3.5 million tonnes (in $CO_2$ eq.), accounting for 0.3% of total GHG emissions. They decreased by 46.7% since CY1990 and decreased by 0.7% compared to the previous year. Their decrease since CY1990 is mainly the result of a decrease in emissions from the solvents. (-66.9%)

The breakdown of the CY2018 emissions showed that the largest source was semiconductor manufacture accounting for 51%. It is followed by solvents such as those for washing metals (43%), and fluorochemical production (3%).

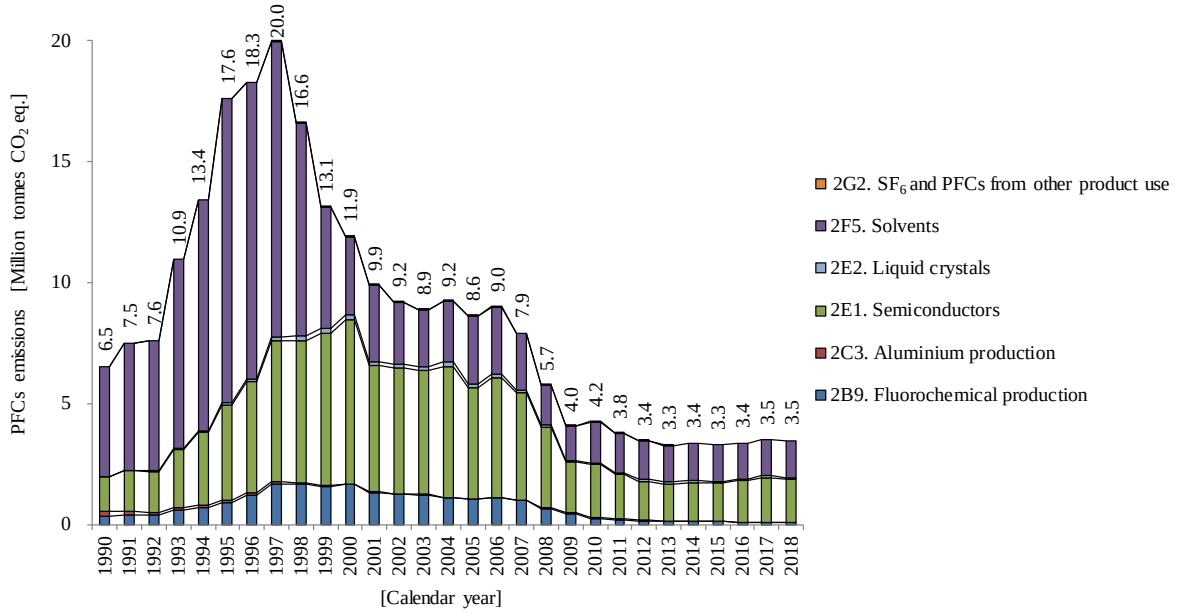


Figure 2-9 Trends in PFC emissions

Table 2-6 Trends in PFC emissions

[Thousand tonnes $CO_2$ eq.]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2B9. Fluorochemical production | 331 | 914 | 1,661 | 1,041 | 459 | 248 | 206 | 148 | 111 | 107 | 115 | 97 | 78 | 87 |
| 2C3. Aluminium production | 204 | 104 | 26 | 22 | 16 | 15 | 15 | 13 | 10 | 2 | NO | NO | NO | NO |
| 2E. Electronics industry | 1,455 | 4,020 | 6,986 | 4,746 | 2,148 | 2,261 | 1,922 | 1,692 | 1,631 | 1,707 | 1,669 | 1,792 | 1,931 | 1,855 |
| 2E1. Semiconductors | 1,423 | 3,933 | 6,771 | 4,594 | 2,109 | 2,214 | 1,863 | 1,624 | 1,556 | 1,617 | 1,582 | 1,721 | 1,847 | 1,776 |
| 2E2. Liquid crystals | 31 | 87 | 214 | 152 | 39 | 46 | 59 | 68 | 76 | 90 | 86 | 71 | 84 | 79 |
| 2F5. Solvents | 4,550 | 12,572 | 3,200 | 2,815 | 1,420 | 1,721 | 1,605 | 1,583 | 1,518 | 1,537 | 1,517 | 1,465 | 1,484 | 1,505 |
| 2G2. $SF_6$ and PFCs from other product use | NO | NO | NO | 0.3 | 3 | 4 | 6 | NO | 10 | 9 | 8 | 21 | 20 | 39 |
| Total | 6,539 | 17,610 | 11,873 | 8,623 | 4,047 | 4,250 | 3,755 | 3,436 | 3,280 | 3,361 | 3,308 | 3,375 | 3,512 | 3,487 |

### 2.1.7. $SF_6$

$SF_6$ emissions in CY2018 were 2.0 million tonnes (in $CO_2$ eq.), accounting for 0.2% of total GHG emissions. They decreased by 84.1% since CY1990 and decreased by 1.3% compared to the previous year. Their decrease since CY1990 is mainly a result of a decrease from electrical equipment, due to an enhancement of gas management system such as gas recovery largely in electric power companies. (-92.9%)

The breakdown of the CY2018 emissions showed that the largest source was other product use (e.g. accelerator, etc.) accounting for 39%. It is followed by electrical equipment (28%) and magnesium production (13%).

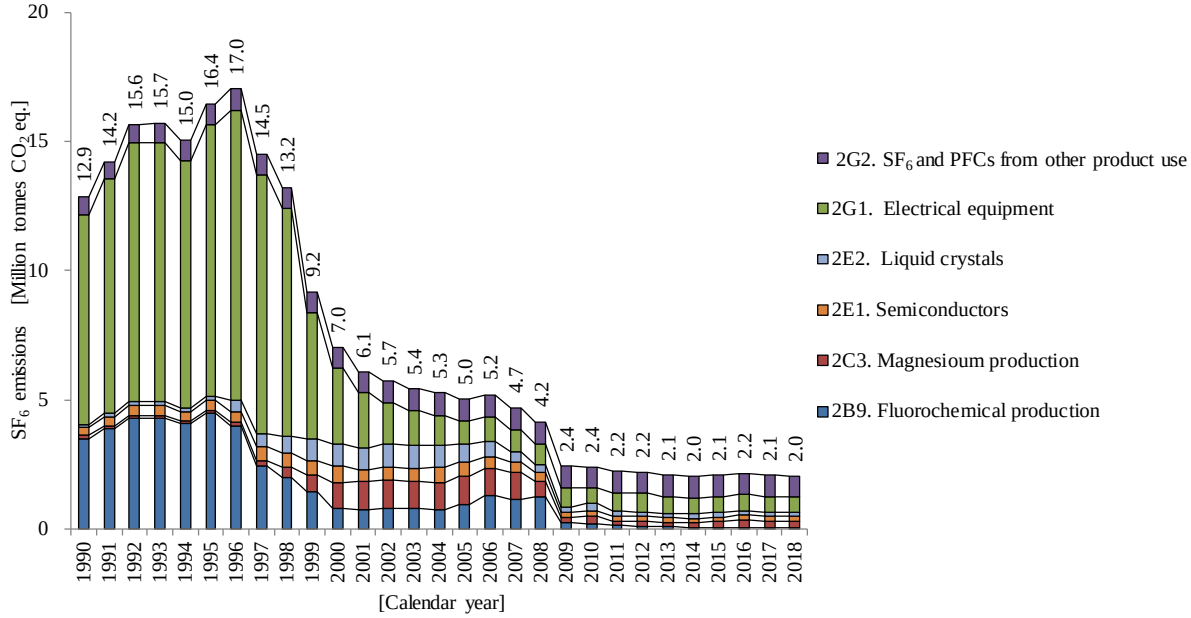


Figure 2-10 Trends in $SF_6$ emissions

Table 2-7 Trends in $SF_6$ emissions

[Thousand tonnes $CO_2$ eq.]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2B9. Fluorochemical production | 3,471 | 4,492 | 821 | 930 | 233 | 189 | 132 | 123 | 93 | 62 | 52 | 50 | 41 | 46 |
| 2C3. Magnesium production | 147 | 114 | 980 | 1,104 | 228 | 294 | 182 | 182 | 160 | 182 | 228 | 315 | 246 | 274 |
| 2E. Electronics industry | 419 | 542 | 1,506 | 1,252 | 410 | 494 | 394 | 356 | 351 | 366 | 375 | 349 | 363 | 349 |
| 2E1. Semiconductors | 309 | 400 | 629 | 540 | 211 | 225 | 196 | 184 | 181 | 175 | 184 | 192 | 200 | 182 |
| 2E2. Liquid crystals | 110 | 142 | 877 | 712 | 199 | 269 | 198 | 172 | 170 | 191 | 191 | 157 | 163 | 167 |
| 2G. Other product manufacture and use | 8,814 | 11,300 | 3,724 | 1,741 | 1,549 | 1,422 | 1,513 | 1,546 | 1,472 | 1,429 | 1,419 | 1,445 | 1,421 | 1,375 |
| 2G1. Electrical equipment | 8,112 | 10,498 | 2,910 | 899 | 711 | 622 | 707 | 719 | 643 | 602 | 610 | 655 | 620 | 572 |
| 2G2. $SF_6$ and PFCs from other product use | 702 | 802 | 815 | 842 | 838 | 799 | 806 | 827 | 829 | 827 | 809 | 789 | 801 | 803 |
| Total | 12,850 | 16,448 | 7,031 | 5,027 | 2,420 | 2,398 | 2,222 | 2,207 | 2,075 | 2,039 | 2,075 | 2,159 | 2,070 | 2,043 |

### 2.1.8. $NF_3$

$NF_3$ emissions in CY2018 were 0.3 million tonnes (in $CO_2$ eq.), accounting for 0.02% of total GHG emissions. They increased by 766.3% since CY1990 and decreased by 37.2% compared to the previous year. The increase since CY1990 is mainly a result of an increase in fugitives from florocarbon production ($NF_3$). (by 1,978.2%)

The breakdown of the CY2018 emissions showed that the largest source was semiconductor manufacture accounting for 72%. It is followed by fluorochemical production (21%) and liquid crystal manufacture (7%).

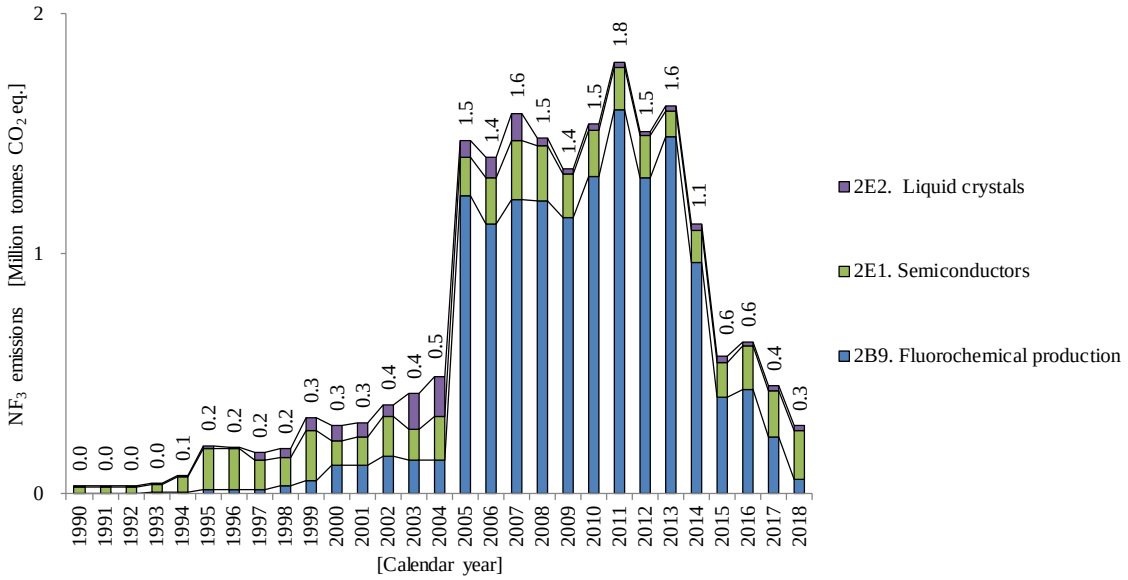


Figure 2-11 Trends in $NF_3$ emissions

Table 2-8 Trends in $NF_3$ emissions

[Thousand tonnes $CO_2$ eq.]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2B9. Fluorochemical production | 3 | 17 | 120 | 1,240 | 1,149 | 1,323 | 1,601 | 1,314 | 1,486 | 965 | 404 | 432 | 234 | 58 |
| 2E. Electronics industry | 30 | 184 | 165 | 232 | 205 | 217 | 199 | 198 | 131 | 158 | 167 | 203 | 216 | 225 |
| 2E1. Semiconductors | 27 | 168 | 100 | 161 | 182 | 191 | 175 | 177 | 110 | 132 | 145 | 183 | 194 | 203 |
| 2E2. Liquid crystals | 3 | 16 | 66 | 71 | 23 | 26 | 24 | 21 | 21 | 26 | 22 | 20 | 22 | 21 |
| Total | 33 | 201 | 286 | 1,472 | 1,354 | 1,540 | 1,800 | 1,512 | 1,617 | 1,123 | 571 | 634 | 450 | 282 |

### 2.1.9. Indirect $CO_2$

Indirect $CO_2$[8] emissions in FY2018 were 2.1 million tonnes (in $CO_2$ eq.), accounting for 0.2% of total GHG emissions. They decreased by 62.4% since FY1990 and decreased by 0.66% compared to the previous year. Their decrease since FY1990 was due to the decrease in indirect $CO_2$ emissions derived from NMVOC from the use of paint through the wider use of low VOC paint and VOC removal by adsorption devices.

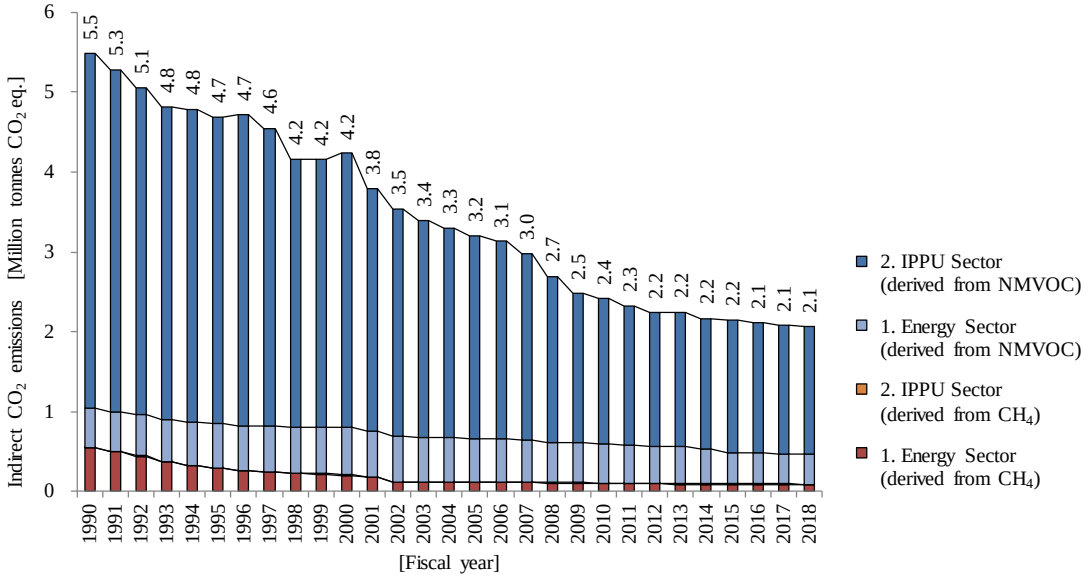


Figure 2-12 Trends in Indirect $CO_2$ emissions

Table 2-9 Trends in Indirect $CO_2$ emissions

[Thousand tonnes $CO_2$ eq.]

| Emission Source | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Derived from $CH_4$ | 554 | 298 | 208 | 113 | 106 | 103 | 101 | 99 | 95 | 93 | 92 | 92 | 93 | 86 |
| 1. Energy Sector | 547 | 291 | 202 | 107 | 101 | 97 | 95 | 94 | 90 | 89 | 87 | 87 | 88 | 82 |
| 2. IPPU Sector | 7 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 4 |
| Derived from NMVOC | 4,929 | 4,394 | 4,025 | 3,083 | 2,372 | 2,306 | 2,218 | 2,142 | 2,149 | 2,075 | 2,059 | 2,016 | 1,984 | 1,977 |
| 1. Energy Sector | 480 | 545 | 590 | 548 | 500 | 497 | 482 | 465 | 463 | 441 | 390 | 386 | 380 | 375 |
| 2. IPPU Sector | 4,448 | 3,849 | 3,435 | 2,535 | 1,872 | 1,809 | 1,736 | 1,676 | 1,686 | 1,634 | 1,669 | 1,630 | 1,604 | 1,602 |
| Total | 5,482 | 4,692 | 4,233 | 3,196 | 2,478 | 2,410 | 2,319 | 2,241 | 2,244 | 2,168 | 2,151 | 2,108 | 2,077 | 2,063 |

[8] Emissions derived from combustion-origin and biomass-origin CO, $CH_4$, and NMVOC are excluded to avoid double counting and/or by concept of carbon neutrality.

## 2.2. Description and Interpretation of Emission and Removal Trends by Categories

The breakdown of GHG emissions and removals in FY2018 by sector[9] showed that energy (excluding indirect $CO_2$, hereafter, definition omitted) accounted for 87.5% of total GHG emissions. It is followed by industrial processes and product use (excluding indirect $CO_2$, hereafter, definition omitted) (8.1%), agriculture (2.7%), waste (1.6%), and indirect $CO_2$ emissions (0.2%).

Removals by LULUCF in FY2018 were equivalent to 4.6% of total GHG emissions.

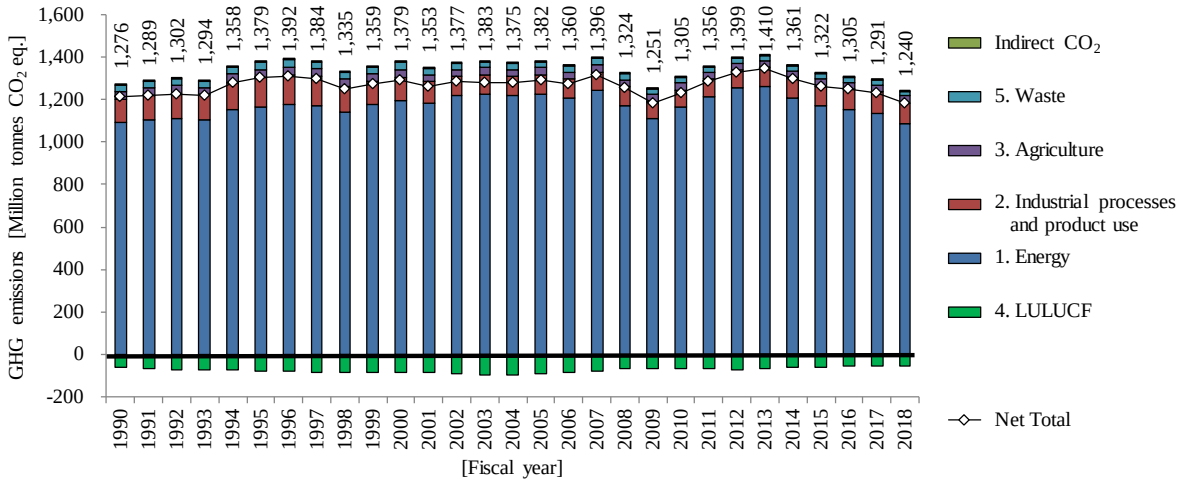


Figure 2-13 Trends in GHG emissions and removals in each sector

[9] As indicated in the *2006 IPCC Guidelines* and the CRF.

Table 2-10 Trends in GHG emissions and removals in each sector

| [Million tonnes $CO_2$ eq.] | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Energy*1 | 1,091.9 | 1,102.2 | 1,110.6 | 1,104.5 | 1,155.3 | 1,167.4 | 1,178.2 | 1,173.4 | 1,139.4 | 1,176.0 |
| 2. Industrial processes and product use*1 | 110.9 | 115.4 | 117.3 | 119.4 | 127.0 | 137.1 | 139.3 | 136.3 | 123.6 | 110.9 |
| 3. Agriculture | 37.4 | 36.7 | 37.9 | 34.7 | 38.3 | 37.0 | 36.2 | 35.9 | 34.5 | 34.7 |
| 4. LULUCF*2 | -62.2 | -70.3 | -73.3 | -76.4 | -76.1 | -77.1 | -81.7 | -84.1 | -85.5 | -85.7 |
| 5. Waste | 29.7 | 29.7 | 30.9 | 30.4 | 32.9 | 33.1 | 33.3 | 33.7 | 33.3 | 32.7 |
| Indirect $CO_2$ | 5.5 | 5.3 | 5.1 | 4.8 | 4.8 | 4.7 | 4.7 | 4.6 | 4.2 | 4.2 |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | 1,270.0 | 1,284.0 | 1,296.7 | 1,289.1 | 1,353.4 | 1,374.5 | 1,387.0 | 1,379.3 | 1,330.8 | 1,354.4 |
| Net Total (including LULUCF, excluding indirect $CO_2$) | 1,207.8 | 1,213.7 | 1,223.4 | 1,212.7 | 1,277.3 | 1,297.4 | 1,305.3 | 1,295.2 | 1,245.2 | 1,268.6 |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | 1,275.5 | 1,289.3 | 1,301.7 | 1,293.9 | 1,358.2 | 1,379.2 | 1,391.7 | 1,383.9 | 1,334.9 | 1,358.5 |
| Net Total (including LULUCF, including indirect $CO_2$) | 1,213.3 | 1,219.0 | 1,228.4 | 1,217.5 | 1,282.1 | 1,302.1 | 1,310.0 | 1,299.8 | 1,249.4 | 1,272.8 |

| [Million tonnes $CO_2$ eq.] | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Energy*1 | 1,198.0 | 1,185.7 | 1,217.4 | 1,226.1 | 1,221.8 | 1,228.5 | 1,205.7 | 1,241.8 | 1,174.2 | 1,112.6 |
| 2. Industrial processes and product use*1 | 109.0 | 98.0 | 91.1 | 89.7 | 86.3 | 87.4 | 90.2 | 89.3 | 84.9 | 77.5 |
| 3. Agriculture | 35.3 | 34.8 | 35.0 | 34.0 | 35.1 | 35.2 | 35.0 | 36.1 | 35.5 | 34.8 |
| 4. LULUCF*2 | -87.8 | -88.3 | -89.7 | -100.0 | -96.4 | -91.2 | -85.8 | -81.2 | -70.9 | -66.9 |
| 5. Waste | 32.5 | 30.8 | 29.7 | 29.4 | 28.5 | 27.7 | 26.3 | 26.0 | 26.6 | 23.5 |
| Indirect $CO_2$ | 4.2 | 3.8 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 2.7 | 2.5 |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | 1,374.8 | 1,349.3 | 1,373.2 | 1,379.1 | 1,371.7 | 1,378.8 | 1,357.2 | 1,393.2 | 1,321.2 | 1,248.4 |
| Net Total (including LULUCF, excluding indirect $CO_2$) | 1,287.0 | 1,261.1 | 1,283.5 | 1,279.1 | 1,275.3 | 1,287.6 | 1,271.4 | 1,312.0 | 1,250.3 | 1,181.5 |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | 1,379.0 | 1,353.1 | 1,376.7 | 1,382.5 | 1,375.0 | 1,382.0 | 1,360.3 | 1,396.2 | 1,323.9 | 1,250.9 |
| Net Total (including LULUCF, including indirect $CO_2$) | 1,291.2 | 1,264.9 | 1,287.0 | 1,282.5 | 1,278.6 | 1,290.8 | 1,274.5 | 1,315.0 | 1,253.0 | 1,184.0 |

| [Million tonnes $CO_2$ eq.] | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Energy*1 | 1,162.6 | 1,213.3 | 1,253.7 | 1,261.1 | 1,210.5 | 1,171.6 | 1,152.7 | 1,137.0 | 1,085.7 |
| 2. Industrial processes and product use*1 | 80.7 | 82.7 | 85.2 | 89.5 | 92.1 | 93.2 | 96.2 | 99.0 | 100.1 |
| 3. Agriculture | 35.9 | 35.3 | 34.8 | 34.8 | 34.2 | 33.6 | 33.5 | 33.4 | 33.3 |
| 4. LULUCF*2 | -70.4 | -69.7 | -72.7 | -66.0 | -64.3 | -59.4 | -54.3 | -58.5 | -57.4 |
| 5. Waste | 23.3 | 22.4 | 22.7 | 22.4 | 21.5 | 21.3 | 20.4 | 19.9 | 19.3 |
| Indirect $CO_2$ | 2.4 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 |
| Gross Total (excluding LULUCF, excluding indirect $CO_2$) | 1,302.5 | 1,353.6 | 1,396.3 | 1,407.8 | 1,358.3 | 1,319.8 | 1,302.8 | 1,289.2 | 1,238.3 |
| Net Total (including LULUCF, excluding indirect $CO_2$) | 1,232.1 | 1,283.9 | 1,323.6 | 1,341.8 | 1,294.0 | 1,260.4 | 1,248.6 | 1,230.7 | 1,181.0 |
| Gross Total (excluding LULUCF, including indirect $CO_2$) | 1,305.0 | 1,355.9 | 1,398.6 | 1,410.1 | 1,360.5 | 1,322.0 | 1,305.0 | 1,291.3 | 1,240.4 |
| Net Total (including LULUCF, including indirect $CO_2$) | 1,234.5 | 1,286.3 | 1,325.8 | 1,344.0 | 1,296.2 | 1,262.6 | 1,250.7 | 1,232.8 | 1,183.0 |

*1 Excluding indirect $CO_2$

*2 LULUCF: Land Use, Land-Use Change and Forestry

### 2.2.1. Energy

Emissions from the energy sector in FY2018 were 1,086 million tonnes (in $CO_2$ equivalents). They decreased by 0.6% since FY1990 and decreased by 4.5% compared to the previous year.

The breakdown of the FY2018 emissions showed that $CO_2$ from fuel combustion accounted for 99.2%. The largest source within fuel combustion[10] was solid fuel $CO_2$, which accounted for 40%, and is then followed by liquid fuel $CO_2$ (36%) and gaseous fuel $CO_2$ (21%).

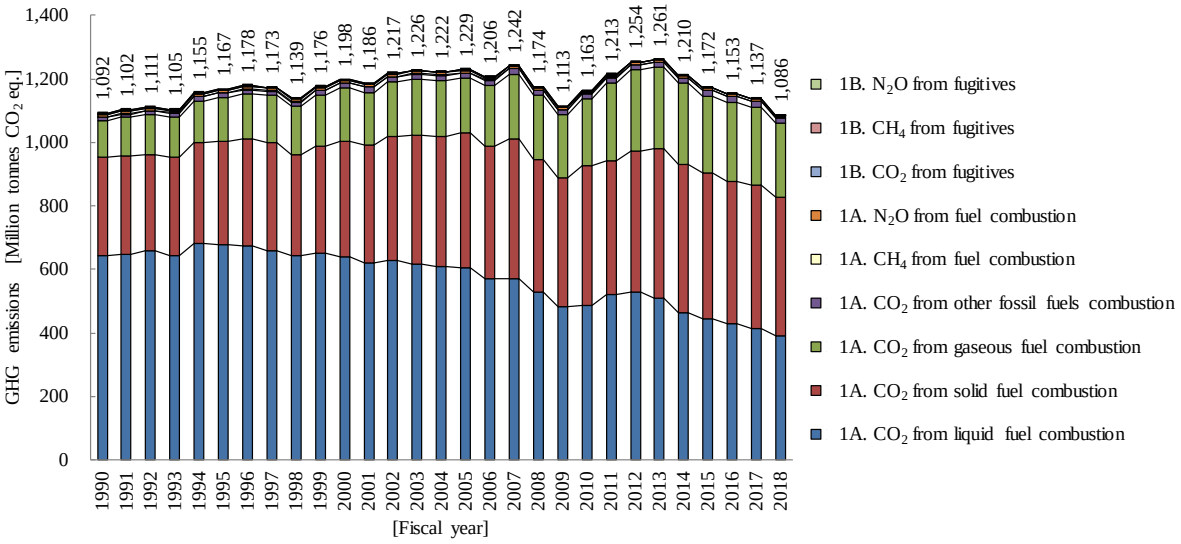


Figure 2-14 Trends in GHG emissions from the energy sector

Table 2-11 Trends in GHG emissions from the energy sector

[Thousand tonnes $CO_2$ eq.]

| Source category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A. Fuel combustion | 1,086,785 | 1,164,199 | 1,195,649 | 1,227,045 | 1,111,181 | 1,161,198 | 1,211,908 | 1,252,380 | 1,259,888 | 1,209,236 | 1,170,422 | 1,151,494 | 1,135,769 | 1,084,564 |
| Liquid fuel $CO_2$ | 644,312 | 677,416 | 640,667 | 606,112 | 483,777 | 488,924 | 520,349 | 530,754 | 508,462 | 464,737 | 444,007 | 428,294 | 415,803 | 392,517 |
| Solid fuel $CO_2$ | 309,482 | 327,102 | 364,079 | 422,447 | 404,591 | 438,513 | 423,245 | 442,778 | 473,705 | 465,143 | 458,776 | 449,606 | 451,606 | 435,755 |
| Gaseous fuel $CO_2$ | 114,167 | 137,927 | 166,073 | 172,415 | 199,127 | 209,932 | 244,686 | 254,051 | 253,378 | 255,508 | 243,368 | 248,829 | 242,817 | 231,175 |
| Other fossil fuels (Waste) $CO_2$ | 10,878 | 12,431 | 15,214 | 17,077 | 15,630 | 15,890 | 15,964 | 17,134 | 16,703 | 16,330 | 16,841 | 17,565 | 18,200 | 18,040 |
| $CH_4$ | 1,350 | 1,381 | 1,276 | 1,434 | 1,366 | 1,437 | 1,147 | 1,166 | 1,112 | 1,099 | 1,052 | 1,050 | 1,043 | 1,014 |
| $N_2O$ | 6,597 | 7,941 | 8,341 | 7,559 | 6,690 | 6,503 | 6,517 | 6,497 | 6,529 | 6,420 | 6,377 | 6,151 | 6,299 | 6,063 |
| 1B. Fugitive emissions from fuel | 5,165 | 3,169 | 2,347 | 1,484 | 1,417 | 1,359 | 1,345 | 1,341 | 1,255 | 1,255 | 1,212 | 1,251 | 1,236 | 1,155 |
| $CO_2$ | 192 | 521 | 512 | 508 | 501 | 475 | 477 | 490 | 438 | 449 | 425 | 457 | 436 | 414 |
| $CH_4$ | 4,973 | 2,647 | 1,836 | 976 | 916 | 885 | 867 | 851 | 816 | 806 | 788 | 794 | 800 | 741 |
| $N_2O$ | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 1C. $CO_2$ transport and storage | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO |
| Total | 1,091,950 | 1,167,367 | 1,197,996 | 1,228,529 | 1,112,598 | 1,162,558 | 1,213,253 | 1,253,720 | 1,261,143 | 1,210,491 | 1,171,634 | 1,152,746 | 1,137,006 | 1,085,719 |

### 2.2.2. Industrial Processes and Product Use

Emissions from the industrial processes and product use sector in FY2018 were 100.1 million tonnes (in $CO_2$ eq.). They decreased by 9.8% since FY1990 and increased by 1.1% compared to the previous year.

The breakdown of GHG emissions from this sector in FY2018 showed that the largest source was HFC emissions from product uses as ODS substitutes, accounting for 47%. It was followed by the mineral industry emissions such as $CO_2$ emissions from cement production (34%) and $CO_2$ emissions from the metal industry (6%).

[10] Fuel types are categorized in accordance with classification indicated in the *2006 IPCC Guidelines* and the CRF.

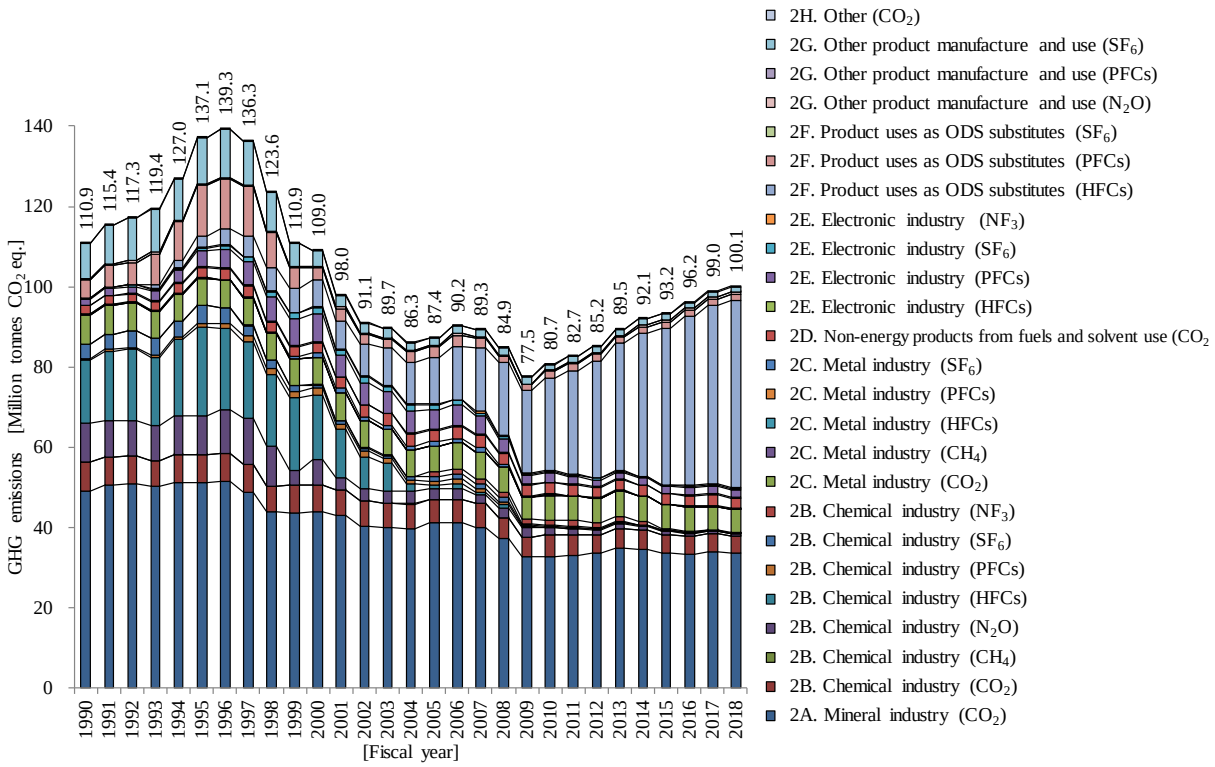


Figure 2-15 Trends in GHG emissions from the industrial processes and product use sector

Table 2-12 Trends in GHG emissions from the industrial processes and product use sector

[Thousand tonnes $CO_2$ eq.]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2A. Mineral industry ($CO_2$) | 49,230 | 51,146 | 43,919 | 41,230 | 32,779 | 32,752 | 33,089 | 33,629 | 35,004 | 34,731 | 33,659 | 33,533 | 33,971 | 33,707 |
| 2B. Chemical industry | 36,433 | 44,158 | 31,780 | 12,633 | 9,392 | 9,218 | 8,753 | 7,696 | 7,911 | 6,945 | 6,104 | 5,754 | 5,595 | 5,040 |
| $CO_2$ | 7,041 | 7,014 | 6,810 | 5,795 | 4,872 | 5,427 | 5,103 | 4,652 | 4,787 | 4,683 | 4,591 | 4,300 | 4,485 | 4,220 |
| $CH_4$ | 37 | 37 | 34 | 34 | 36 | 36 | 36 | 28 | 28 | 25 | 32 | 27 | 25 | 23 |
| $N_2O$ | 9,620 | 9,665 | 6,348 | 2,558 | 2,360 | 1,813 | 1,507 | 1,293 | 1,259 | 979 | 798 | 676 | 599 | 506 |
| HFCs | 15,930 | 22,019 | 15,984 | 1,035 | 284 | 181 | 168 | 138 | 147 | 124 | 113 | 172 | 133 | 100 |
| PFCs | 331 | 914 | 1,661 | 1,041 | 459 | 248 | 206 | 148 | 111 | 107 | 115 | 97 | 78 | 87 |
| $SF_6$ | 3,471 | 4,492 | 821 | 930 | 233 | 189 | 132 | 123 | 93 | 62 | 52 | 50 | 41 | 46 |
| $NF_3$ | 3 | 17 | 120 | 1,240 | 1,149 | 1,323 | 1,601 | 1,314 | 1,486 | 965 | 404 | 432 | 234 | 58 |
| 2C. Metal industry | 7,617 | 7,088 | 7,766 | 7,643 | 5,728 | 6,427 | 6,182 | 6,278 | 6,378 | 6,325 | 6,185 | 6,168 | 6,011 | 6,006 |
| $CO_2$ | 7,244 | 6,850 | 6,740 | 6,497 | 5,468 | 6,101 | 5,965 | 6,063 | 6,189 | 6,122 | 5,939 | 5,836 | 5,746 | 5,712 |
| $CH_4$ | 23 | 21 | 20 | 20 | 15 | 18 | 18 | 18 | 18 | 18 | 17 | 16 | 17 | 18 |
| HFCs | NO | NO | NO | NO | NO | NO | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| PFCs | 204 | 104 | 26 | 22 | 16 | 15 | 15 | 13 | 10 | 2 | NO | NO | NO | NO |
| $SF_6$ | 147 | 114 | 980 | 1,104 | 228 | 294 | 182 | 182 | 160 | 182 | 228 | 315 | 246 | 274 |
| 2D. Non-energy products from fuels and solvent use ($CO_2$) | 2,040 | 2,377 | 2,659 | 2,865 | 2,864 | 2,748 | 2,701 | 2,551 | 2,685 | 2,527 | 2,486 | 2,583 | 2,682 | 2,644 |
| 2E. Electronic industry | 1,904 | 5,016 | 8,941 | 6,457 | 2,916 | 3,140 | 2,661 | 2,370 | 2,225 | 2,346 | 2,326 | 2,463 | 2,634 | 2,542 |
| HFCs | 1 | 271 | 285 | 227 | 152 | 168 | 145 | 124 | 112 | 115 | 115 | 119 | 125 | 113 |
| PFCs | 1,455 | 4,020 | 6,986 | 4,746 | 2,148 | 2,261 | 1,922 | 1,692 | 1,631 | 1,707 | 1,669 | 1,792 | 1,931 | 1,855 |
| $SF_6$ | 419 | 542 | 1,506 | 1,252 | 410 | 494 | 394 | 356 | 351 | 366 | 375 | 349 | 363 | 349 |
| $NF_3$ | 30 | 184 | 165 | 232 | 205 | 217 | 199 | 198 | 131 | 158 | 167 | 203 | 216 | 225 |
| 2F. Product uses as ODS substitutes | 4,551 | 15,496 | 9,783 | 14,336 | 21,918 | 24,686 | 27,396 | 30,680 | 33,361 | 37,079 | 40,551 | 43,747 | 46,115 | 48,278 |
| HFCs | 1 | 2,923 | 6,583 | 11,522 | 20,498 | 22,966 | 25,791 | 29,097 | 31,844 | 35,543 | 39,034 | 42,282 | 44,631 | 46,772 |
| PFCs | 4,550 | 12,572 | 3,200 | 2,815 | 1,420 | 1,721 | 1,605 | 1,583 | 1,518 | 1,537 | 1,517 | 1,465 | 1,484 | 1,505 |
| $SF_6$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 2G. Other product manufacture and use | 9,105 | 11,749 | 4,096 | 2,109 | 1,811 | 1,701 | 1,789 | 1,854 | 1,841 | 2,065 | 1,829 | 1,894 | 1,860 | 1,784 |
| $N_2O$ | 291 | 449 | 371 | 368 | 259 | 275 | 270 | 308 | 359 | 627 | 402 | 429 | 420 | 370 |
| PFCs | NO | NO | NO | 0.3 | 3 | 4 | 6 | NO | 10 | 9 | 8 | 21 | 20 | 39 |
| $SF_6$ | 8,814 | 11,300 | 3,724 | 1,741 | 1,549 | 1,422 | 1,513 | 1,546 | 1,472 | 1,429 | 1,419 | 1,445 | 1,421 | 1,375 |
| 2H. Other ($CO_2$) | 65 | 72 | 87 | 90 | 72 | 77 | 88 | 100 | 94 | 91 | 97 | 107 | 111 | 105 |
| Total | 110,945 | 137,102 | 109,030 | 87,363 | 77,481 | 80,750 | 82,660 | 85,158 | 89,499 | 92,108 | 93,237 | 96,250 | 98,979 | 100,105 |

Despite the increase in HFC emissions from product uses as substitutes for ODS compared to FY1990, emissions from the industrial processes and product use sector decreased in the same period. The main driving factors for the decrease in emissions since FY1990 were the decrease in emissions of HFC-23 produced as a by-product of HCFC-22 production due to regulation under the Act on the Protection of

the Ozone Layer Through the Control of Specified Substances and Other Measures (chemical industry), the decrease in $CO_2$ emissions from cement production (mineral industry) as the clinker production declined, and the decrease in $N_2O$ emissions from adipic acid production (chemical industry) as the $N_2O$ abatement equipment came on stream.

### 2.2.3. Agriculture

Emissions from the agriculture sector in FY2018 were 33.3 million tonnes (in $CO_2$ eq.). They decreased by 11.1% since FY1990 and by 0.4% compared to the previous year.

The breakdown of the FY2018 emissions from this sector showed that the largest source was the rice cultivation ($CH_4$) accounting for 41%. It was followed the enteric fermentation ($CH_4$) by (22%), and the agricultural soils ($N_2O$) (16%) as a result of the nitrogen-based fertilizer applications.

The main driving factor for the decrease in emissions since FY1990 was the decrease in $CH_4$ emissions from enteric fermentation due to the decrease in the number of cattle, and the decrease in $N_2O$ emissions from the agricultural soils, because the amount of nitrogen fertilizers applied and organic fertilizers from livestock manure applied had decreased.

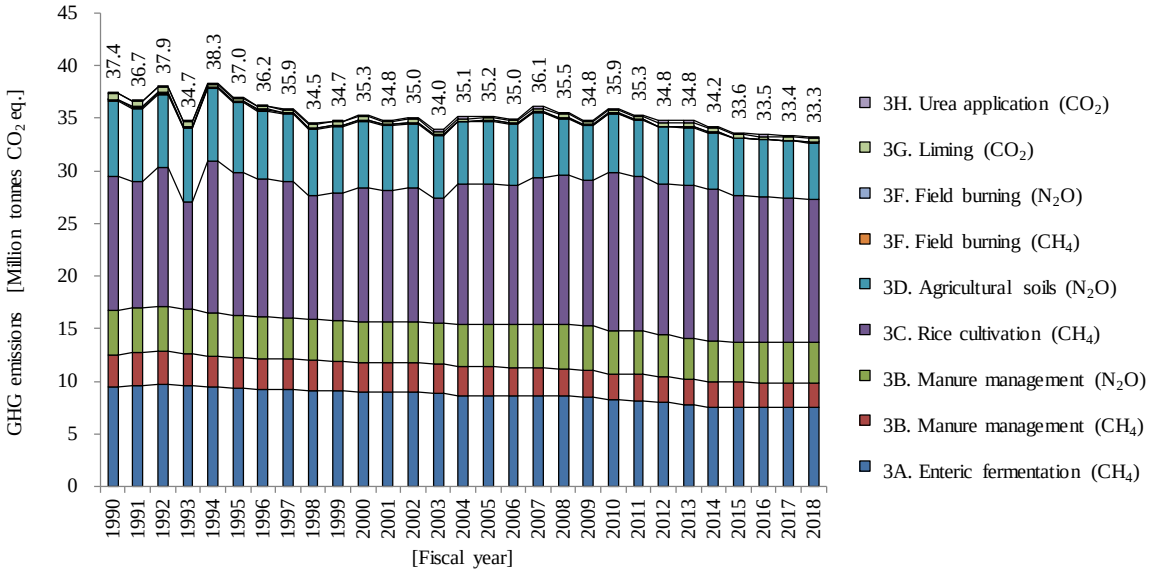


Figure 2-16 Trends in GHG emissions from the agriculture sector

Table 2-13 Trends in GHG emissions from the agriculture sector

[Thousand tonnes $CO_2$ eq.]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3A. Enteric fermentation ($CH_4$) | 9,423 | 9,318 | 8,966 | 8,651 | 8,480 | 8,202 | 8,154 | 7,953 | 7,737 | 7,543 | 7,534 | 7,481 | 7,494 | 7,466 |
| 3B. Manure management | 7,329 | 6,971 | 6,654 | 6,711 | 6,791 | 6,649 | 6,601 | 6,489 | 6,334 | 6,229 | 6,210 | 6,169 | 6,250 | 6,245 |
| $CH_4$ | 3,121 | 2,988 | 2,804 | 2,717 | 2,573 | 2,513 | 2,508 | 2,465 | 2,406 | 2,364 | 2,362 | 2,321 | 2,324 | 2,324 |
| $N_2O$ | 4,208 | 3,983 | 3,850 | 3,994 | 4,218 | 4,136 | 4,093 | 4,024 | 3,927 | 3,865 | 3,849 | 3,847 | 3,926 | 3,922 |
| 3C. Rice cultivation ($CH_4$) | 12,771 | 13,605 | 12,749 | 13,445 | 13,863 | 15,041 | 14,680 | 14,325 | 14,565 | 14,437 | 13,908 | 13,907 | 13,627 | 13,561 |
| 3D. Agricultural soils ($N_2O$) | 7,115 | 6,580 | 6,327 | 5,894 | 5,175 | 5,506 | 5,391 | 5,397 | 5,448 | 5,388 | 5,426 | 5,390 | 5,440 | 5,412 |
| 3F. Field burning of agricultural residues | 166 | 145 | 126 | 112 | 99 | 96 | 95 | 93 | 94 | 92 | 88 | 88 | 84 | 83 |
| $CH_4$ | 127 | 111 | 96 | 86 | 76 | 74 | 73 | 71 | 72 | 70 | 67 | 67 | 64 | 63 |
| $N_2O$ | 39 | 34 | 30 | 26 | 23 | 23 | 22 | 22 | 22 | 22 | 21 | 21 | 20 | 20 |
| 3G. Liming ($CO_2$) | 550 | 304 | 333 | 231 | 270 | 243 | 247 | 370 | 380 | 363 | 259 | 253 | 294 | 294 |
| 3H. Urea application ($CO_2$) | 59 | 56 | 110 | 179 | 120 | 160 | 168 | 150 | 198 | 189 | 201 | 193 | 193 | 193 |
| Total | 37,413 | 36,979 | 35,265 | 35,224 | 34,798 | 35,898 | 35,337 | 34,777 | 34,756 | 34,241 | 33,625 | 33,479 | 33,381 | 33,252 |

### 2.2.4. Land Use, Land Use Change and Forestry (LULUCF)

Net removals (including $CO_2$, $CH_4$ and $N_2O$ emissions) from the LULUCF sector in FY2018 was 57.4 million tonnes (in $CO_2$ eq.). They decreased by 7.8% since FY1990 and decreased by 2.0% compared to the previous year. The long-term declining trend in removals from 2003 is largely due to the maturity of Japanese forests.

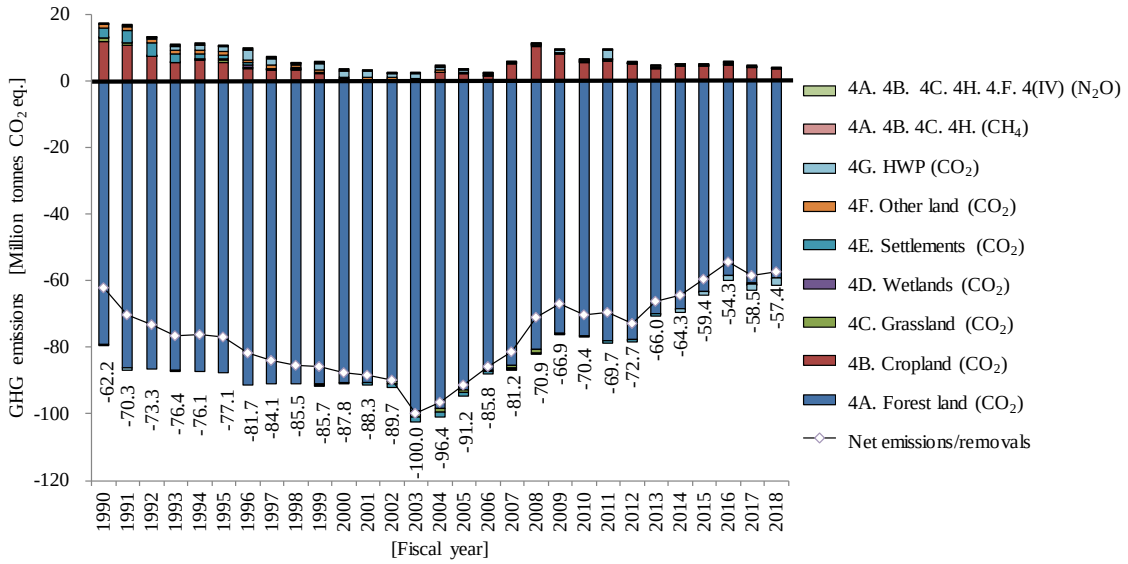


Figure 2-17 Trends in GHG emissions and removals from the LULUCF sector

Table 2-14 Trends in GHG emissions and removals from the LULUCF sector

[Thousand tonnes $CO_2$ eq.]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4A. Forest land | -78,931 | -87,475 | -90,507 | -92,529 | -75,735 | -76,245 | -77,982 | -77,553 | -69,865 | -68,131 | -62,977 | -58,434 | -60,696 | -58,895 |
| $CO_2$ | -79,061 | -87,606 | -90,637 | -92,662 | -75,867 | -76,371 | -78,110 | -77,676 | -69,991 | -68,279 | -63,108 | -58,562 | -60,849 | -59,027 |
| $CH_4$ | 10 | 10 | 9 | 11 | 10 | 5 | 6 | 2 | 4 | 23 | 6 | 1 | 23 | 2 |
| $N_2O$ | 120 | 121 | 121 | 122 | 122 | 121 | 122 | 121 | 122.5 | 125.2 | 125.0 | 126.5 | 129.5 | 129.6 |
| 4B. Cropland | 11,787 | 5,518 | 107 | 2,332 | 8,069 | 5,565 | 5,969 | 4,989 | 3,718 | 4,483 | 4,409 | 4,890 | 4,016 | 3,591 |
| $CO_2$ | 11,697 | 5,436 | 34 | 2,266 | 8,007 | 5,503 | 5,908 | 4,929 | 3,658 | 4,422 | 4,350 | 4,831 | 3,956 | 3,530 |
| $CH_4$ | 61 | 58 | 56 | 54 | 53 | 53 | 52 | 52 | 52 | 52 | 51 | 51 | 51 | 51 |
| $N_2O$ | 30 | 24 | 18 | 12 | 9 | 9 | 8 | 8 | 9 | 9 | 9 | 8 | 9 | 9 |
| 4C. Grassland | 1,093 | 720 | 78 | -935 | -5 | 154 | 287 | 14 | -4 | 179 | 20 | -37 | -151 | -236 |
| $CO_2$ | 1,062 | 689 | 48 | -966 | -36 | 124 | 256 | -19 | -35 | 147 | -12 | -67 | -181 | -266 |
| $CH_4$ | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 16 | 16 | 15 | 15 | 15 |
| $N_2O$ | 15 | 16 | 15 | 15 | 16 | 15 | 16 | 17 | 16 | 16 | 16 | 15 | 15 | 15 |
| 4D. Wetlands | 91 | 359 | 426 | 42 | 121 | 114 | 59 | 68 | 24 | 24 | 59 | 59 | 17 | 17 |
| $CO_2$ | 91 | 359 | 426 | 42 | 121 | 114 | 59 | 68 | 24 | 24 | 59 | 59 | 17 | 17 |
| $CH_4$ | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO |
| $N_2O$ | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO | IE,NA,NE,NO |
| 4E. Settlements | 2,865 | 1,288 | -447 | -962 | -296 | -384 | -814 | -570 | -443 | -283 | 107 | 196 | -156 | -27 |
| $CO_2$ | 2,865 | 1,288 | -447 | -962 | -296 | -384 | -814 | -570 | -443 | -283 | 107 | 196 | -156 | -27 |
| $CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| $N_2O$ | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO |
| 4F. Other land | 1,191 | 987 | 715 | 196 | 277 | 258 | 322 | 225 | 186 | 193 | 201 | 210 | 168 | 166 |
| $CO_2$ | 1,180 | 976 | 706 | 189 | 272 | 254 | 317 | 221 | 182 | 190 | 198 | 207 | 165 | 164 |
| $CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| $N_2O$ | 11 | 10 | 9 | 7 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 |
| 4G. HWP ($CO_2$) | -370 | 1,475 | 1,821 | 621 | 642 | 50 | 2,461 | 62 | 321 | -843 | -1,230 | -1,200 | -1,777 | -2,046 |
| 4H. Other (Organic soil in settlements converted from other land-use categories) | 15 | 13 | 13 | 11 | 10 | 9 | 9 | 8 | 8 | 8 | 7 | 7 | 7 | 7 |
| $CH_4$ | 14 | 13 | 12 | 10 | 9 | 9 | 8 | 8 | 7 | 7 | 7 | 7 | 6 | 6 |
| $N_2O$ | 0.8 | 0.8 | 0.7 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| 4(IV) Indirect $N_2O$ | 41 | 38 | 35 | 32 | 31 | 31 | 31 | 31 | 31 | 32 | 32 | 32 | 32 | 33 |
| Total | -62,219 | -77,078 | -87,758 | -91,191 | -66,887 | -70,448 | -69,659 | -72,725 | -66,023 | -64,339 | -59,371 | -54,276 | -58,540 | -57,390 |

The breakdown of the FY2018 emissions and removals from this sector showed that the largest was $CO_2$ removals of 59.0 million tonnes, accounting for 103% of this sector's net total emissions / removals.

### 2.2.5. Waste

Emissions from the waste sector in FY2018 were 19.3 million tonnes (in $CO_2$ eq.). They decreased by 35.2% since FY1990 and by 3.0% compared to the previous year.

The breakdown of the FY2018 emissions from this sector showed that the largest source was waste incineration ($CO_2$), associated with waste derived from fossil fuels such as waste plastic and waste oil, accounting for 53%. It was followed by solid waste disposal ($CH_4$) (15%) and wastewater treatment and discharge ($N_2O$) (10%).

The main driving factor for the decrease in emissions since FY1990 was the decrease in $CH_4$ emissions from solid waste disposal on land as a result of decrease in the amount of disposal of biodegradable waste due to improvement in the volume reduction ratio by intermediate treatment under the Waste Management and Public Cleansing Act (Act No.137, 1970) and the Basic Law for Establishing the Recycling-based Society, and other recycling law (Act No.110, 2000).

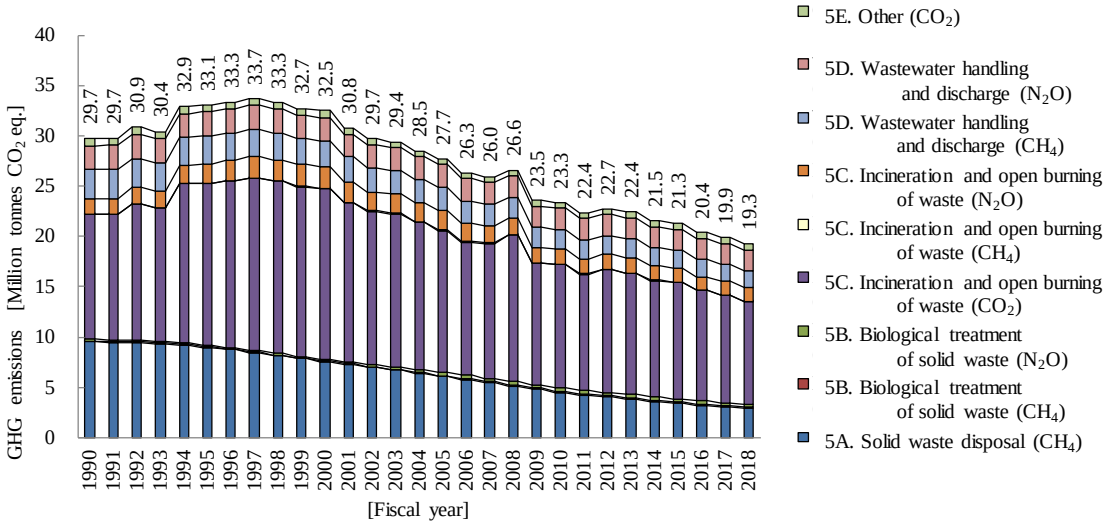


Figure 2-18 Trends in GHG emissions from the waste sector

Table 2-15 Trends in GHG emissions from the waste sector

[Thousand tonnes $CO_2$ eq.]

| Category | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5A. Solid waste disposal ($CH_4$) | 9,570 | 8,985 | 7,570 | 6,090 | 4,835 | 4,521 | 4,272 | 4,058 | 3,855 | 3,635 | 3,444 | 3,247 | 3,093 | 2,930 |
| 5B. Biological treatment of solid waste | 235 | 233 | 235 | 414 | 460 | 402 | 444 | 440 | 435 | 433 | 441 | 446 | 388 | 385 |
| $CH_4$ | 54 | 53 | 54 | 95 | 106 | 93 | 102 | 101 | 100 | 100 | 102 | 103 | 90 | 89 |
| $N_2O$ | 181 | 179 | 181 | 319 | 354 | 309 | 342 | 338 | 335 | 333 | 340 | 343 | 298 | 296 |
| 5C. Incineration and open burning of waste | 13,895 | 17,983 | 19,164 | 16,084 | 13,644 | 13,826 | 13,078 | 13,717 | 13,623 | 12,995 | 13,016 | 12,313 | 12,115 | 11,678 |
| $CO_2$ | 12,429 | 16,046 | 16,988 | 14,103 | 12,062 | 12,300 | 11,549 | 12,183 | 12,076 | 11,561 | 11,508 | 10,992 | 10,682 | 10,239 |
| $CH_4$ | 28 | 29 | 21 | 18 | 13 | 12 | 11 | 11 | 12 | 10 | 10 | 9 | 10 | 10 |
| $N_2O$ | 1,438 | 1,908 | 2,156 | 1,963 | 1,570 | 1,515 | 1,518 | 1,523 | 1,535 | 1,423 | 1,498 | 1,312 | 1,423 | 1,429 |
| 5D. Wastewater treatment and discharge | 5,329 | 5,189 | 4,857 | 4,560 | 4,091 | 4,069 | 4,037 | 3,925 | 3,893 | 3,825 | 3,777 | 3,742 | 3,640 | 3,600 |
| $CH_4$ | 2,942 | 2,750 | 2,556 | 2,280 | 1,997 | 1,954 | 1,908 | 1,855 | 1,811 | 1,779 | 1,749 | 1,714 | 1,648 | 1,617 |
| $N_2O$ | 2,387 | 2,439 | 2,301 | 2,280 | 2,094 | 2,115 | 2,129 | 2,069 | 2,082 | 2,045 | 2,027 | 2,028 | 1,992 | 1,983 |
| 5E. Other ($CO_2$) | 703 | 668 | 656 | 507 | 514 | 527 | 524 | 528 | 605 | 617 | 625 | 619 | 637 | 673 |
| Total | 29,732 | 33,057 | 32,483 | 27,655 | 23,545 | 23,345 | 22,355 | 22,668 | 22,411 | 21,504 | 21,304 | 20,367 | 19,873 | 19,267 |

### 2.2.6. Indirect $CO_2$

See 2.1.9. above.

## 2.3. Description and Interpretation of Emission Trends for Indirect GHGs and $SO_X$

Under the revised UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention, it is required to report emissions not only of the 7 types of GHGs ($CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, and $NF_3$), but also emissions of indirect GHGs ($NO_X$, CO, and NMVOC) as well as $SO_X$. Their emission trends are indicated below.

Nitrogen oxide ($NO_X$) emissions in FY2018 were 1.3 million tonnes. They decreased by 33.4% since FY1990 and 2.9% compared to the previous year.

Carbon monoxide (CO) emissions in FY2018 were 2.6 million tonnes. They decreased by 40.0% since FY1990 and 3.9% compared to the previous year[11].

Non-methane volatile organic compounds (NMVOC) emissions in FY2018 were 0.9 million tonnes. They decreased by 59.6% since FY1990 and decreased by 1.0% compared to the previous year.

Sulfur oxide ($SO_X$)[12] emissions in FY2018 were 0.7 million tonnes. They decreased by 44.4% since FY1990 and 0.1% compared to the previous year.

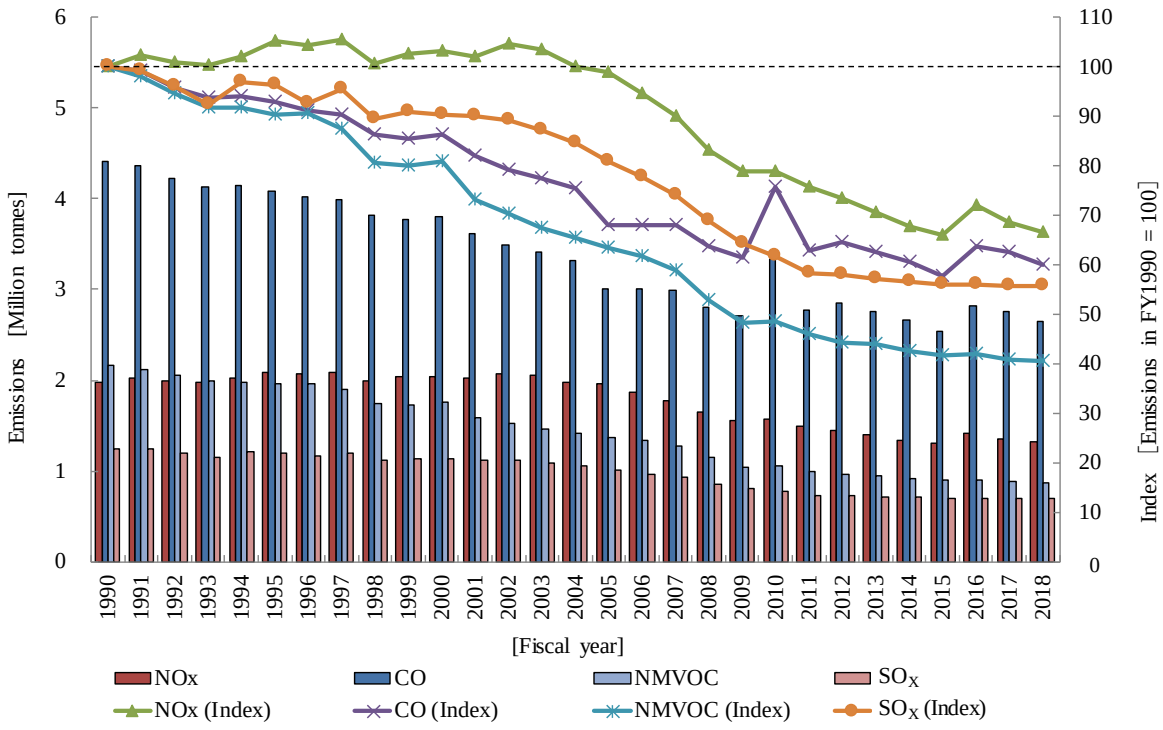


Figure 2-19 Trends in emissions of indirect GHGs and $SO_X$

Note: The line chart shows the trend as an index of FY1990 emissions set at 100.

[11] The reason for the increase of CO emissions in FY2010 compared to the previous year was the change in the EF for road transportation, and the reason for the decrease in CO emissions in FY2011 compared to the previous year was the change in the share of furnace types in the iron and steel industry.

[12] Most $SO_X$ consists of $SO_2$. For major sources, $SO_2$ emissions are estimated.

## 2.4. Emissions and removals from KP-LULUCF activities

The net removals from Kyoto Protocol Article 3.3 and 3.4 activities in FY2018 were 43.0 million tonnes (in $CO_2$ eq.). The breakdown of emissions and removals by each activity is shown below. For detailed information, see Chapter 11.

Table 2-16 Accounting summary for activities under articles 3.3 and 3.4 of the Kyoto Protocol (CRF Accounting table)

| GREENHOUSE GAS SOURCE AND SINK ACTIVITIES | Base Year (1990) | NET EMISSIONS/REMOVALS | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| | (kt $CO_2$ eq) | | | | | | |
| A. Article 3.3 activities | | | | | | | |
| A.1. Afforestation/reforestation | | -1558 | -1563 | -1562 | -1562 | -1536 | -1442 |
| Excluded emissions from natural disturbances | | NA | NA | NA | NA | NA | NA |
| Excluded subsequent removals from land subject to natural disturbances | | NA | NA | NA | NA | NA | NA |
| A.2. Deforestation | | 2049 | 2055 | 2274 | 2275 | 1611 | 1605 |
| B. Article 3.4 activities | | | | | | | |
| B.1. Forest management | | | | | | | |
| Net emissions/removals | | -51149 | -51449 | -49216 | -46650 | -46469 | -45361 |
| Excluded emissions from natural disturbances | | NA | NA | NA | NA | NA | NA |
| Excluded subsequent removals from land subject to natural disturbances | | NA | NA | NA | NA | NA | NA |
| Any debits from newly established forest (CEF-ne) | | NA | NA | NA | NA | NA | NA |
| Forest management reference level (FMRL) | | 0 | 0 | 0 | 0 | 0 | 0 |
| Technical corrections to FMRL | | 1069 | 1252 | 1404 | 1544 | 1687 | 1821 |
| Forest management cap | | | | | | | |
| B.2. Cropland management | 10265 | 3693 | 4476 | 4413 | 4917 | 4139 | 3721 |
| B.3. Grazing land management | 840 | -190 | 9 | -70 | -118 | -127 | -209 |
| B.4. Revegetation | -82 | -1228 | -1247 | -1267 | -1285 | -1308 | -1322 |
| B.5. Wetland drainage and rewetting (not elected) | NA | NA | NA | NA | NA | NA | NA |

Note: The total values and results of summing up each figure are not always the same because of the difference in display digit.

## *References*


1. Cabinet Office, Government of Japan, *Annual Report on National Accounts.*
2. IPCC, *Fourth Assessment Report*, 2007.
3. Ministry of Internal Affairs and Communications, Statistics Bureau, *Annual Report of Population Estimates.*
4. Ministry of Internal Affairs and Communications, Statistics Bureau, *Population Census.*

# Chapter 3. Energy (CRF sector 1)

## 3.1. Overview of Sector

Emissions from the energy sector consist of two main categories: fuel combustion and fugitive emissions from fuels. Fuel combustion includes emissions released into the atmosphere when fossil fuels (e.g., coal, oil products, and natural gas) are combusted. Fugitive emissions are intentional or unintentional releases of gases from fossil fuels by anthropogenic activities.

In Japan, fossil fuels are used to produce energy for a wide variety of purposes (e.g., production, transportation, and consumption of energy products) and $CO_2$ (Carbon Dioxide), $CH_4$ (Methane), $N_2O$ (Nitrous Oxide), $NO_X$ (Nitrogen Oxide), CO (Carbon Monoxide), and NMVOC (Non-Methane Volatile Organic Compounds) are emitted in the process.

In FY2018, GHG emissions ($CO_2$, $CH_4$ and $N_2O$) from the energy sector accounted for 1,085,719 kt-$CO_2$ eq., and represented 87.5% of Japan's total GHG emissions (excluding LULUCF). The emissions from the energy sector had decreased by 0.6% compared to FY1990.

The methodologies are shown in the below table.

Table 3-1 Methodologies used in the energy sector

| GREENHOUSE GAS SOURCE CATEGORIES | $CO_2$ | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| 1.A. Fuel combustion | CS,T2 | CS | CS,T1,T2,T3 | CR,CS,D | CS,T1,T2,T3 | CR,CS,D |
| 1. Energy industries | CS,T2 | CS | CS,T3 | CS | CS,T3 | CS |
| 2. Manufacturing industries and construction | CS,T2 | CS | CS,T1,T3 | CR,CS,D | CS,T1,T3 | CR,CS,D |
| 3. Transport | T2 | CS | T1,T2,T3 | CS,D | T1,T2,T3 | CS,D |
| 4. Other sectors | CS,T2 | CS | CS,T1,T3 | CR,CS,D | CS,T1,T3 | CR,CS,D |
| 5. Other | | | | | | |
| 1.B. Fugitive emissions from fuels | CS,T1 | CS,D | CS,D,T1,T2,T3 | CS,D | T1 | D |
| 1. Solid fuels | CS | CS | D,T1,T2,T3 | CS,D | | |
| 2. Oil and natural gas | CS,T1 | CS,D | CS,T1 | CS,D | T1 | D |
| 1.C. $CO_2$ transport and storage | | | | | | |

Note:
D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country specific method or EF, CR: CORINAIR

## 3.2. Fuel Combustion (1.A.)

This category covers GHG emissions from combustion of fossil fuels such as coal, oil, and natural gas, and incineration of waste for energy purposes and with energy recovery.[1]

This section includes GHG emissions from five sources: energy industries (1.A.1): emissions from power generation and heat supply; manufacturing industries and construction (1.A.2): emissions from manufacturing industry and construction; transport (1.A.3): emissions from transport of passenger and freight; other sectors (1.A.4): emissions from commercial/institutional, residential, and agriculture/forestry/fishing sources; and other (1.A.5): emissions from other sources.

[1] The emissions from waste incineration had been reported in the waste sector in the 2008 submission, regardless of their use as energy or energy recovery. However, to comply with ERT recommendations and the requirements of the IPCC Guidelines, the emissions are reported in the energy sector since the 2009 submission.

Table 3-2 Trends in GHGs emissions from fuel combustion (1.A)

| Gas | Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 1.A.1. Energy industries | kt-$CO_2$ | 368,529 | 378,904 | 395,495 | 449,661 | 441,432 | 473,849 | 534,792 | 581,482 | 583,367 | 552,884 | 527,321 | 522,736 | 508,760 | 472,488 |
| | a. Public electricity and heat production | kt-$CO_2$ | 303,055 | 317,587 | 330,118 | 378,044 | 373,133 | 404,240 | 468,952 | 516,377 | 521,751 | 493,352 | 468,475 | 469,005 | 456,772 | 418,339 |
| | b. Petroleum refining | kt-$CO_2$ | 36,397 | 41,085 | 46,978 | 50,888 | 47,184 | 47,715 | 44,478 | 43,298 | 42,939 | 41,103 | 41,664 | 35,883 | 35,147 | 36,211 |
| | c. Manufacture of solid fuels and other energy industries | kt-$CO_2$ | 29,077 | 20,232 | 18,399 | 20,728 | 21,115 | 21,894 | 21,361 | 21,807 | 18,677 | 18,429 | 17,182 | 17,849 | 16,840 | 17,938 |
| | 1.A.2. Manufacturing industries and construction | kt-$CO_2$ | 349,703 | 357,556 | 346,635 | 334,189 | 283,829 | 300,375 | 299,343 | 299,008 | 304,121 | 296,553 | 287,513 | 273,647 | 269,847 | 262,837 |
| | a. Iron and steel | kt-$CO_2$ | 150,689 | 143,096 | 152,113 | 154,175 | 135,644 | 153,172 | 148,896 | 151,309 | 157,569 | 155,124 | 148,897 | 142,785 | 139,784 | 136,047 |
| | b. Non-ferrous metals | kt-$CO_2$ | 8,428 | 7,380 | 6,332 | 5,705 | 4,066 | 3,999 | 3,871 | 4,037 | 3,778 | 3,673 | 3,282 | 3,556 | 3,172 | 3,114 |
| | c. Chemicals | kt-$CO_2$ | 58,039 | 64,239 | 59,022 | 54,488 | 48,956 | 49,188 | 48,484 | 46,108 | 47,287 | 45,499 | 44,571 | 41,084 | 41,841 | 40,638 |
| | d. Pulp, paper and print | kt-$CO_2$ | 27,105 | 31,427 | 31,679 | 29,738 | 23,425 | 22,592 | 23,266 | 23,761 | 23,778 | 22,848 | 23,248 | 20,802 | 20,466 | 20,229 |
| | e. Food processing, beverages and tobacco | kt-$CO_2$ | 7,649 | 10,132 | 11,511 | 12,217 | 9,906 | 9,925 | 10,900 | 10,653 | 9,901 | 9,668 | 8,669 | 8,678 | 8,163 | 8,188 |
| | f. Non-metallic minerals | kt-$CO_2$ | 43,620 | 46,453 | 40,150 | 35,482 | 29,281 | 28,775 | 28,681 | 28,962 | 29,865 | 29,059 | 28,134 | 27,207 | 27,005 | 26,677 |
| | g. Other | kt-$CO_2$ | 54,173 | 54,828 | 45,828 | 42,385 | 32,551 | 32,725 | 35,246 | 34,178 | 31,943 | 30,682 | 30,712 | 29,535 | 29,416 | 27,946 |
| | 1.A.3. Transport | kt-$CO_2$ | 200,986 | 241,993 | 252,656 | 237,777 | 221,488 | 221,969 | 217,138 | 218,004 | 215,115 | 210,131 | 208,853 | 206,949 | 205,394 | 202,914 |
| | a. Domestic aviation | kt-$CO_2$ | 7,162 | 10,278 | 10,677 | 10,799 | 9,781 | 9,193 | 9,001 | 9,524 | 10,149 | 10,173 | 10,067 | 10,187 | 10,399 | 10,536 |
| | b. Road transportation | kt-$CO_2$ | 179,213 | 216,223 | 226,256 | 213,317 | 200,656 | 201,457 | 197,148 | 197,158 | 193,437 | 188,521 | 187,641 | 185,709 | 184,024 | 181,333 |
| | c. Railways | kt-$CO_2$ | 935 | 822 | 711 | 647 | 590 | 574 | 554 | 554 | 540 | 524 | 523 | 499 | 499 | 499 |
| | d. Domestic navigation | kt-$CO_2$ | 13,675 | 14,669 | 15,012 | 13,014 | 10,462 | 10,745 | 10,434 | 10,769 | 10,989 | 10,912 | 10,622 | 10,555 | 10,472 | 10,546 |
| | e. Other transportation | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 1.A.4. Other sectors | kt-$CO_2$ | 159,621 | 176,423 | 191,246 | 196,425 | 156,376 | 157,066 | 152,972 | 146,222 | 149,645 | 142,151 | 139,305 | 140,962 | 144,425 | 139,247 |
| | a. Commercial/institutional | kt-$CO_2$ | 79,184 | 88,256 | 98,693 | 106,091 | 75,808 | 75,023 | 73,925 | 67,332 | 74,462 | 69,509 | 67,726 | 68,071 | 69,487 | 71,725 |
| | b. Residential | kt-$CO_2$ | 58,167 | 67,477 | 72,226 | 70,395 | 61,351 | 64,217 | 62,541 | 62,626 | 60,319 | 58,014 | 55,392 | 55,712 | 59,260 | 52,152 |
| | c. Agriculture/forestry/fishing | kt-$CO_2$ | 22,270 | 20,690 | 20,326 | 19,939 | 19,217 | 17,826 | 16,505 | 16,264 | 14,863 | 14,628 | 16,188 | 17,179 | 15,678 | 15,370 |
| | 1.A.5 Other | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | a. Stationary | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | b. Mobile | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Total | kt-$CO_2$ | 1,078,839 | 1,154,876 | 1,186,033 | 1,218,052 | 1,103,125 | 1,153,259 | 1,204,244 | 1,244,716 | 1,252,248 | 1,201,718 | 1,162,992 | 1,144,294 | 1,128,427 | 1,077,487 |
| $CH_4$ | 1.A.1. Energy industries | kt-$CH_4$ | 18.37 | 16.01 | 10.53 | 9.94 | 10.31 | 10.79 | 11.60 | 12.02 | 9.57 | 9.00 | 8.55 | 8.90 | 8.32 | 7.98 |
| | a. Public electricity and heat production | kt-$CH_4$ | 0.82 | 1.02 | 1.31 | 1.21 | 1.09 | 1.19 | 4.50 | 5.02 | 3.61 | 3.36 | 3.20 | 3.32 | 3.33 | 3.12 |
| | b. Petroleum refining | kt-$CH_4$ | 0.09 | 0.11 | 0.22 | 1.51 | 2.42 | 2.50 | 0.12 | 0.12 | 0.12 | 0.11 | 0.12 | 0.10 | 0.09 | 0.10 |
| | c. Manufacture of solid fuels and other energy industries | kt-$CH_4$ | 17.46 | 14.88 | 9.01 | 7.22 | 6.80 | 7.10 | 6.99 | 6.88 | 5.84 | 5.52 | 5.23 | 5.48 | 4.89 | 4.77 |
| | 1.A.2. Manufacturing industries and construction | kt-$CH_4$ | 14.39 | 15.14 | 14.83 | 17.68 | 19.94 | 21.51 | 17.56 | 18.61 | 19.84 | 20.77 | 19.84 | 19.49 | 19.58 | 19.67 |
| | a. Iron and steel | kt-$CH_4$ | 4.66 | 4.28 | 5.03 | 7.03 | 7.87 | 9.19 | 6.20 | 6.57 | 6.84 | 7.08 | 6.74 | 6.68 | 6.51 | 6.49 |
| | b. Non-ferrous metals | kt-$CH_4$ | 0.39 | 0.36 | 0.29 | 0.23 | 0.19 | 0.18 | 0.23 | 0.25 | 0.24 | 0.25 | 0.23 | 0.24 | 0.22 | 0.21 |
| | c. Chemicals | kt-$CH_4$ | 0.31 | 0.32 | 0.49 | 1.26 | 2.12 | 2.37 | 0.94 | 0.85 | 0.86 | 0.76 | 0.72 | 0.67 | 0.68 | 0.67 |
| | d. Pulp, paper and print | kt-$CH_4$ | 1.06 | 1.06 | 1.13 | 1.34 | 1.47 | 1.60 | 1.36 | 1.33 | 1.43 | 1.50 | 1.48 | 1.36 | 1.38 | 1.41 |
| | e. Food processing, beverages and tobacco | kt-$CH_4$ | 0.09 | 0.13 | 0.15 | 0.16 | 0.14 | 0.14 | 0.23 | 0.37 | 0.50 | 0.60 | 0.59 | 0.62 | 0.61 | 0.65 |
| | f. Non-metallic minerals | kt-$CH_4$ | 4.16 | 4.96 | 3.95 | 3.63 | 3.17 | 3.08 | 2.72 | 2.90 | 3.19 | 3.19 | 3.06 | 2.98 | 2.96 | 2.97 |
| | g. Other | kt-$CH_4$ | 3.72 | 4.02 | 3.80 | 4.03 | 4.99 | 4.95 | 5.88 | 6.33 | 6.78 | 7.40 | 7.03 | 6.94 | 7.22 | 7.28 |
| | 1.A.3. Transport | kt-$CH_4$ | 11.65 | 12.36 | 12.48 | 9.89 | 7.34 | 6.98 | 6.64 | 6.39 | 6.05 | 5.73 | 5.49 | 5.31 | 5.11 | 4.98 |
| | a. Domestic aviation | kt-$CH_4$ | 0.23 | 0.26 | 0.29 | 0.22 | 0.07 | 0.07 | 0.06 | 0.06 | 0.07 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| | b. Road transportation | kt-$CH_4$ | 10.10 | 10.68 | 10.76 | 8.43 | 6.27 | 5.88 | 5.58 | 5.30 | 4.98 | 4.67 | 4.45 | 4.28 | 4.09 | 3.95 |
| | c. Railways | kt-$CH_4$ | 0.05 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | d. Domestic navigation | kt-$CH_4$ | 1.27 | 1.36 | 1.39 | 1.20 | 0.97 | 1.00 | 0.97 | 1.00 | 0.98 | 0.97 | 0.95 | 0.94 | 0.93 | 0.94 |
| | e. Other transportation | kt-$CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 1.A.4. Other sectors | kt-$CH_4$ | 9.57 | 11.76 | 13.18 | 19.86 | 17.05 | 18.20 | 10.09 | 9.63 | 9.02 | 8.45 | 8.21 | 8.29 | 8.73 | 7.92 |
| | a. Commercial/institutional | kt-$CH_4$ | 1.30 | 3.00 | 4.30 | 10.29 | 8.03 | 8.96 | 2.78 | 2.35 | 2.08 | 1.76 | 1.77 | 1.77 | 1.89 | 1.92 |
| | b. Residential | kt-$CH_4$ | 7.04 | 7.71 | 7.88 | 7.69 | 6.55 | 6.89 | 6.73 | 6.69 | 6.38 | 6.12 | 5.82 | 5.88 | 6.27 | 5.46 |
| | c. Agriculture/forestry/fishing | kt-$CH_4$ | 1.23 | 1.04 | 1.00 | 1.87 | 2.48 | 2.35 | 0.59 | 0.59 | 0.55 | 0.57 | 0.62 | 0.64 | 0.57 | 0.54 |
| | 1.A.5 Other | kt-$CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | a. Stationary | kt-$CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | b. Mobile | kt-$CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Total | kt-$CH_4$ | 53.98 | 55.26 | 51.02 | 57.37 | 54.65 | 57.47 | 45.90 | 46.65 | 44.47 | 43.94 | 42.09 | 41.99 | 41.74 | 40.56 |
| | | kt-$CO_2$ eq. | 1,350 | 1,381 | 1,276 | 1,434 | 1,366 | 1,437 | 1,147 | 1,166 | 1,112 | 1,099 | 1,052 | 1,050 | 1,043 | 1,014 |
| $N_2O$ | 1.A.1. Energy industries | kt-$N_2O$ | 2.98 | 4.54 | 5.41 | 7.10 | 6.99 | 6.95 | 7.61 | 7.68 | 7.91 | 7.87 | 7.88 | 7.33 | 7.85 | 7.27 |
| | a. Public electricity and heat production | kt-$N_2O$ | 1.72 | 3.09 | 3.72 | 5.32 | 5.19 | 5.13 | 6.02 | 6.12 | 6.61 | 6.64 | 6.60 | 6.12 | 6.68 | 6.23 |
| | b. Petroleum refining | kt-$N_2O$ | 1.05 | 1.31 | 1.58 | 1.61 | 1.60 | 1.61 | 1.42 | 1.42 | 1.21 | 1.17 | 1.22 | 1.14 | 1.11 | 0.99 |
| | c. Manufacture of solid fuels and other energy industries | kt-$N_2O$ | 0.22 | 0.14 | 0.12 | 0.17 | 0.21 | 0.21 | 0.17 | 0.14 | 0.09 | 0.07 | 0.06 | 0.07 | 0.06 | 0.05 |
| | 1.A.2. Manufacturing industries and construction | kt-$N_2O$ | 4.22 | 5.72 | 6.30 | 6.27 | 5.91 | 5.78 | 5.77 | 5.83 | 5.91 | 5.78 | 5.78 | 5.54 | 5.51 | 5.37 |
| | a. Iron and steel | kt-$N_2O$ | 1.12 | 1.34 | 1.40 | 1.47 | 1.46 | 1.50 | 1.21 | 1.26 | 1.32 | 1.33 | 1.30 | 1.26 | 1.22 | 1.17 |
| | b. Non-ferrous metals | kt-$N_2O$ | 0.25 | 0.23 | 0.21 | 0.08 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | c. Chemicals | kt-$N_2O$ | 0.74 | 1.19 | 1.19 | 1.04 | 0.94 | 0.96 | 1.07 | 1.02 | 1.06 | 0.99 | 0.99 | 0.90 | 0.99 | 0.92 |
| | d. Pulp, paper and print | kt-$N_2O$ | 0.48 | 0.91 | 0.95 | 0.98 | 1.16 | 1.14 | 1.15 | 1.17 | 1.22 | 1.26 | 1.26 | 1.21 | 1.19 | 1.18 |
| | e. Food processing, beverages and tobacco | kt-$N_2O$ | 0.04 | 0.05 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.06 | 0.07 |
| | f. Non-metallic minerals | kt-$N_2O$ | 0.80 | 1.06 | 1.73 | 1.98 | 1.74 | 1.56 | 1.58 | 1.62 | 1.65 | 1.63 | 1.66 | 1.59 | 1.53 | 1.54 |
| | g. Other | kt-$N_2O$ | 0.80 | 0.94 | 0.76 | 0.64 | 0.48 | 0.50 | 0.62 | 0.62 | 0.52 | 0.45 | 0.46 | 0.46 | 0.46 | 0.45 |
| | 1.A.3. Transport | kt-$N_2O$ | 12.55 | 13.77 | 13.41 | 9.45 | 7.34 | 6.88 | 6.54 | 6.29 | 6.05 | 5.86 | 5.76 | 5.67 | 5.64 | 5.61 |
| | a. Domestic aviation | kt-$N_2O$ | 0.21 | 0.29 | 0.32 | 0.32 | 0.29 | 0.28 | 0.27 | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.31 |
| | b. Road transportation | kt-$N_2O$ | 11.60 | 12.77 | 12.41 | 8.53 | 6.54 | 6.10 | 5.77 | 5.49 | 5.26 | 5.07 | 4.99 | 4.91 | 4.87 | 4.84 |
| | c. Railways | kt-$N_2O$ | 0.37 | 0.32 | 0.28 | 0.25 | 0.23 | 0.23 | 0.22 | 0.22 | 0.21 | 0.20 | 0.20 | 0.19 | 0.19 | 0.19 |
| | d. Domestic navigation | kt-$N_2O$ | 0.36 | 0.39 | 0.40 | 0.34 | 0.28 | 0.28 | 0.28 | 0.29 | 0.28 | 0.28 | 0.27 | 0.27 | 0.27 | 0.27 |
| | e. Other transportation | kt-$N_2O$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 1.A.4. Other sectors | kt-$N_2O$ | 2.38 | 2.61 | 2.86 | 2.54 | 2.20 | 2.20 | 1.95 | 2.00 | 2.03 | 2.04 | 1.98 | 2.10 | 2.14 | 2.10 |
| | a. Commercial/institutional | kt-$N_2O$ | 1.52 | 1.80 | 2.10 | 1.83 | 1.58 | 1.59 | 1.36 | 1.42 | 1.51 | 1.53 | 1.46 | 1.57 | 1.62 | 1.63 |
| | b. Residential | kt-$N_2O$ | 0.28 | 0.32 | 0.35 | 0.34 | 0.28 | 0.29 | 0.29 | 0.28 | 0.27 | 0.25 | 0.24 | 0.24 | 0.26 | 0.22 |
| | c. Agriculture/forestry/fishing | kt-$N_2O$ | 0.59 | 0.49 | 0.41 | 0.37 | 0.35 | 0.32 | 0.30 | 0.29 | 0.26 | 0.26 | 0.28 | 0.29 | 0.26 | 0.25 |
| | 1.A.5 Other | kt-$N_2O$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | a. Stationary | kt-$N_2O$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | b. Mobile | kt-$N_2O$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Total | kt-$N_2O$ | 22.14 | 26.65 | 27.99 | 25.36 | 22.45 | 21.82 | 21.87 | 21.80 | 21.91 | 21.54 | 21.40 | 20.64 | 21.14 | 20.34 |
| | | kt-$CO_2$ eq. | 6,597 | 7,941 | 8,341 | 7,559 | 6,690 | 6,503 | 6,517 | 6,497 | 6,529 | 6,420 | 6,377 | 6,151 | 6,299 | 6,063 |
| Total of all gases | | kt-$CO_2$ eq. | 1,086,785 | 1,164,199 | 1,195,649 | 1,227,045 | 1,111,181 | 1,161,198 | 1,211,908 | 1,252,380 | 1,259,888 | 1,209,236 | 1,170,422 | 1,151,494 | 1,135,769 | 1,084,564 |

In FY2018, emissions from fuel combustion were 1,084,564 kt-$CO_2$ eq., which accounted for 87.4% of Japan's total GHG emissions (excluding LULUCF). By looking at the share of the emissions by gas,

$CO_2$ comprises 99.3% of the GHG emissions from fuel combustion.

The $CO_2$ emissions in FY2018 were decreased by 4.5% compared to the previous year. The main driving factor for the decrease is the $CO_2$ emissions from energy industries (1.A.1).

By looking at the changes in $CO_2$ emissions by subcategory, emissions from the energy industries (1.A.1) increased by 28.2% since FY1990 and decreased by 7.1% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increase in thermal power generation. From FY1990 to FY2007, the emissions increased with an increase in electricity demand. From FY2011 to FY2013, the emissions increased mainly due to an increase in the share of thermal power generation as a result of the suspension of operation of the nuclear power plants triggered by the Great East Japan Earthquake. Since then, the enhancement of introduction of renewable energy and the resumption of operation of the nuclear power plants are in progress.

The $CO_2$ emissions from manufacturing industries and construction (1.A.2) decreased by 24.8% since FY1990 and decreased by 2.6% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption. The emissions are considered to have a moderate correlation with the *Indices of Industrial Production* (IIP) (Ministry of Economy, Trade and Industry (METI)). In the middle of 2000s, the $CO_2$ emissions were stable while the IIP increased, that implies the improvement of energy efficiency. (Agency for Natural Resources and Energy, 2019)

The $CO_2$ emissions from transport (1.A.3) increased by 1.0% compared to FY1990 and decreased by 1.2% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increase in emissions from passenger vehicles, compensating for the decrease in emissions from freight transportation. Although the emissions from road transportation increased in 1990s due to an increase in distance traveled, the emissions have decreased in the 2000s mainly due to an improvement of fuel efficiency.

The $CO_2$ emissions from other sectors (1.A.4) decreased by 12.8% since FY1990 and decreased by 3.6% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption. The $CO_2$ emissions from commercial/institutional (1.A.4.a) are considered to have a moderate correlation with the *Indices of Tertiary Industry Activity* (METI) until 2005. The emissions have decreased since then due to the decrease in the demand of liquid fuels.

On the annual review in 2012 (FCCC/ARR/2012/JPN, paragraph 33), the Expert Review Team (ERT) recommended that Japan improve the transparency of the information on the drivers of emission trends in the energy sector. In response to the recommendation, the table below provides some indicators that might have relations to the emission trends. Please note that these indicators are not used for estimating the emissions. Also, please refer to Chapter 2 for the charts of emission trends.

Table 3-3 Trends in indicators that might have relations to the GHGs emissions from fuel combustion (1.A)

| No. | Related subcategories | Indicators | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.A. Fuel combustion | Final electricity consumption | TWh | 765 | 872 | 973 | 1,025 | 989 | 1,035 | 997 | 991 | 990 | 974 | 949 | 951 | 965 | 946 |
| 2 | 1.A.2. Manufacturing | Indices of Industrial Production | CY2015=100 | 109.1 | 103.3 | 107.7 | 109.3 | 93.0 | 101.2 | 100.5 | 97.8 | 101.1 | 100.5 | 99.8 | 100.6 | 103.5 | 103.8 |
| 3 | 1.A.3.b. Road transportation | Vehicle kilometers traveled (VKT) | billion VKT | 585 | 673 | 728 | 727 | 709 | 708 | 712 | 723 | 724 | 718 | 721 | 730 | 740 | 748 |
| 4 | 1.A.4.a.Commercial/ institutional | Indices of Tertiary Industry Activity | CY2010=100 | 85.8 | 93.1 | 97.5 | 103.1 | 99.0 | 99.9 | 100.7 | 102.0 | 103.2 | 102.1 | 103.5 | 103.9 | 105.0 | 106.2 |

Note: 1: *General Energy Statistics* by Agency for Natural Resources and Energy (ANRE), 2: Ministry of Economy, Trade and

Industry (METI), 3: *Statistical Yearbook of Motor Vehicle Fuel Consumption*, etc. by Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 4: METI

### 3.2.1. Comparison of the Sectoral Approach with the Reference Approach

This chapter explains a comparison between reference approach and sectoral approach in accordance with the *UNFCCC Inventory Reporting Guidelines* (Decision 24/CP.19 Annex I, paragraph 40). For the methodological issues of the sectoral approach, please refer to the section 3.2.4. b).

#### 3.2.1.1. Methodological Issues of the Reference Approach

The reference approach is to calculate the $CO_2$ emissions from combustion, using a country's energy supply data. The $CO_2$ emissions estimated by the reference approach are not included in the national total and used for verification purpose. The $CO_2$ emissions by the reference approach are estimated by the following formula:

$$E = \sum_i [(A_i - N_i) \times GCV_i \times 10^{-3} \times EF_i \times OF_i] \times 44/12$$

*E* : $CO_2$ emissions from fossil fuel combustion [t-$CO_2$]
*A* : Apparent energy consumption (original unit [t, kL, $10^3 \times m^3$])
*N* : Non-energy use of fossil fuels (original unit)
*GCV* : Gross calorific value (higher heating value) [MJ/original unit]
*EF* : Carbon content of the fuel [t-C/TJ]
*OF* : Oxidation factor
*i* : Type of fuel

The apparent energy consumptions *A* are estimated by the following formula:

Primary fuels: $A = P + IM - EX \pm SC - IB$

Secondary fuels: $A = IM - EX \pm SC - IB$

Table 3-4 Sources of each term of reference approach estimation equation

| Symbol | Term | Source[2] |
|---|---|---|
| *P* | Production | • Indigenously Produced (#110000) in Agency for Natural Resources and Energy's *General Energy Statistics* (Japan's Energy Balance Table)<br>• (Waste only) Consumption of sectoral approach[3] |
| *IM* | Imports | Imported (#120000) in the statistics + International bunker fuels (see section 3.2.2. ) |
| *EX* | Exports | Export (#160000) in the statistics |
| *SC* | Stock change / supply | Stockpile Change / Supply (#170000) in the statistics |
| *IB* | International bunkers | See section 3.2.2. |
| *N* | Non-energy use | Non-energy and feedstock use (#950000) in the statistics (see section 3.2.3. ) |

The carbon contents of the fuels, the oxidation factors and the gross calorific values are in common with the sectoral approach (refer to the section 3.2.4. b).

The details of estimation results by reference approach are shown in the Common Reporting Format (CRF) table 1.A(b). The correspondence between fuels of the *General Energy Statistics* and those of

[2] Numbers with # indicate the corresponding sector (row) numbers in the *General Energy Statistics* (Japan's Energy Balance Table).
[3] In response to the recommendation on the annual review in 2018 (FCCC/ARR/2018/JPN, E.11)

the table is shown in Annex 4.

- *Discrepancies between the figures reported in the CRF tables and the IEA statistics*

Some discrepancies exist between the fuel data of energy supply and demand in the CRF tables and the data of energy supply and demand reported in the International Energy Agency (IEA) statistics. Please refer to the details of discrepancies and their reasons in Annex 4 (A4.1).

#### 3.2.1.2. Difference in Energy Consumption

As shown in Table 3-5, fluctuations of difference[4] of energy consumption between the reference approach and the sectoral approach during FY1990-2018 range between -1.79% (FY2012) and +1.76% (FY2004).

Energy consumption from wastes used for energy and from the incineration of wastes with energy recovery is calculated in the sectoral approach in accordance with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

There is a large difference between those two approaches for solid fuels in FY2004 (+10.63%). It means that, in FY2004, because stocks of the coal on the consumer side (steel making coal [$0110[5]]) increased, the large difference occurred between the reference approach estimated from the provider side and the sectoral approach estimated from the consumer side. In addition, there is a large difference between those two approaches for solid fuels in FY2008 (+6.82%). This is because stocks of the coal on the consumer side (imported steam coal [$0121]) increased, like in FY2004. It should be noted that the stock changes explained here are not 'Stockpile change / supply' in 'Primary energy supply' sector, but 'Transformation and consumption stockpile change' in 'Energy transformation & own use' sector and 'Final energy consumption' sector.

#### 3.2.1.3. Difference in $CO_2$ Emissions

As shown in Table 3-6, fluctuations of a difference of $CO_2$ emissions between the reference approach and the sectoral approach during FY1990-2018 range between -0.74% (FY1990) and +3.83% (FY2004).

Emissions from wastes used for energy and from the incineration of wastes with energy recovery are not reported in waste incineration (5.C.) but reported in fuel combustion (1.A.) in accordance with the *2006 IPCC Guidelines*.

The differences between both approaches for solid fuels were large values in FY2004 and FY2008 (+9.94%, +6.24%), and small values in FY2005 and FY2009 (+2.05%, -1.92%). It is because of the same reason as the difference of energy consumption which is described in the previous section.

[4] Difference = [(Reference approach)-(Sectoral approach)]/(Sectoral approach)

[5] Numbers with $ indicate the corresponding energy source (column) numbers in the *General Energy Statistics* (Japan's Energy Balance Table).

Table 3-5 Comparison of energy consumption[6]

[PJ]

| | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reference Approach** | | | | | | | | | | | | | | |
| Liquid fuels | 9,526 | 10,132 | 9,442 | 8,919 | 7,125 | 7,179 | 7,531 | 7,640 | 7,395 | 6,811 | 6,501 | 6,285 | 6,196 | 5,847 |
| Solid fuels | 3,285 | 3,602 | 4,179 | 4,763 | 4,385 | 4,979 | 4,653 | 4,864 | 5,284 | 5,080 | 5,137 | 5,022 | 5,024 | 4,927 |
| Gaseous fuels | 2,042 | 2,465 | 3,050 | 3,275 | 3,762 | 3,979 | 4,665 | 4,854 | 4,882 | 4,948 | 4,646 | 4,718 | 4,686 | 4,499 |
| Other fossil fuels | 281 | 318 | 373 | 457 | 442 | 450 | 450 | 471 | 461 | 466 | 462 | 494 | 505 | 504 |
| Peat | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| **Total RA** | **15,135** | **16,517** | **17,045** | **17,415** | **15,714** | **16,587** | **17,298** | **17,829** | **18,022** | **17,304** | **16,745** | **16,519** | **16,411** | **15,778** |
| **Sectoral Approach** | | | | | | | | | | | | | | |
| Liquid fuels | 9,459 | 9,973 | 9,451 | 8,949 | 7,180 | 7,261 | 7,704 | 7,850 | 7,463 | 6,839 | 6,544 | 6,308 | 6,139 | 5,798 |
| Solid fuels | 3,368 | 3,597 | 3,986 | 4,638 | 4,447 | 4,819 | 4,660 | 4,878 | 5,222 | 5,119 | 5,049 | 4,956 | 4,981 | 4,832 |
| Gaseous fuels | 2,209 | 2,667 | 3,226 | 3,355 | 3,883 | 4,093 | 4,772 | 4,954 | 4,939 | 4,981 | 4,744 | 4,850 | 4,731 | 4,532 |
| Other fossil fuels | 281 | 318 | 373 | 457 | 442 | 450 | 450 | 471 | 461 | 466 | 462 | 494 | 505 | 504 |
| Peat | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| **Total** | **15,318** | **16,555** | **17,035** | **17,399** | **15,952** | **16,624** | **17,586** | **18,153** | **18,085** | **17,405** | **16,800** | **16,608** | **16,356** | **15,665** |
| **Difference (%)** | | | | | | | | | | | | | | |
| Liquid fuels | 0.71% | 1.60% | -0.09% | -0.33% | -0.77% | -1.13% | -2.25% | -2.68% | -0.91% | -0.40% | -0.66% | -0.37% | 0.93% | 0.85% |
| Solid fuels | -2.46% | 0.15% | 4.86% | 2.70% | -1.39% | 3.32% | -0.17% | -0.29% | 1.19% | -0.77% | 1.73% | 1.34% | 0.86% | 1.97% |
| Gaseous fuels | -7.56% | -7.58% | -5.43% | -2.38% | -3.12% | -2.80% | -2.24% | -2.01% | -1.16% | -0.67% | -2.08% | -2.72% | -0.96% | -0.72% |
| Other fossil fuels | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Peat | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| **Total** | **-1.20%** | **-0.23%** | **0.06%** | **0.09%** | **-1.49%** | **-0.22%** | **-1.64%** | **-1.79%** | **-0.35%** | **-0.58%** | **-0.32%** | **-0.54%** | **0.33%** | **0.72%** |

Table 3-6 Comparison of $CO_2$ emissions

[Mt-$CO_2$]

| | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reference Approach** | | | | | | | | | | | | | | |
| Liquid fuels | 659.9 | 701.9 | 656.2 | 621.1 | 497.6 | 501.8 | 523.6 | 532.9 | 512.2 | 472.1 | 450.1 | 434.6 | 428.9 | 404.2 |
| Solid fuels | 295.7 | 323.7 | 377.9 | 431.1 | 396.8 | 450.8 | 420.8 | 439.9 | 474.5 | 457.3 | 462.1 | 451.1 | 450.8 | 440.8 |
| Gaseous fuels | 104.4 | 126.1 | 155.9 | 167.4 | 192.4 | 203.5 | 238.6 | 248.4 | 249.9 | 253.2 | 237.8 | 241.5 | 239.9 | 228.9 |
| Other fossil fuels | 10.9 | 12.4 | 15.2 | 17.1 | 15.6 | 15.9 | 16.0 | 17.1 | 16.7 | 16.3 | 16.8 | 17.6 | 18.2 | 18.0 |
| Peat | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| **Total RA** | **1,071** | **1,164** | **1,205** | **1,237** | **1,102** | **1,172** | **1,199** | **1,238** | **1,253** | **1,199** | **1,167** | **1,145** | **1,138** | **1,092** |
| **Sectoral Approach** | | | | | | | | | | | | | | |
| Liquid fuels | 644.3 | 677.4 | 640.7 | 606.1 | 483.8 | 488.9 | 520.3 | 530.8 | 508.5 | 464.7 | 444.0 | 428.3 | 415.8 | 392.5 |
| Solid fuels | 309.5 | 327.1 | 364.1 | 422.4 | 404.6 | 438.5 | 423.2 | 442.8 | 473.7 | 465.1 | 458.8 | 449.6 | 451.6 | 435.8 |
| Gaseous fuels | 114.2 | 137.9 | 166.1 | 172.4 | 199.1 | 209.9 | 244.7 | 254.1 | 253.4 | 255.5 | 243.4 | 248.8 | 242.8 | 231.2 |
| Other fossil fuels | 10.9 | 12.4 | 15.2 | 17.1 | 15.6 | 15.9 | 16.0 | 17.1 | 16.7 | 16.3 | 16.8 | 17.6 | 18.2 | 18.0 |
| Peat | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| **Total** | **1,079** | **1,155** | **1,186** | **1,218** | **1,103** | **1,153** | **1,204** | **1,245** | **1,252** | **1,202** | **1,163** | **1,144** | **1,128** | **1,077** |
| **Difference (%)** | | | | | | | | | | | | | | |
| Liquid fuels | 2.42% | 3.62% | 2.43% | 2.47% | 2.86% | 2.64% | 0.62% | 0.40% | 0.74% | 1.58% | 1.38% | 1.48% | 3.16% | 2.97% |
| Solid fuels | -4.47% | -1.05% | 3.79% | 2.05% | -1.92% | 2.79% | -0.58% | -0.65% | 0.17% | -1.70% | 0.72% | 0.34% | -0.18% | 1.15% |
| Gaseous fuels | -8.56% | -8.61% | -6.11% | -2.89% | -3.39% | -3.06% | -2.48% | -2.24% | -1.39% | -0.92% | -2.29% | -2.93% | -1.20% | -0.99% |
| Other fossil fuels | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Peat | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| **Total** | **-0.74%** | **0.80%** | **1.62%** | **1.53%** | **-0.06%** | **1.62%** | **-0.44%** | **-0.52%** | **0.08%** | **-0.24%** | **0.33%** | **0.05%** | **0.83%** | **1.33%** |

### 3.2.1.4. Comparison between Differences in Energy Consumption and that of $CO_2$ Emissions

The difference in energy consumption and the difference in $CO_2$ emissions generally show a similar tendency for their trends.

[6] In this chapter, soild fuels mean coal and coal products (including coal derived gas), liquid fuels mean crude oil and oil products (including LPG, etc.), and gaseous fuels mean natural gas (including LNG, etc.) and city gas, unless otherwise specified. (cf. *2006 IPCC Guidelines*, Vol.2, Table 1.1)

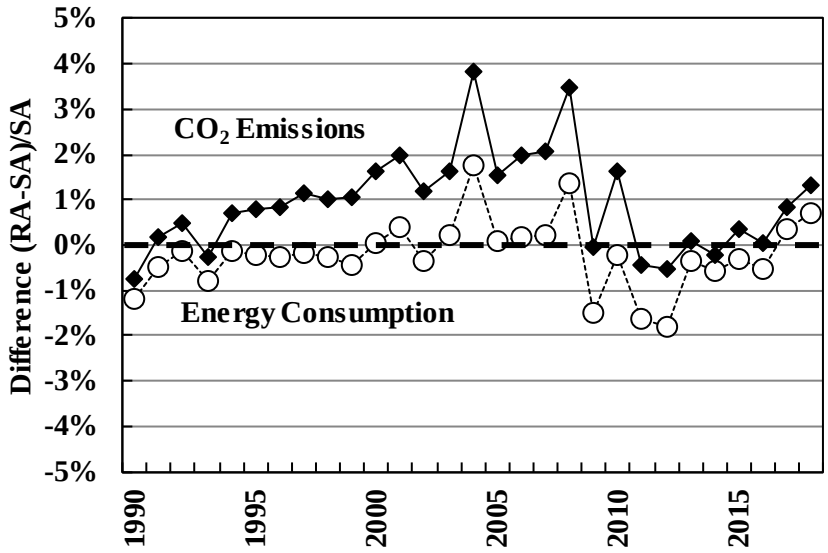


Figure 3-1 Trends in difference of energy consumption and $CO_2$ emissions

### 3.2.1.5. Causes of the difference between Reference Approach and Sectoral Approach

The difference in energy consumption and in $CO_2$ emissions can be explained mainly by the difference of the amount of non-energy use which was deducted under energy transformation & own use sector of the Energy Balance Table (*General Energy Statistics*).

#### *1) Matters not sufficiently considered in the calculation process of Reference Approach*

In the current estimation of reference approach, the energy consumption amount, which is obtained by subtracting the amount of non-energy use from the amount supplied inside the country, is assumed to be completely combusted. However, in real situation, some of the energy amount is not combusted but stored, and the increase or decrease of the stored amount is not reflected in reference approach.

- ***Other Transformation [#289000]***

In Energy transformation & own use sector such as oil refining, energy source shipment/drawdown amounts do not necessarily match production/receipt amounts. Other than energy received through one's own imports or that produced by refining, factors involved include returns from consumption/sales sectors of products once shipped, transactions of small amounts of byproduct energy from other companies, stock buildups and drawdowns due to product storage tank installation or decommissioning at factories and business sites, and losses due to accidents or fires.

When energy source inconsistencies due to such causes in the Energy transformation & own use sector are determined, the other transformation sector represents its amount. However, this input/output are not reflected in reference approach emission calculation.

- ***Transformation and Consumption Stockpile Change [#350000]***

This sector represents the increase or decrease of stock in Energy transformation & own use sector and Final energy consumption sector. However, this increase/decrease was not reflected in reference approach emission calculation.

- ***Other factors***

Some emissions are not calculated for the sources that the emissions are relatively low compared to total emissions in reference approach, in order not to be too complicated. For example, the emissions from lubricants used in two stroke engines are not accounted for in the reference approach emission calculation.

***2) Matters which cannot be avoided for the characteristics of survey data***

- ***Supply Side Discrepancy [#401000]***

Statistical discrepancy is originally the intrinsic error arising at the sampling stage in statistical studies (source error), and mutual discrepancies among the statistics for supply, conversion, and consumption. It is sometimes difficult to guess where the discrepancies come from (relative error).

These errors induce the discrepancies among domestic supply, conversion, and final energy consumption, calculated as difference between both approaches.

***3) Matters related to the difference of energy and carbon balance between energy input and output***

- ***'Coal Blending' [#211000], 'Oil Product Blending' [#221000], 'Coal Products Secondary Transformation' [#281000], 'Oil Products Secondary Transformation' [#282000]***

This sector represents energy conversion that does not belong to any of the sectors from Coke production [#212000] to Steel process gas [#215000] and from Oil refinery [#222000] to District heat supply [#270000], and actions considered to be energy conversion in which coal or oil product brands are changed by only simple operations such as blending or moisture adjustment.

Carbon weight is considered to be consistent before and after blending or conversions. However, given that carbon content per calorific value is changed following such as blending, in statistics, carbon weight could be varied before and after blending or conversions. This difference can generate the variation between two approaches.

***4) Matters related to the conversion to another fuel type***

- ***Gas Conversion and Production [#231000]***

This sector represents energy conversion arising from city gas production. City gas is made from liquid and solid fuels such as liquefied petroleum gas (LPG) and coke oven gas (COG) as well as gaseous fuels such as liquefied natural gas (LNG). Thus, the fact that some liquid and solid fuels are converted to gaseous fuels is not reflected in reference approach emission calculation. The emissions calculated by the sectoral approach tend to be larger than those by reference approach for gaseous fuels and smaller for liquid and solid fuels. This sector does not affect the difference between two approaches in total.

Table 3-7 Comparison of $CO_2$ emissions (detail)

[Mt-$CO_2$]

| | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RA** | **1,071** | **1,164** | **1,205** | **1,237** | **1,102** | **1,172** | **1,199** | **1,238** | **1,253** | **1,199** | **1,167** | **1,145** | **1,138** | **1,092** |
| Liquid fuels | 659.9 | 701.9 | 656.2 | 621.1 | 497.6 | 501.8 | 523.6 | 532.9 | 512.2 | 472.1 | 450.1 | 434.6 | 428.9 | 404.2 |
| Solid fuels | 295.7 | 323.7 | 377.9 | 431.1 | 396.8 | 450.8 | 420.8 | 439.9 | 474.5 | 457.3 | 462.1 | 451.1 | 450.8 | 440.8 |
| Gaseous fuels | 104.4 | 126.1 | 155.9 | 167.4 | 192.4 | 203.5 | 238.6 | 248.4 | 249.9 | 253.2 | 237.8 | 241.5 | 239.9 | 228.9 |
| Other fossil fuels | 10.9 | 12.4 | 15.2 | 17.1 | 15.6 | 15.9 | 16.0 | 17.1 | 16.7 | 16.3 | 16.8 | 17.6 | 18.2 | 18.0 |
| Peat | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| **SA** | **1,079** | **1,155** | **1,186** | **1,218** | **1,103** | **1,153** | **1,204** | **1,245** | **1,252** | **1,202** | **1,163** | **1,144** | **1,128** | **1,077** |
| Liquid fuels | 644.3 | 677.4 | 640.7 | 606.1 | 483.8 | 488.9 | 520.3 | 530.8 | 508.5 | 464.7 | 444.0 | 428.3 | 415.8 | 392.5 |
| Solid fuels | 309.5 | 327.1 | 364.1 | 422.4 | 404.6 | 438.5 | 423.2 | 442.8 | 473.7 | 465.1 | 458.8 | 449.6 | 451.6 | 435.8 |
| Gaseous fuels | 114.2 | 137.9 | 166.1 | 172.4 | 199.1 | 209.9 | 244.7 | 254.1 | 253.4 | 255.5 | 243.4 | 248.8 | 242.8 | 231.2 |
| Other fossil fuels | 10.9 | 12.4 | 15.2 | 17.1 | 15.6 | 15.9 | 16.0 | 17.1 | 16.7 | 16.3 | 16.8 | 17.6 | 18.2 | 18.0 |
| Peat | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| **RA-SA** | **-8.0** | **9.2** | **19.2** | **18.7** | **-0.7** | **18.7** | **-5.3** | **-6.5** | **1.0** | **-2.9** | **3.9** | **0.6** | **9.4** | **14.4** |
| Liquid fuels | 15.6 | 24.5 | 15.6 | 15.0 | 13.9 | 12.9 | 3.2 | 2.1 | 3.7 | 7.4 | 6.1 | 6.3 | 13.1 | 11.7 |
| Solid fuels | -13.8 | -3.4 | 13.8 | 8.6 | -7.8 | 12.2 | -2.5 | -2.9 | 0.8 | -7.9 | 3.3 | 1.5 | -0.8 | 5.0 |
| Gaseous fuels | -9.8 | -11.9 | -10.1 | -5.0 | -6.7 | -6.4 | -6.1 | -5.7 | -3.5 | -2.3 | -5.6 | -7.3 | -2.9 | -2.3 |
| Other fossil fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Peat | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Supply side discrepancy** | **-12.0** | **4.6** | **13.1** | **11.6** | **0.5** | **8.7** | **-6.3** | **-5.0** | **-2.1** | **-1.0** | **0.7** | **0.1** | **5.0** | **6.8** |
| Liquid fuels | 1.4 | 7.2 | 0.8 | 0.5 | 0.4 | -0.5 | -1.0 | -1.8 | -2.4 | -2.3 | -0.1 | -1.0 | 1.6 | -1.3 |
| Solid fuels | -14.3 | -2.7 | 12.9 | 11.1 | 2.2 | 11.0 | -3.5 | -2.0 | -0.6 | -0.8 | 1.2 | 2.5 | 3.7 | 6.3 |
| Gaseous fuels | 0.9 | 0.0 | -0.7 | 0.0 | -2.1 | -1.7 | -1.8 | -1.2 | 0.9 | 2.1 | -0.4 | -1.4 | -0.4 | 1.8 |
| **Coal blending** | **0.3** | **0.4** | **0.5** | **0.7** | **0.6** | **0.7** | **0.7** | **0.7** | **-0.2** | **-0.2** | **0.0** | **-0.1** | **-0.1** | **-0.1** |
| Liquid fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Solid fuels | 0.3 | 0.4 | 0.5 | 0.7 | 0.6 | 0.7 | 0.7 | 0.7 | -0.2 | -0.2 | 0.0 | -0.1 | -0.1 | -0.1 |
| Gaseous fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Oil product blending** | **-1.8** | **-0.5** | **0.2** | **0.4** | **0.0** | **0.1** | **0.0** | **-0.1** | **-1.4** | **-1.3** | **-1.4** | **-1.5** | **-1.5** | **-1.6** |
| Liquid fuels | -1.8 | -0.5 | 0.2 | 0.4 | 0.0 | 0.1 | 0.0 | -0.1 | -1.4 | -1.3 | -1.4 | -1.5 | -1.5 | -1.6 |
| Solid fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Gaseous fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Coal products secondary transformation** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| Liquid fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Solid fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Gaseous fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Oil products secondary transformation** | **1.1** | **0.4** | **0.4** | **0.8** | **1.2** | **1.5** | **1.2** | **1.4** | **1.2** | **1.3** | **1.2** | **1.2** | **1.9** | **2.1** |
| Liquid fuels | 1.1 | 0.4 | 0.4 | 0.8 | 1.2 | 1.5 | 1.2 | 1.4 | 1.2 | 1.3 | 1.2 | 1.2 | 1.9 | 2.1 |
| Solid fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Gaseous fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Gas conversion and production** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| Liquid fuels | 9.7 | 10.9 | 9.0 | 5.9 | 4.1 | 4.4 | 4.6 | 4.7 | 4.7 | 4.9 | 4.1 | 4.2 | 4.6 | 4.6 |
| Solid fuels | 0.8 | 0.5 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Gaseous fuels | -10.5 | -11.4 | -9.4 | -6.0 | -4.1 | -4.4 | -4.6 | -4.7 | -4.7 | -4.9 | -4.1 | -4.2 | -4.6 | -4.6 |
| **Other transformation** | **-0.4** | **-0.5** | **2.2** | **2.8** | **1.5** | **2.7** | **-3.9** | **-5.6** | **-1.1** | **-4.5** | **-0.9** | **-2.1** | **-0.8** | **0.4** |
| Liquid fuels | -0.5 | -0.6 | 2.1 | 2.8 | 1.5 | 2.6 | -3.9 | -5.7 | -1.2 | -4.6 | -0.9 | -2.2 | -0.9 | 0.3 |
| Solid fuels | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Gaseous fuels | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 |
| **Transformation and consumption stockpile change** | **2.6** | **1.7** | **2.4** | **-0.3** | **-9.7** | **2.7** | **1.3** | **2.8** | **1.3** | **-4.3** | **1.7** | **-2.9** | **-1.7** | **1.1** |
| Liquid fuels | 0.7 | 1.5 | -0.9 | -0.1 | -0.7 | 0.4 | -0.9 | 2.6 | -2.9 | -0.3 | -1.6 | -2.7 | -1.4 | -0.3 |
| Solid fuels | 1.9 | 0.6 | 3.0 | -1.6 | -8.6 | 2.4 | 1.7 | -0.2 | 3.7 | -4.6 | 4.3 | 1.4 | -2.4 | 0.9 |
| Gaseous fuels | 0.0 | -0.3 | 0.3 | 1.4 | -0.3 | -0.1 | 0.6 | 0.4 | 0.5 | 0.6 | -0.9 | -1.6 | 2.1 | 0.5 |
| **Total** | **-10.4** | **6.0** | **18.7** | **16.0** | **-6.0** | **16.4** | **-6.9** | **-5.7** | **-2.5** | **-10.1** | **1.3** | **-5.3** | **2.7** | **8.7** |
| Liquid fuels | 10.5 | 18.9 | 11.6 | 10.3 | 6.4 | 8.5 | 0.0 | 1.1 | -2.1 | -2.4 | 1.2 | -2.0 | 4.3 | 3.9 |
| Solid fuels | -11.4 | -1.2 | 16.9 | 10.3 | -5.9 | 14.1 | -1.1 | -1.5 | 2.9 | -5.6 | 5.5 | 3.8 | 1.2 | 7.1 |
| Gaseous fuels | -9.5 | -11.6 | -9.8 | -4.6 | -6.5 | -6.2 | -5.8 | -5.4 | -3.2 | -2.1 | -5.4 | -7.1 | -2.8 | -2.2 |
| **(RA-SA)-(Total)** | **2.4** | **3.2** | **0.5** | **2.6** | **5.3** | **2.3** | **1.6** | **-0.7** | **3.5** | **7.2** | **2.5** | **5.9** | **6.7** | **5.7** |
| Liquid fuels | 5.1 | 5.6 | 3.9 | 4.7 | 7.5 | 4.4 | 3.2 | 1.0 | 5.8 | 9.7 | 4.9 | 8.3 | 8.8 | 7.8 |
| Solid fuels | -2.4 | -2.2 | -3.0 | -1.7 | -1.9 | -1.8 | -1.3 | -1.4 | -2.0 | -2.3 | -2.1 | -2.3 | -2.1 | -2.0 |
| Gaseous fuels | -0.3 | -0.3 | -0.4 | -0.4 | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 | -0.2 | -0.2 | -0.1 | -0.1 |

### 3.2.2. International Bunker Fuels

#### *a) Category Description*

This section provides the estimation methods for determining $CO_2$, $CH_4$, and $N_2O$ emissions from the fuel consumed for international navigation and aviation.

The emissions from bunker fuels used for international navigation and aviation are not included in the national totals but are reported as the memo item in the CRFs in accordance with the *UNFCCC Inventory Reporting Guidelines* and the *2006 IPCC Guidelines*.

#### *b) Methodological Issues*

- ***Estimation Method***

The emissions of $CO_2$, $CH_4$ and $N_2O$ from this source are derived by multiplying the consumption of each fuel type handled by bonds by the emission factor.

- ***Emission Factors***

➢ *$CO_2$*

The emission factors used for $CO_2$ are the same as those from fuel combustion ($CO_2$) in the energy sector (Refer to Section 3.2.4. b)).

On the annual review in 2012 (FCCC/ARR/2012/JPN) and 2013 (FCCC/ARR/2013/JPN), the ERT noted that the Japanese carbon emission factor (EF) for jet kerosene (18.3 t-C/TJ based on the gross calorific value) is lower than the EF for jet kerosene included in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (18.5 t-C/TJ based on the gross calorific value[7]). The ERT recommended that Japan provide additional information.

The Japanese carbon emission factor for jet kerosene is obtained from actual measurement. In addition, the 95% confidence interval of EF for jet kerosene is 18.1-19.3 t-C/TJ (based on the gross calorific value) in the *2006 IPCC Guidelines* and the Japanese EF is inside the range. Therefore, Japan considers that this country-specific EF is appropriate value, comparing to the default value.

➢ *$CH_4$, $N_2O$*

The default values given in the *2006 IPCC Guidelines* are used for $CH_4$ and $N_2O$ emission factors.

Table 3-8 Emission factors for $CH_4$ and $N_2O$ from international bunkers

| Transport mode | Type of fuel | $CH_4$ emission factor [kg-$CH_4$/TJ(NCV)] | $N_2O$ emission factor [kg-$N_2O$/TJ(NCV)] |
|---|---|---|---|
| Aircraft | Jet fuel | 0.5 1) | 2 1) |
| Shipping | Fuel oil A, fuel oil B, fuel oil C, diesel oil, kerosene | 7 2) | 2 2) |

Note:
1) *2006 IPCC Guidelines* Vol. 2, Table 3.6.5
2) *2006 IPCC Guidelines* Vol. 2, Table 3.5.3. According to the *2006 IPCC Guidelines* Vol. 3 page 5.7, $CH_4$ and $N_2O$ emissions from lubricants are very small in comparison to $CO_2$, and these can be neglected for the greenhouse gas calculation. Therefore, the emissions are not estimated.

- ***Activity Data***

The totals for bonded imports and bonded exports given in *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal*

[7] This value is also the default value in the *2006 IPCC Guidelines*.

*and Coke*) (METI) are used for the emissions of $CO_2$, $CH_4$, and $N_2O$ from the relevant source.

A and B in the diagram below correspond to the items under bonded exports and bonded imports, respectively, in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*). C equals to the sum of A and B and it is used as the activity data for this source of emissions. This is considered to be approximately equivalent to the amount of the fuels sold in Japan for international aviation and navigation.

It is assumed that jet fuel is used by aircraft, while fuel oil A, B, C, diesel oil, kerosene and lubricants are used by vessels. Fuel oil A, B, and C are used for the propulsion of international water-borne vessels. Diesel oil and kerosene are used only for fuels of private power generators (e.g. air heating). All lubricants are assumed to be oxidized during use from the viewpoint of conservativeness as lubricants consumption by type is unknown.

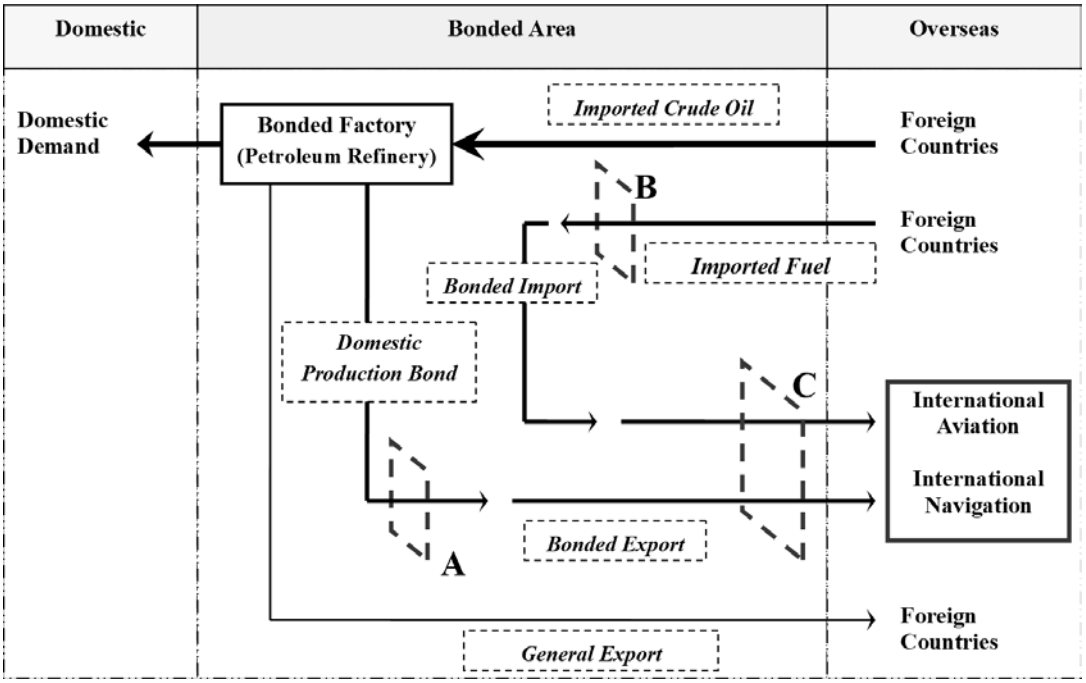


Figure 3-2 Activity data for international bunkers

➢ *$CO_2$*

The kiloliter-based consumption data given in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) are converted to Joule-based data using the actual calorific values given in the *General Energy Statistics*.

➢ *$CH_4$, $N_2O$*

The *2006 IPCC Guidelines* provide default emission factors that are based on net calorific values. Therefore, the activity data in gross calorific values are converted to net calorific values by multiplying them by the conversion rate.

● ***Glossary***

Bonded Jet Fuel

Under the Tariff Law, aircraft (Japanese and non-Japanese) flying international routes are deemed to be

"aircraft for international use", and the fuel they consume is tariff-free, subject to the completion of the required procedures. The application of this legislation means that if fuel is refined from crude oil imported to Japanese refinery, both the crude oil import tariff and the petroleum and coal tax are waived. Similarly, if fuel has been imported as a product, the product import tariff is waived. The foregoing is termed as "bonded jet fuel".

Bonded Fuel Oil

Vessels that ply between Japan and other countries are deemed to be "foreign trade vessels", under the Tariff Law. The majority of their fuel is consumed outside Japanese territorial waters, and, therefore, both the tariffs and the petroleum and coal tax are waived. The foregoing is termed as "bonded fuel oil".

Bonded Export

The demand for fuel supplied to aircraft (Japanese and non-Japanese) flying international routes and ships (Japanese and non-Japanese) that ply foreign ocean routes is termed as "bonded demand". Jet fuel is supplied to aircraft while fuel oil is supplied to ships. Of these bonded demands, the fuel supplied from products that was produced from crude oil is counted as bonded export by METI.

Bonded Import (Bond to Bond)

Fuel products that are imported from foreign countries, landed in a bonded area and supplied from the bonded area to bonded demand without going through domestic customs, is counted as bonded import by METI.

### 3.2.3. Feedstocks and Non-Energy Use of Fuels

The *General Energy Statistics* is used as the activity data for estimating GHG emissions from fuel combustion (1.A.). The Total energy consumption (#500000) in the statistics includes the amount of energy used as feedstocks without the combustion and oxidation process. The energy consumption in the category of Non-energy and feedstock use (#950000) represents such amount of energy. For the purpose of estimating the emissions, the consumption in the category of Non-energy and feedstock use was deducted from Total energy consumption.

The consumption in the category of Non-energy and feedstock use includes the following: (1) Consumption which can be confirmed as clearly non-energy uses by official statistics, such as surveys of feedstock inputs according to the *Yearbook of the Current Survey of Energy Consumption* (METI) which is the reference of the *General Energy Statistics*; and (2) Amount of products which are produced for the purpose of non-energy use from the beginning. (However, the portion which is confirmed from official statistics such as the *Yearbook of the Current Survey of Energy Consumption* as having been employed for energy uses is treated as energy consumption and is excluded from non-energy use.)

The feedstocks and non-energy use of fuels are reported in "Fuel quantity for NEU" and "Carbon excluded" columns of the the Common Reporting Format (CRF) table 1.A(d). The correspondence between fuels of the *General Energy Statistics* and those of the table is shown in Annex 4.

The $CO_2$ emissions from combustion or oxidation of the fuel used for non-energy purpose such as feedstock use of products in any process of manufacturing, use and abandonment of products are separately reported in other sectors shown in Table 3-9. (For detail, see each related chapter.) The

emissions are reported in "Reported $CO_2$ emissions" column of the CRF table 1.A(d).

Among emissions from manufacturing processes of iron and steel and non-ferrous metals, emissions from fuel combustion should be reported in Energy sector (1.A) and emissions from reducing agent should be reported in Industrial processes and product use sector (2.C). Both emissions are reported together in Energy sector (1.A), because Japan considers that it is the most appropriate to grasp all emissions from manufacturing processes of iron and steel, and non-ferrous metals comprehensively from the viewpoints of accuracy, and avoiding double-counting and omissions. Each manufacturing process and category is shown in Table 3-10.

Table 3-9 Allocation of $CO_2$ emissions from fuel used for non-energy purpose such as feedstock

| $CO_2$ emitting process | CRF Category | Type of fuel used for non-energy purpose such as feedstock | Emission factor | |
|---|---|---|---|---|
| | | | | Calorific value |
| Ammonia production | 2.B.1 | Naphtha | See Table 3-11 | See Table 3-20 |
| | | Liquefied petroleum gas (LPG), (until FY2002) | | |
| | | Refinery gas (off-gas) (until FY2011) | | |
| | | Indigenous natural gas | | |
| | | Coal (steam coal, imports) | | |
| | | Petroleum coke | | |
| | | Liquefied natural gas (LNG) | | |
| | | Coke oven gas (COG) (until FY2001) | | |
| Silicon carbide production | 2.B.5.a | Petroleum coke | 2.3 [t-$CO_2$/t] (per petroleum coke consumption amount) | |
| Calcium carbide production | 2.B.5.b | Coke | From reducing agent in production: 1.09 [t-$CO_2$/t] (confidential information in and after FY2008), from use: 1.10 [t-$CO_2$/t] (both EFs per calcium carbide production amount) | |
| Titanium dioxide production | 2.B.6 | Petroleum coke | Rutile $TiO_2$: confidential information<br>Synthetic rutile: 1.43 [t-$CO_2$/t] (per production amount) | |
| Methanol production | 2.B.8.a | Natural gas (until FY1995) | 0.67 [t-$CO_2$/t] (per methanol production amount) | |
| Ethylene production | 2.B.8.b | Naphtha, LPG, etc. | Confidential information | |
| Carbon black production | 2.B.8.f | Coal tar, etc. | 2.06 [t-$CO_2$/t] (per carbon black production amount) | |
| Maleic anhydride production | 2.B.8.g | LPG | 1.65 [t-$CO_2$/t] (per maleic anhydride production amount made by oxidation of n-butane) | |
| Hydrogen production | 2.B.8.g | Natural gas, etc. | Report by member companies of the Japan Industrial and Medical Gases Association | |
| Automobile and marine engine oils (excluding total loss type) [1)] | 2.D.1 | Lubricants | See Table 3-11 | |
| Paraffin wax use | 2.D.2 | Bitumen | See Table 3-11 | |

Note:

1) $CO_2$ emissions from automobile and marine engine oils (total loss type) are included in Transport (1.A.3).

2) $CO_2$ emissions from fuel used for non-energy purpose may occur when fossil-fuel derived waste is incinerated or decomposed, and when fossil-fuel derived chemical products are used as feedstock to produce other chemical products. These $CO_2$ emissions are reported under 1.A (other fossil fuels), 2.D.3, 2.B.8, 2.H.2, 5.C or 5.E. However, This table and "Reported $CO_2$ emissions" column of CRF table 1.A(d) do not include these emissions in accordance with the *2006 IPCC Guidelines*, Vol.3, page 1.16.

Table 3-10 Reported category of $CO_2$ emissions from iron and steel and non-ferrous metals process

| $CO_2$ emitting process | Type of fuel used for non-energy purpose such as feedstock | Allocation as per IPCC Guidelines | Allocation used by the Party |
|---|---|---|---|
| Iron and steel reduction, Pig iron, Direct reduced iron, Sinter, Pellet | Coke, pulverized coal, waste plastics, coke oven gas, blast furnace gas | 2.C.1 | 1.A.2.a (Iron and steel) |
| Ferroalloys production | Steam coal, coke | 2.C.2 | 1.A.2.a (Iron and steel) |
| Aluminium production | Coke (Main ingredient in the anode paste) | 2.C.3 | 1.A.2.f (Non-metallic minerals) |
| Lead production | Coke | 2.C.5 | 1.A.2.b (Non-ferrous metals) |
| Zinc production | Coke | 2.C.6 | 1.A.2.b (Non-ferrous metals) |

### 3.2.4. $CO_2$ Emissions from Energy Industries (1.A.1.: $CO_2$)

#### *a) Category Description*

This section provides the methods for estimating $CO_2$ emissions from public electricity and heat production (1.A.1.a), petroleum refining (1.A.1.b), and manufacture of solid fuels and other energy industries (1.A.1.c).

In FY2018, $CO_2$ emissions from this category accounted for 472,488 kt-$CO_2$, and represented 38.1% of Japan's total GHG emissions (excluding LULUCF). Public electricity and heat production (1.A.1.a) accounts for 88.5% and is the largest subcategory in energy industries (1.A.1).

The IEFs (Implied Emission Factor)[8] of $CO_2$ emissions from solid fuels in 1.A.1.c (Manufacture of solid fuels and other energy industries) have been pulled up and down by fluctuation of carbon balances derived from the transformation of solid fuels by the manufacture of solid fuels. The apparent annual change of this category is caused by the mass-balance, energy-balance and carbon-balance between coking coal, coke and other coal products, and may be influenced by statistical error, unobserved stockpiles in the process and/or spontaneous input-output unbalance.

#### *b) Methodological Issues*

- ***Estimation Method***

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2). Country-specific emission factors are used for all types of fuel.

$$E = \sum_{ij} \left[ (A_{ij} - N_{ij}) \times GCV_i \times 10^{-3} \times EF_i \times OF_i \right] \times 44/12$$

*E* : $CO_2$ emissions from fossil fuel combustion [ t-$CO_2$ ]
*A* : Energy consumption (original unit [t, kL, $10^3 \times m^3$])
*N* : Non-energy use of fossil fuels (original unit)
*GCV* : Gross calorific value [ MJ/original unit ]
*EF* : Carbon content of the fuel [ t-C/TJ ]
*OF* : Oxidation factor
*i* : Type of fuel
*j* : Sector

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as "other fossil fuels" and "biomass" in accordance with the *2006 IPCC*

[8] Indicators obtained by dividing the emissions in the common reporting format (CRF) by the activity data in the CRF.

*Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The $CO_2$ emissions from biomass are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*. In the *General Energy Statistics*, the consumptions of biofuels are included in those of gasoline and diesel oil, but the $CO_2$ emissions from biofuels are not considered as fossil fuel origin by adjusting the calorific value and the carbon emission factors of gasoline and diesel oil.

$CO_2$ generated from an oil refinery plant was captured and stored from fiscal year 2004 to 2007 and 2016 onward, and it is reported under "$CO_2$ amount captured" in liquid fuels of 1.A.1.b Petroleum refining of the CRF table 1.A(a). It is subtracted from the emissions estimated by the above formula. Please refer to the section 3.4.4. for details.

- ***Emission Factors***

➢ *Carbon emission factors*

The carbon content of fuels expressed as the unit of gross calorific value (higher heating value) was used for carbon emission factors. The emission factors are mostly country-specific values.

The emission factors were developed based on three different concepts; (a) Energy sources other than Blast Furnace Gas (BFG) and City gas, (b) BFG, and (c) City gas.

Table 3-11 provides the emission factors for $CO_2$ by fuel types.

Table 3-11 Carbon emission factors for fuel combustion in gross calorific value (Unit: t-C/TJ)

| Fuel | | | | Code [1] | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solid fuels | Coal | Steel making coal | | $0110 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.6 | 24.6 | 24.6 | 24.6 | 24.6 | 24.6 |
| | | Coking coal | | $0111 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 24.5 |
| | | Pulverized coal injection (PCI) coal | | $0112 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 25.1 | 25.1 | 25.1 | 25.1 | 25.1 | 25.1 |
| | | Imported steam coal | | $0121 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 24.3 |
| | | Imported steam coal for general use | | $0122 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 24.3 |
| | | Imported steam coal for power generation use | | $0123 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.7 | 24.4 | 24.4 | 24.4 | 24.4 | 24.4 | 24.3 |
| | | Indigenous produced steam coal | | $0124 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 | 23.7 | 23.7 | 23.7 | 23.7 | 23.7 | 24.2 |
| | | Hard coal, anthracite & lignite | | $0130 | 25.5 | 25.5 | 25.5 | 25.5 | 25.5 | 25.5 | 25.5 | 25.5 | 25.9 | 25.9 | 25.9 | 25.9 | 25.9 | 25.9 |
| | Coal Products | Coke | | $0211 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 30.2 | 30.2 | 30.2 | 30.2 | 30.2 | 29.9 |
| | | Coal tar | | $0212 | 20.9 | 20.9 | 20.9 | 20.9 | 20.9 | 20.9 | 20.9 | 20.9 | 20.9 | 20.9 | 20.9 | 20.9 | 20.9 | 20.9 |
| | | Coal briquette | | $0213 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 25.9 | 25.9 | 25.9 | 25.9 | 25.9 | 25.9 |
| | | Coke oven gas | | $0221 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 |
| | | Blast furnace gas | | $0222 | 27.2 | 26.9 | 26.7 | 26.5 | 26.5 | 26.4 | 26.3 | 26.2 | 26.5 | 26.6 | 26.5 | 26.5 | 26.5 | 26.3 |
| | | Converter furnace gas | | $0225 | 38.4 | 38.4 | 38.4 | 38.4 | 38.4 | 38.4 | 38.4 | 38.4 | 41.7 | 41.7 | 41.7 | 41.7 | 41.7 | 42.0 |
| Liquid fuels | Oil | Crude oil for refinery use | | $0310 | 19.1 | 19.0 | 19.0 | 19.1 | 19.0 | 19.1 | 19.1 | 19.1 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 |
| | | Crude oil for refinery use | | $0311 | 19.1 | 19.0 | 19.0 | 19.1 | 19.0 | 19.1 | 19.1 | 19.1 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 |
| | | Residual and straight run fuel oil for refinery use | | $0312 | 21.3 | 21.4 | 21.4 | 21.4 | 21.4 | 21.4 | 21.5 | 21.5 | 19.7 | 19.6 | 19.5 | 19.6 | 19.4 | 19.4 |
| | | Crude oil for power generation use | | $0320 | 19.1 | 19.1 | 19.2 | 19.6 | 19.3 | 19.2 | 19.1 | 19.1 | 19.2 | 19.2 | 19.3 | 19.3 | 19.3 | 19.3 |
| | | Bituminous mixture fuel | | $0321 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| | | Natural gas liquid (NGL) & condensate | | $0330 | 16.1 | 16.7 | 17.5 | 18.2 | 18.4 | 18.4 | 17.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.2 |
| | | NGL&condensate for refinery use | | $0331 | 17.4 | 18.1 | 18.0 | 18.3 | 18.4 | 18.4 | 17.3 | 18.4 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.2 |
| | | NGL&condensate for power generation use | | $0332 | 17.5 | 17.6 | 17.6 | 18.2 | 17.9 | 17.9 | 17.9 | 17.9 | 18.2 | 18.2 | 18.2 | 18.2 | 18.2 | 18.2 |
| | | NGL&condensate for petrochemical use | | $0333 | 15.6 | 16.2 | 16.8 | 17.6 | 17.9 | 18.0 | 16.9 | 18.2 | 18.3 | 18.2 | 18.2 | 18.3 | 18.2 | 18.2 |
| | Oil Products | | Pure naphtha | $0420 | 18.2 | 18.2 | 18.2 | 18.2 | 18.2 | 18.2 | 18.2 | 18.2 | 18.6 | 18.6 | 18.6 | 18.6 | 18.6 | 18.6 |
| | | | Reformed feedstock Oil | $0421 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 19.3 | 19.3 | 19.3 | 19.3 | 19.3 | 19.3 |
| | | Fuel oil | Gasoline (crude oil origin)[2] | $0431 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 |
| | | | Gasoline (biofuel blended)[3] | | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.2 | 18.2 | 18.2 | 18.6 | 18.6 | 18.6 | 18.5 | 18.5 | 18.5 |
| | | | Jet fuel oil | $0432 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.6 | 18.6 | 18.6 | 18.6 | 18.6 | 18.6 |
| | | | Kerosene | $0433 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 |
| | | | Gas oil or diesel oil (crude oil origin)[2] | $0434 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.8 | 18.8 | 18.8 | 18.8 | 18.8 | 18.8 |
| | | | Gas oil or diesel oil (biofuel blended)[3] | | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 | 18.8 | 18.8 | 18.8 | 18.8 | 18.8 | 18.8 |
| | | | Fuel oil A | $0436 | 18.9 | 18.9 | 18.9 | 18.9 | 18.9 | 18.9 | 18.9 | 18.9 | 19.3 | 19.3 | 19.3 | 19.3 | 19.3 | 19.3 |
| | | | Fuel oil C | $0437 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 20.2 | 20.2 | 20.2 | 20.2 | 20.2 | 20.2 |
| | | | Fuel oil B | $0438 | 19.2 | 19.2 | 19.2 | 19.2 | 19.2 | 19.2 | 19.2 | 19.2 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| | | | Fuel oil C for general use | $0439 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 20.2 | 20.2 | 20.2 | 20.2 | 20.2 | 20.2 |
| | | | Fuel oil C for power generation use | $0440 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.8 | 19.8 | 19.8 | 19.8 | 19.8 | 20.1 |
| | | Miscellaneous oil products | Lubricant oil | $0451 | 19.2 | 19.2 | 19.2 | 19.2 | 19.2 | 19.2 | 19.2 | 19.2 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 | 19.9 |
| | | | Other heavy oil products | $0452 | 20.8 | 20.8 | 20.8 | 20.8 | 20.8 | 20.8 | 20.8 | 20.8 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 |
| | | | Oil coke | $0455 | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | 25.4 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 |
| | | | Galvanic furnace gas | $0456 | 38.4 | 38.4 | 38.4 | 38.4 | 38.4 | 38.4 | 38.4 | 38.4 | 41.7 | 41.7 | 41.7 | 41.7 | 41.7 | 42.0 |
| | | | Refinery gas | $0457 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.4 | 14.4 | 14.4 | 14.4 | 14.4 | 14.4 |
| | | | Liquefied petroleum gas (LPG) | $0458 | 16.5 | 16.5 | 16.5 | 16.5 | 16.5 | 16.5 | 16.5 | 16.5 | 16.4 | 16.4 | 16.4 | 16.4 | 16.4 | 16.4 |
| Gaseous fuels | Natural Gas | Liquefied natural gas (LNG) | | $0510 | 13.9 | 13.9 | 13.9 | 13.9 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 13.9 |
| | | Indigenous natural gas | | $0520 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 13.9 |
| | | Indigenous natural gas | | $0521 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 13.9 |
| | | Coal mining gas | | $0522 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 |
| | | Boil off gas from crude oil | | $0523 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 13.9 |
| | City Gas | City gas | | $0610 | 14.4 | 14.4 | 14.2 | 14.1 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 |
| | | Small scale community gas | | $0620 | 16.5 | 16.5 | 16.5 | 16.5 | 16.5 | 16.5 | 16.5 | 16.5 | 16.4 | 16.4 | 16.4 | 16.4 | 16.4 | 16.4 |
| (Reference) | Biomass | Woods | | $N131 | 30.2 | 30.2 | 30.2 | 30.9 | 30.9 | 30.9 | 30.9 | 30.9 | 29.6 | 29.6 | 29.6 | 29.6 | 29.6 | 29.6 |
| | | Waste woods | | $N132 | 30.2 | 30.2 | 30.2 | 30.9 | 30.9 | 30.9 | 30.9 | 30.9 | 29.6 | 29.6 | 29.6 | 29.6 | 29.6 | 29.6 |
| | | Bioethanol | | $N134 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 17.6 | 17.6 | 17.6 | 17.6 | 17.6 | 17.6 |
| | | Biodiesel | | $N135 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 17.6 | 17.6 | 17.6 | 17.6 | 17.6 | 17.6 |
| | | Thermal use of black liquor | | $N136 | 26.8 | 26.8 | 26.8 | 25.6 | 25.6 | 25.6 | 25.6 | 25.6 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 |
| | | Gas biomass | | $N137 | 12.4 | 12.4 | 12.4 | 12.4 | 12.4 | 12.4 | 12.4 | 12.4 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 |

1) Code number for fuels of the *General Energy Statistics* (Energy Balance Table)

2) Used in the reference approach.

3) Used in the sectoral approach.

Table 3-12 References and methodologies of carbon emission factors for fuel combustion (FY1990-2012)

| Fuel | | | | Code | FY1990-2012 |
|---|---|---|---|---|---|
| Solid fuels | Coal | | Steel making coal | $0110 | Same as coking coal |
| | | | Coking coal | $0111 | Kainou (2005) |
| | | | Pulverized coal injection (PCI) coal | $0112 | Same as coking coal |
| | | | Imported steam coal | $0121 | Same as imported steam coal for general use |
| | | | Imported steam coal for general use | $0122 | Environmental Agency (1992) |
| | | | Imported steam coal for power generation use | $0123 | Same as imported steam coal for general use |
| | | | Indigenous produced steam coal | $0124 | Environmental Agency (1992) |
| | | | Hard coal, anthracite & lignite | $0130 | Kainou (2005) |
| | Coal Products | | Coke | $0211 | Environmental Agency (1992) |
| | | | Coal tar | $0212 | Kainou (2005) |
| | | | Coal briquette | $0213 | Environmental Agency (1992) |
| | | | Coke oven gas | $0221 | Kainou (2005) |
| | | | Blast furnace gas | $0222 | Values based on the carbon balance in blast furnace and converter furnace in the *General Energy Statistics* |
| | | | Converter furnace gas | $0225 | Kainou (2005) |
| Liquid fuels | Oil | | Crude oil for refinery use | $0310 | Same as crude oil for refinery use |
| | | | Crude oil for refinery use | $0311 | Weighted average of brand-specific CEFs based on the share of imports |
| | | | Residual and straight run fuel oil for refinery use | $0312 | |
| | | | Crude oil for power generation use | $0320 | Estimated by interpolating by approximate equation of crude oil for refinery use |
| | | | Bituminous mixture fuel | $0321 | Kainou (2005) |
| | | | Natural gas liquid (NGL) / condensate | $0330 | Weighted average of brand-specific CEFs based on the share of imports |
| | | | NGL/condensate for refinery use | $0331 | |
| | | | NGL/condensate for power generation use | $0332 | |
| | | | NGL/condensate for petrochemical use | $0333 | |
| | Oil Products | Fuel oil | Pure naphtha | $0420 | Environmental Agency (1992) |
| | | | Reformed feedstock Oil | $0421 | Values of gasoline |
| | | | Gasoline (crude oil origin) | $0431 | Environmental Agency (1992) |
| | | | Gasoline (biofuel blended) | | Weighted average of CEFs of crude oil origin and biomass origin based on the share of domestic consumption |
| | | | Jet fuel oil | $0432 | Environmental Agency (1992) |
| | | | Kerosene | $0433 | Environmental Agency (1992) |
| | | | Gas oil or diesel oil (crude oil origin) | $0434 | Environmental Agency (1992) |
| | | | Gas oil or diesel oil (biofuel blended) | | Weighted average of CEFs of crude oil origin and biomass origin based on the share of domestic consumption |
| | | | Fuel oil A | $0436 | Environmental Agency (1992) |
| | | | Fuel oil C | $0437 | Same as fuel oil C for general use |
| | | | Fuel oil B | $0438 | Environmental Agency (1992) |
| | | | Fuel oil C for general use | $0439 | Environmental Agency (1992) |
| | | | Fuel oil C for power generation use | $0440 | Environmental Agency (1992) |
| | | Miscellaneous oil products | Lubricant oil | $0451 | Environmental Agency (1992) |
| | | | Other heavy oil products | $0452 | Environmental Agency (1992) |
| | | | Petroleum coke | $0455 | Environmental Agency (1992) |
| | | | Galvanic furnace gas | $0456 | Values of converter furnace gas |
| | | | Refinery gas | $0457 | Environmental Agency (1992) |
| | | | Liquefied petroleum gas (LPG) | $0458 | Weighted average of theoretical CEFs of propane and butane based on the share of these matters in indigenous production and imports of the fuel |
| Gaseous fuels | Natural Gas | | Liquefied natural gas (LNG) | $0510 | Weighted average of CEFs by production area based on the share of imports by country |
| | | | Indigenous natural gas | $0520 | Kainou (2005) |
| | | | Indigenous natural gas | $0521 | Values of indigenous natural gas |
| | | | Coal mining gas | $0522 | Environmental Agency (1992) |
| | | | Boil off gas from crude oil | $0523 | Values of indigenous natural gas |
| | City Gas | | City gas | $0610 | Estimated from the carbon balance of "city gas conversion and production" in the *General Energy Statistics* |
| | | | Small scale community gas | $0620 | Values of liquefied petroleum gas |
| (Reference) | Biomass | | Woods | $N131 | Actual measurements provided by JPA |
| | | | Waste woods | $N132 | |
| | | | Bioethanol | $N134 | Theoretical carbon emission factor of ethanol in normal condition |
| | | | Biodiesel | $N135 | |
| | | | Thermal use of black liquor | $N136 | Actual measurements provided by JPA |
| | | | Gas biomass | $N137 | Theoretical carbon emission factor of methane in normal condition |

Note:
FEPC: Federation of Electric Power Companies of Japan, JCIA: Japan Chemical Industry Association, JGA: Japan Gas Association,
JISF: Japan Iron and Steel Federation, JNGA: Japan Natural Gas Association, JPA: Japan Paper Association,
PAJ: Petroleum Association of Japan, SATP: Standard ambient temperature and pressure

Table 3-13 References and methodologies of carbon emission factors for fuel combustion (FY2013-2017)

| Fuel | | | | | Code | FY2013-2017 |
|---|---|---|---|---|---|---|
| Solid fuels | Coal | Steel making coal | | | $0110 | Weighted average of CEFs of coking coal and PCI coal using consumptions of the fuels |
| | | Coking coal | | | $0111 | Simple average of CEFs obtained from actual measurements provided by JISF |
| | | Pulverized coal injection (PCI) coal | | | $0112 | Simple average of CEFs obtained from actual measurements provided by JISF |
| | | Imported steam coal | | | $0121 | Same as imported steam coal for general use |
| | | Imported steam coal for general use | | | $0122 | Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC. |
| | | Imported steam coal for power generation use | | | $0123 | Same as imported steam coal for general use |
| | | Indigenous produced steam coal | | | $0124 | Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC. |
| | | Hard coal, anthracite & lignite | | | $0130 | Estimated by interpolating by the approximate equation of imported steam coal |
| | Coal Products | Coke | | | $0211 | Simple average of CEFs obtained from actual measurements provided by JISF |
| | | Coal tar | | | $0212 | Continuous use of the current value |
| | | Coal briquette | | | $0213 | Values of hard coal, anthracite & lignite |
| | | Coke oven gas | | | $0221 | Simple average of CEFs estimated from actual measurements provided by JISF |
| | | Blast furnace gas | | | $0222 | Values based on the carbon balance in blast furnace and converter furnace in the *General Energy* |
| | | Converter furnace gas | | | $0225 | Simple average of CEFs estimated from actual measurements provided by JISF |
| Liquid fuels | Oil | Crude oil for refinery use | | | $0310 | Same as crude oil for refinery use |
| | | Crude oil for refinery use | | | $0311 | Weighted average of brand-specific CEFs based on imports by brand. The brand-specific CEFs were estimated by the approximate equation of crude oil based on brand-specific GCV obtained from actual measurements provided by PAJ. |
| | | Residual and straight run fuel oil for refinery use | | | $0312 | |
| | | Crude oil for power generation use | | | $0320 | Weighted average of monthly CEFs using monthly receipts. The monthly CEFs were estimated by approximate equation of crude oil using GCV from *Electric Power Statistics* (ANRE). |
| | | Bituminous mixture fuel | | | $0321 | Continuous use of the current value |
| | | Natural gas liquid (NGL) / condensate | | | $0330 | Weighted average of brand-specific CEFs using monthly receipts by brand. The brand-specific CEFs were estimated by approximate equation of crude oil using brand-specific GCV obtained from actual measurements provided by PAJ. |
| | | NGL/condensate for refinery use | | | $0331 | |
| | | NGL/condensate for power generation use | | | $0332 | |
| | | NGL/condensate for petrochemical use | | | $0333 | |
| | Oil Products | Fuel oil | Pure naphtha | | $0420 | Value of regular gasoline, which is simple average of CEF obtained from actual measurements provided by PAJ |
| | | | Reformed feedstock Oil | | $0421 | Value of premium gasoline, which is simple average of CEF obtained from actual measurements provided by PAJ |
| | | | Gasoline (crude oil origin) | | $0431 | Weighted average of CEFs of regular and premium gasoline using domestic shipments by type. The CEF of each gasoline were obtained from actual measurements provided by PAJ. |
| | | | Gasoline (biofuel blended) | | | Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption |
| | | | Jet fuel oil | | $0432 | Weighted average of CEFs of kerosene type jet fuel and gasoline type jet fuel using the final consumptions by type in the *General Energy Statistics*. The CEFs of each type were obtained from actual measurements provided by PAJ. |
| | | | Kerosene | | $0433 | Simple average of CEFs obtained from actual measurements provided by PAJ |
| | | | Gas oil or diesel oil (crude oil origin) | | $0434 | Simple average of CEFs obtained from actual measurements provided by PAJ |
| | | | Gas oil or diesel oil (biofuel blended) | | | Weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption |
| | | | Fuel oil A | | $0436 | Simple average of CEFs obtained from actual measurements provided by PAJ |
| | | | Fuel oil C | | $0437 | Same as fuel oil C for general use |
| | | | Fuel oil B | | $0438 | Estimated by interpolating by approximate equation of oil products using GCV obtained from actual measurements provided by PAJ |
| | | | Fuel oil C for general use | | $0439 | Simple average of CEFs obtained from actual measurements provided by PAJ |
| | | | Fuel oil C for power generation use | | $0440 | Estimated by approximate equation of oil products using GCV from *Electric Power Statistics* (ANRE). |
| | | Miscellaneous oil products | Lubricant oil | | $0451 | Estimated by interpolating by approximate equation of oil products based on GCV obtained from actual measurements provided by PAJ |
| | | | Other heavy oil products | | $0452 | Estimated by interpolating by approximate equation of oil products based on GCV estimated from energy balance of slack fuel oil input and fuel oil C output |
| | | | Petroleum coke | | $0455 | Simple average of CEFs obtained from actual measurements provided by JCIA |
| | | | Galvanic furnace gas | | $0456 | Values of converter furnace gas |
| | | | Refinery gas | | $0457 | Simple average of CEFs estimated from actual measurements provided by PAJ |
| | | | Liquefied petroleum gas (LPG) | | $0458 | Weighted average of theoretical CEFs of propane and butane using domestic supply amount of each gas |
| Gaseous fuels | Natural Gas | Liquefied natural gas (LNG) | | | $0510 | Weighted average of CEFs by production area using imports by country. The CEFs by production area were estimated from *Gas Industry Handbook* (JGA). |
| | | Indigenous natural gas | | | $0520 | Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA. |
| | | Indigenous natural gas | | | $0521 | Values of indigenous natural gas ($0520) |
| | | Coal mining gas | | | $0522 | Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA. |
| | | Boil off gas from crude oil | | | $0523 | Values of indigenous natural gas ($0520) |
| | City Gas | City gas | | | $0610 | Estimated from the carbon balance of "city gas conversion and production" in the *General Energy Statistics* |
| | | Small scale community gas | | | $0620 | Values of liquefied petroleum gas |
| (Reference) | Biomass | Woods | | | $N131 | Simple average of CEFs obtained by actual measurements provided by JPA |
| | | Waste woods | | | $N132 | |
| | | Bioethanol | | | $N134 | Theoretical carbon emission factor of ethanol in SATP condition |
| | | Biodiesel | | | $N135 | |
| | | Thermal use of black liquor | | | $N136 | Actual measurements provided by JPA |
| | | Gas biomass | | | $N137 | Theoretical carbon emission factor of methane in SATP condition |

Table 3-14 References and methodologies of carbon emission factors for fuel combustion (FY2018 onward)

| Fuel | | | | | Code | FY2018 onward |
|---|---|---|---|---|---|---|
| Solid fuels | Coal | Steel making coal | | | $0110 | Weighted average of CEFs of coking coal and PCI coal using consumptions of the fuels |
| | | Coking coal | | | $0111 | Simple average of CEFs obtained from actual measurements provided by JISF |
| | | Pulverized coal injection (PCI) coal | | | $0112 | Simple average of CEFs obtained from actual measurements provided by JISF |
| | | Imported steam coal | | | $0121 | Same as imported steam coal for general use |
| | | Imported steam coal for general use | | | $0122 | Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC. |
| | | Imported steam coal for power generation use | | | $0123 | Same as imported steam coal for general use |
| | | Indigenous produced steam coal | | | $0124 | Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC. |
| | | Hard coal, anthracite & lignite | | | $0130 | Continuous use of the current value |
| | Coal Products | Coke | | | $0211 | Simple average of CEFs obtained from actual measurements provided by JISF |
| | | Coal tar | | | $0212 | Continuous use of the current value |
| | | Coal briquette | | | $0213 | Continuous use of the current value |
| | | Coke oven gas | | | $0221 | Simple average of CEFs estimated from actual measurements provided by JISF |
| | | Blast furnace gas | | | $0222 | Values based on the carbon balance in blast furnace and converter furnace in the *General Energy* |
| | | Converter furnace gas | | | $0225 | Simple average of CEFs estimated from actual measurements provided by JISF |
| Liquid fuels | Oil | Crude oil for refinery use | | | $0310 | Same as crude oil for refinery use |
| | | Crude oil for refinery use | | | $0311 | Weighted average of brand-specific CEFs based on imports by brand. The brand-specific CEFs were estimated by the approximate equation of crude oil based on brand-specific GCV obtained from actual measurements provided by PAJ. |
| | | Residual and straight run fuel oil for refinery use | | | $0312 | |
| | | Crude oil for power generation use | | | $0320 | Weighted average of monthly CEFs using monthly receipts. The monthly CEFs were estimated by approximate equation of crude oil using GCV from *Electric Power Statistics* (ANRE). |
| | | Bituminous mixture fuel | | | $0321 | Continuous use of the current value |
| | | Natural gas liquid (NGL) / condensate | | | $0330 | Weighted average of brand-specific CEFs using monthly receipts by brand. The brand-specific CEFs were estimated by approximate equation of crude oil using brand-specific GCV obtained from actual measurements provided by PAJ. |
| | | NGL/condensate for refinery use | | | $0331 | |
| | | NGL/condensate for power generation use | | | $0332 | |
| | | NGL/condensate for petrochemical use | | | $0333 | |
| | Oil Products | Fuel oil | Pure naphtha | | $0420 | Continuous use of the current value |
| | | | Reformed feedstock Oil | | $0421 | Continuous use of the current value |
| | | | Gasoline (crude oil origin) | | $0431 | Weighted average of CEFs of regular and premium gasoline using domestic shipments by type. The CEF of each gasoline were obtained from actual measurements provided by PAJ. |
| | | | Gasoline (biofuel blended) | | | Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption |
| | | | Jet fuel oil | | $0432 | Weighted average of CEFs of kerosene type jet fuel and gasoline type jet fuel using the final consumptions by type in the *General Energy Statistics*. The CEFs of each type were obtained from actual measurements provided by PAJ. |
| | | | Kerosene | | $0433 | Continuous use of the current value |
| | | | Gas oil or diesel oil (crude oil origin) | | $0434 | Continuous use of the current value |
| | | | Gas oil or diesel oil (biofuel blended) | | | Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption |
| | | | Fuel oil A | | $0436 | Continuous use of the current value |
| | | | Fuel oil C | | $0437 | Same as fuel oil C for general use |
| | | | Fuel oil B | | $0438 | Continuous use of the current value |
| | | | Fuel oil C for general use | | $0439 | Continuous use of the current value |
| | | | Fuel oil C for power generation use | | $0440 | Estimated by approximate equation of oil products using GCV from *Electric Power Statistics* (ANRE). |
| | | Miscellaneous oil products | Lubricant oil | | $0451 | Continuous use of the current value |
| | | | Other heavy oil products | | $0452 | Estimated by interpolating by approximate equation of oil products based on GCV estimated from energy balance of slack fuel oil input and fuel oil C output |
| | | | Petroleum coke | | $0455 | Continuous use of the current value |
| | | | Galvanic furnace gas | | $0456 | Values of converter furnace gas |
| | | | Refinery gas | | $0457 | Continuous use of the current value |
| | | | Liquefied petroleum gas (LPG) | | $0458 | Weighted average of theoretical CEFs of propane and butane using domestic supply amount of each gas |
| Gaseous fuels | Natural Gas | Liquefied natural gas (LNG) | | | $0510 | Weighted average of CEFs by production area using imports by country. The CEFs by production area were estimated from actual measurements provided by FEPC and JGA. |
| | | Indigenous natural gas | | | $0520 | Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA. |
| | | Indigenous natural gas | | | $0521 | Values of indigenous natural gas ($0520) |
| | | Coal mining gas | | | $0522 | Continuous use of the current value |
| | | Boil off gas from crude oil | | | $0523 | Values of indigenous natural gas ($0520) |
| | City Gas | City gas | | | $0610 | Estimated from the carbon balance of "city gas conversion and production" in the *General Energy Statistics* |
| | | Small scale community gas | | | $0620 | Values of liquefied petroleum gas |
| (Reference) | Biomass | Woods | | | $N131 | Continuous use of the current value |
| | | Waste woods | | | $N132 | |
| | | Bioethanol | | | $N134 | Continuous use of the current value |
| | | Biodiesel | | | $N135 | Continuous use of the current value |
| | | Thermal use of black liquor | | | $N136 | Continuous use of the current value |
| | | Gas biomass | | | $N137 | Continuous use of the current value |

*(a) Energy sources other than Blast Furnace Gas (BFG) and City gas*

The carbon emission factors of energy sources other than blast furnace gas (BFG) and city gas were established based on Environmental Agency (1992), Ministry of the Environment (2002a), Kainou (2005), Kainou (2014), and Agency for Natural Resources and Energy (2020).

- ***Methodological issues of carbon emission factors from FY1990 to FY2012***

The evaluation results in Kainou (2005) were adopted for setting emission factors. In the choice of carbon emission factors, an adequacy assessment of emission factors was conducted in Environmental Agency (1992), which were used in the inventories submitted up to 2005. These were assessed based on the following three criteria. The values assessed as adequate continue to be used in this inventory.

1) Evaluation and analysis by comparison of theoretical upper and lower limits
2) Evaluation and analysis by comparison with the *Revised 1996 IPCC Guidelines* default values
3) Group evaluation and analysis by carbon balance using the *General Energy Statistics*

The summaries of evaluations are indicated below.

1) Evaluation and analysis by comparison of theoretical upper and lower limits

The validity of carbon emission factors is evaluated by comparing the intended emission factor and the emission factor calculated theoretically from standard enthalpy change of the formation of pure matter, such as hydrogen, methane and carbon monoxide, because most of the fuels for which carbon emission factors are required to be evaluated are hydrocarbons containing a few impurities, and because a physicochemical correspondence exists between the gross calorific values of pure hydrocarbons and carbon emission factors.

2) Evaluation and analysis by comparison with the *Revised 1996 IPCC Guidelines* default values

The validity of carbon emission factors is judged by using the *Revised 1996 IPCC Guidelines* default values or the *2006 IPCC Guidelines* reference values[9] and their statistical reliability (uncertainty) information. However, because the average properties of fuels envisaged in the IPCC Guidelines and those of the fuels used in Japan are not necessarily the same, carbon emission factors can be appropriately judged based on the statistical examination of the group evaluation and analysis mentioned below even when figures deviate, as long as a valid reason for the deviation exists.

3) Group evaluation and analysis by carbon balance using the *General Energy Statistics*

The validity of fuel-specific carbon emission factors for some petroleum and coal product factor groups can be evaluated using the *General Energy Statistics* to analyze the carbon balance in coal and oil products.

With regard to those judged there is no validity, the values shown in Ministry of the Environment (2002a) and *2006 IPCC Guidelines* were compared and verified, and values considered valid were used.

- ***Methodological issues of carbon emission factors from FY2013 to FY2017***

The values through the survey conducted by METI and the Ministry of the Environment (MOE) on the calorific values (CV) and carbon emission factors (CEF) in FY2013 and FY2014 were adopted. The

[9] When *Evaluating and Analyzing the Validity of Carbon Emission Factors for Different Fuels* was submitted, the *2006 IPCC Guidelines* had not been published yet. These values were reference values, and some of these reference values were revised.

outline is described below.

1) Outline of the Survey

The METI and MOE collected the data such as physical properties of various energy sources that relevant industrial associations had, and conducted the survey on the actual measurements of physical properties of samples provided by relevant industrial associations in FY2013 and FY2014. The CVs and CEFs from FY2013 were established using the methodologies presented in Kainou (2014) based on the physical properties of various energy sources obtained from the survey.

2) Basic Methodology of Estimation of Carbon Emission Factors

The CVs and CEFs by energy source were established, based on the properties and priority in accuracy of various energy sources, by the following methods: (1) estimation from theoretical values; (2) estimation from the actual measurements provided by the relevant industrial associations and the actual measurements by the METI and MOE; (3) estimation from the values of major energy sources, and from the weighted average and/or regression analysis using those values; (4) continuous use of the current values.

The estimation methods of the CVs and CEFs of solid, liquid and gaseous fuels based on the theoretical values and the actual measurements (corresponding to the methods (1) and (2)) are as follows:

*Gaseous fuels*

In the cases where component composition can be measured by such techniques as gas chromatography in some energy sources like gaseous fuels, CVs and CEFs are derived by weighted average of those of pure matters by composition. Theoretical CVs and CEFs of pure matters such as methane and propane are estimated from physical properties like standard enthalpy change of the formation.

*Solid and liquid fuels*

In the cases where energy sources are solid fuels or liquid fuels that the weighted average by pure matters are not feasible, CVs and carbon contents are estimated by statistical treatment of the actual measurements of physical properties such as gross calorific values and carbon contents.

The method (3) is that the CVs and CEFs of subject energy sources are estimated by interpolating by the approximate equations. The equations were established based on the actual measurements of steam coal, crude oil and oil products, and they can estimate CVs and CEFs from the physical properties such as density and water content.

3) Quality Control

The CVs and CEFs estimated above were compared with the current values and the default values of the *2006 IPCC Guidelines*, and then the validity is confirmed.

- ***Methodological issues of carbon emission factors from FY2018 onward***

The CEFs from FY2018 onward were established in combination of the CVs, based on the survey conducted by METI and MOE on the CV and CEF in FY2017 through FY2019. The fuels to be revised were selected, considering that the major revision of the CV and CEF has already been done in FY2013, the composition of some fuels does not significantly change during five years or so, the balance between cost and work load of the measurements and impact on emissions. The CV and CEF were established basically by the following methods: (1) They were established in place of the current values using the data provided by industry organizations; (2) They were established in place of the current values using

the existing statistics and references, the estimation equations, and other means; (3) The current values were used continuously. For (1) and (2), Kainou (2014) was referred to if the same estimation methodologies and references were adopted as in FY2013 values.

The CV and CEF estimated above were compared with the FY2013 values and the default values of the *2006 IPCC Guidelines* to evaluate the validity. In addition, the balance of energy and carbon in the coal products manufacturing and petroleum product manufacturing categories was confirmed: the output did not exceed the input due to the establishment of the CV and CEF described above.

*(b) Blast Furnace Gas (BFG)*

During the iron and steel production process, in the blast furnace and converter furnace, the amount of energy and carbon contained in coke and Pulverized Coal Injection (PCI) coal which are injected to the processes and those contained in BFG and Converter Furnace Gas (CFG, or Linz-Donawitz converter gas (LDG)) which are calculated should be theoretically balanced. Since the composition of BFG is unstable, the emission factors for BFG were established with annually calculated values in order to keep the carbon balance in the blast furnace and converter furnace during the iron and steel production process.

The amount of carbon (excluding the carbon contained in CFG from the carbon contained in 'Coke' and 'PCI coal') injected to the blast furnace indicated under 'Steel process gas' is considered to be carbon contained in BFG. The emission factor for BFG was established as the carbon described above divided by the calorific value of the BFG generated. The equation for the emission factor, the overview of the carbon flow for iron and steel and the calculation process are shown below.

The calculation to establish the emission factor for BFG is conducted every year.

$$EF_{BFG} = [(A_{coal} \times EF_{coal} + A_{cake} \times EF_{coke}) - A_{CFG} \times EF_{CFG}]/A_{BFG}$$

| | |
|---|---|
| *EF* | : Carbon emission factor [t-C/TJ] |
| *A* | : Fuel consumption [TJ] |
| *BFG* | : Blast Furnace Gas |
| *coal* | : PCI coal |
| *coke* | : Coke |
| *CFG* | : Converter Furnace Gas |

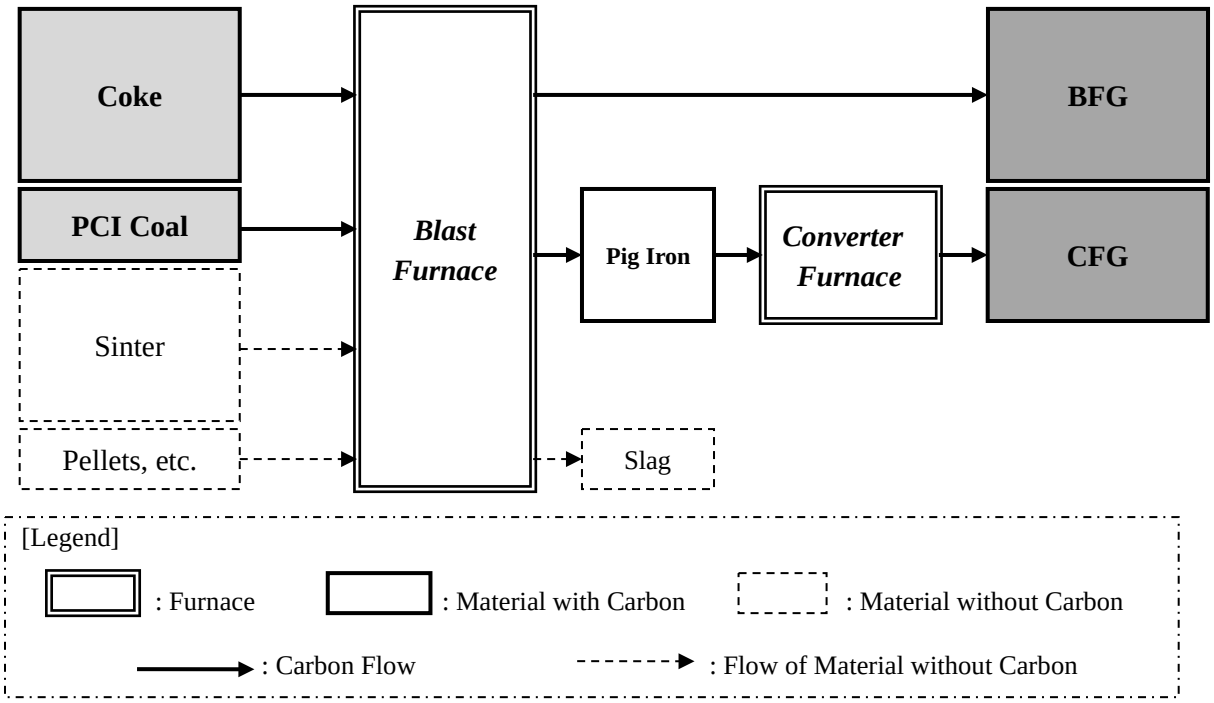


Figure 3-3 Overview of carbon flow for iron & steel manufacturing

Table 3-15 Calculation process of emission factors for BFG

| Steel process gas | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | | | | | | | | | | | | | | | | |
| PCI coal | kt-C | 1,650 | 2,619 | 3,351 | 3,014 | 2,576 | 3,444 | 3,669 | 4,019 | 4,401 | 4,283 | 4,180 | 4,206 | 4,250 | 4,094 | A |
| Coke | kt-C | 12,739 | 11,400 | 12,221 | 11,497 | 10,458 | 11,194 | 10,137 | 10,187 | 10,870 | 10,917 | 10,270 | 10,196 | 9,739 | 9,586 | B |
| Input total | kt-C | 14,389 | 14,019 | 15,572 | 14,511 | 13,034 | 14,637 | 13,806 | 14,206 | 15,271 | 15,200 | 14,449 | 14,402 | 13,989 | 13,680 | C: A + B |
| Output | | | | | | | | | | | | | | | | |
| CFG (LDG) | kt-C | 2,541 | 2,359 | 2,726 | 2,804 | 2,589 | 2,798 | 2,502 | 2,612 | 2,955 | 2,941 | 2,778 | 2,770 | 2,589 | 2,552 | D |
| Difference | kt-C | 11,848 | 11,660 | 12,846 | 11,707 | 10,444 | 11,839 | 11,304 | 11,594 | 12,316 | 12,260 | 11,671 | 11,632 | 11,400 | 11,127 | E: C - D |
| Output | | | | | | | | | | | | | | | | |
| BFG | PJ | 434.8 | 433.5 | 481.8 | 441.4 | 393.7 | 448.7 | 429.6 | 442.8 | 464.5 | 461.7 | 440.1 | 438.9 | 429.8 | 423.2 | F |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EF BFG | t-C/TJ | 27.2 | 26.9 | 26.7 | 26.5 | 26.5 | 26.4 | 26.3 | 26.2 | 26.5 | 26.6 | 26.5 | 26.5 | 26.5 | 26.3 | E / F |

*(c) City gas*

"City gas" consists of "city gas" provided by general gas supplier and "small-scale community gas" provided by small-scale community gas supplier.

*Small-scale community gas suppliers:*

Because most of the small-scale community gas is LPG, the same emission factor was adopted as for LPG.

*General gas suppliers:*

City gas (general gas) is produced from a mixture of raw materials and air dilution. In order to calculate the city gas emission factors, the total carbon contained in fossil fuel used as raw materials was divided by the total calorific value of the produced city gas. The emission factors for city gas were established based on the carbon balance in "city gas production". To calculate the city gas emission factors, the total carbon in fossil fuel inputs used as raw materials (COG, Kerosene, Refinery gas, LPG, LNG and Indigenous natural gas) was divided by the total calorific value of the city gas production.

The calculation to establish the emission factor for city gas is conducted every year.

$$EF_{CG} = \sum_i (A_i \times EF_i) / P_{CG}$$

*EF* : Carbon emission factor [ t-C/TJ ]
*A* : Fuel consumption [TJ]
*P* : Calorific value of the city gas production [TJ]
*CG* : City gas
*i* : Feedstocks (COG, Kerosene, Refinery gas, LPG, LNG, Indigenous natural gas)

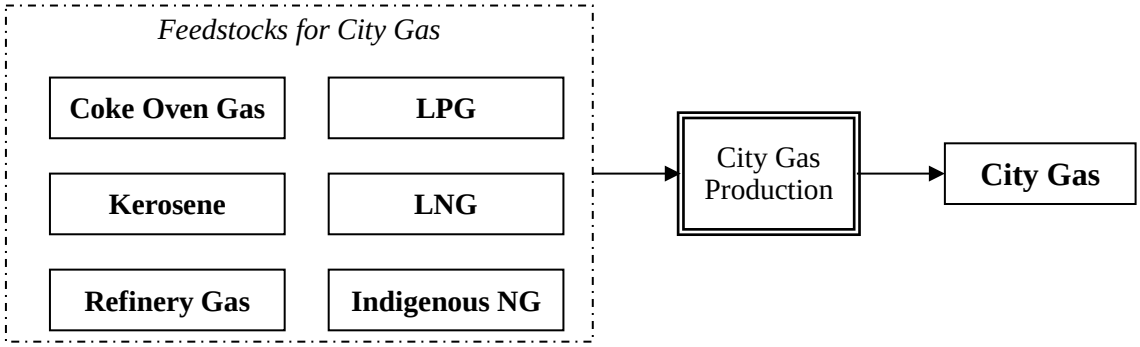


Figure 3-4 Manufacturing flow for city gas

Table 3-16 Calculation process of emission factors for city gas

| City gas | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input | | | | | | | | | | | | | | | | |
| COG | kt-C | 211 | 134 | 105 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | a1 |
| Kerosene | kt-C | 200 | 275 | 69 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | a2 |
| Refinery gas | kt-C | 186 | 199 | 186 | 145 | 94 | 89 | 83 | 82 | 67 | 56 | 37 | 48 | 43 | 46 | a3 |
| LPG | kt-C | 1,957 | 2,129 | 1,809 | 1,092 | 706 | 786 | 869 | 891 | 930 | 992 | 818 | 837 | 947 | 965 | a4 |
| LNG | kt-C | 6,473 | 9,429 | 12,051 | 17,146 | 19,865 | 21,357 | 21,957 | 22,216 | 21,709 | 21,863 | 21,868 | 22,907 | 23,252 | 22,682 | a5 |
| Indigenous NG | kt-C | 551 | 661 | 848 | 1,190 | 1,768 | 1,603 | 1,635 | 1,557 | 1,498 | 1,479 | 1,435 | 1,415 | 1,347 | 1,187 | a6 |
| Input total | kt-C | 9,577 | 12,827 | 15,068 | 19,601 | 22,433 | 23,834 | 24,544 | 24,746 | 24,205 | 24,390 | 24,159 | 25,205 | 25,589 | 24,879 | A: Σa |
| Output | | | | | | | | | | | | | | | | |
| Town gas | PJ | 664.7 | 892.3 | 1,061.1 | 1,392.0 | 1,600.8 | 1,700.3 | 1,750.3 | 1,764.1 | 1,724.3 | 1,737.3 | 1,722.1 | 1,796.5 | 1,822.5 | 1,781.9 | B |
| EF Town gas | t-C/TJ | 14.4 | 14.4 | 14.2 | 14.1 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | A/B |

➢ *Oxidation factor*

For each type of energy, country-specific oxidation factors were established considering the actual conditions of fuel combustion in Japan based on survey on related industrial associations, manufacturing corporations and experts.

*Gaseous Fuels*

Every measurement result of soot concentration of boilers to generate power in 2004 for gaseous fuels combustion showed that no soot was emitted; therefore, it is assumed that gaseous fuels are completely combusted. The results of questionnaires also showed that gaseous fuels were completely combusted. Hence, the oxidation factor for gaseous fuel combustion was set to 1.0.

Table 3-17 Data of gaseous fuel combustion

| Fired condition | Provider | Survey |
|---|---|---|
| Complete combustion | The Federation for Electric Power Companies Japan (FEPC) | Measurement of soot concentration of boilers to generate power in 2004 |

*Liquid Fuels*

The carbon contained in liquid fuels is considered to be almost completely combusted; however,

unburned fuel loss, about 0.5%, may occur depending on its fired condition. Because data of actual measurements were not available, considering meticulous combustion management and smoke treatment in Japan, the oxidation factor for liquid fuels combustion was set to 1.0.

*Solid Fuels*

The oxidation factor for solid fuels varies depending on the fired condition, type of furnace, and coal property; therefore, it is quite difficult to obtain a representational data set of actual measurements of unburned fuel loss. Meanwhile, almost all the unburned carbon generated during combustion in furnace is considered to be contained in coal ash. Coal ash is effectively utilized or landfilled. Carbon contained in coal ash which is used as raw material of cement is oxidized to $CO_2$ and emitted into the atmosphere during the calcinations process.

The average oxidation factor from 1990 to 2003 considering unburned carbon oxidized in the firing process of coal ash was 0.996, expressed as 3 digits. Usually 2 digits are considered to be adequate in the view of other coefficients' accuracy; therefore, the oxidation factor for solid fuels was set to 1.0 rounded off to two digits.

- ***Activity Data***

The fuel consumption data given in the *General Energy Statistics* were used for the activity data. Table 3-18 shows the trend of energy consumption.

Table 3-18 Energy consumptions in Energy Industries (1.A.1) (unit: PJ)

| Fuel | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liquid fuels | 2,596 | 2,198 | 1,618 | 1,669 | 1,257 | 1,352 | 1,885 | 2,166 | 1,866 | 1,465 | 1,313 | 1,170 | 1,034 | 899 |
| Solid fuels | 1,235 | 1,542 | 1,951 | 2,586 | 2,569 | 2,757 | 2,655 | 2,835 | 3,120 | 3,056 | 3,038 | 3,039 | 3,096 | 2,924 |
| Gaseous fuels | 1,564 | 1,786 | 2,167 | 2,021 | 2,451 | 2,624 | 3,266 | 3,475 | 3,488 | 3,552 | 3,300 | 3,394 | 3,218 | 3,038 |
| Other fossil fuels | IE | IE | 0 | 5 | 5 | 5 | 5 | 5 | 0 | 1 | 1 | 1 | 1 | 1 |
| Biomass | 0 | 0 | 0 | 26 | 23 | 28 | 28 | 28 | 32 | 33 | 33 | 54 | 89 | 102 |
| Total | 5,395 | 5,526 | 5,737 | 6,308 | 6,304 | 6,767 | 7,839 | 8,511 | 8,506 | 8,107 | 7,685 | 7,658 | 7,439 | 6,964 |

Note: Fuel type is in accordance with the Common Reporting Format (CRF).

The *General Energy Statistics* (Energy Balance Table) provides a comprehensive overview of domestic energy supply and demand to grasp what are converted from energy sources, such as coal, oil, natural gas and others, provided in Japan, and what are consumed in what sectors. The objective of this *General Energy Statistics* is to help to quantitatively understand energy supply and demand and to make judgments about the situation, in addition to helping with planning for energy and environmental policy, and with measuring, assessing, and otherwise gauging policy effectiveness.

The *General Energy Statistics* shows the main energy sources used in Japan as "Columns" and the supply, conversion and consumption sectors as "Rows" in a matrix. Specifically, the columns comprise 13 major categories (coal, coal products, crude oil, oil products, natural gas, city gas, renewable energy (excl. hydro), hydraulic power generation (excl. pumped), pumped storage, effective recovery use of wasted energy, nuclear power generation, electricity, and heat) and the necessary sub-categories and a more detailed breakdown of the sub-categories. The rows comprise 3 major sectors: primary energy supply (primary supply), energy transformation & own use (conversion), and final energy consumption (final consumption). The rows also contain the necessary sub-categories and a more detailed breakdown of the sub-categories.

In calculating the energy supply and demand amounts for the *General Energy Statistics*, it is assumed that each energy source, such as gasoline or electricity, is homogeneous in terms of gross calorific value

per original unit (MJ/kg, MJ/l, MJ/$m^3$), and that homogeneous energy sources are supplied, converted and consumed. The values for supply, conversion and consumption in original units as determined from official statistical sources are multiplied by the gross calorific value per original unit to obtain energy supply and demand amounts.

The calculation process in the *General Energy Statistics* is as follows:

(1) Setting calorific values and carbon emission factors.

(2) Building an energy supply and demand module.

(3) Preparing original unit tables (preparing a detailed table, a main table and a summary table through the module from relevant official statistics) (units in t, kL, $10^3$ $m^3$, etc.).

(4) Preparing energy unit tables (unit in J).

(5) Preparing energy-derived carbon tables (carbon content).

The *General Energy Statistics* adopts "actual calorific values" calculated based on annual official statistics for some fuel types which can be recalculated. For other fuel types which cannot be recalculated and whose composition is stable, "standard calorific values" based on latest measurement data available at the time, relevant official statistics and documents are adopted.

The complete Energy Balance Tables for the years since FY1990 are available on the following internet site:

http://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2 (Japanese version only)

Please refer to the simplified energy balance tables provided in Annex 4 (A4.2).

For the activity data for energy industries, the data reported in the following sectors in the *General Energy Statistics* were used: "manufacture of coal products" [#210000]; "oil products" [#220000]; "gas conversion and production" [#230000]; "power generation" [#240000] which reports energy consumption associated with electric power generation by electric power suppliers; "district heat supply" [#270000] which provides energy consumption associated with heat energy and cold energy by thermal energy suppliers; "own use, coal products" [#301100] which reports energy consumption associated with captive (own) use of energy industries; "own use, oil products" [#301200]; "own use, gas conversion and production" [#301300]; "own use, power generation" [#301400]; "own use, district heat supply" [#301500].

In addition, fossil fuel consumption of "Auto power production" in "production, transmission and distribution of electricity" [#255330] is also included in the energy industries from FY1990 to FY2015. This is because electricity utilities whose main business is power generation should be included in public electricity and heat production (1.A.1.a) in accordance with the *2006 IPCC Guidelines*, and "production, transmission and distribution of electricity" until FY2015 mainly includes independent power producers (IPP) whose main business is power generation. Since the definition and coverage of the sector of "Electric Utilities" was changed due to the enforcement of the revised Electricity Business Act, which stipulates the full liberalization of the electricity retail market in April 2016, electricity utilities whose main business is power generation such as IPP from FY2016 onwards are included in not "production, transmission and distribution of electricity" [#255330] but "power generation" [#240000].

Table 3-19 shows the correspondence between the sectors of Japan's Energy Balance Table from the

*General Energy Statistics* and those of the CRF.

Table 3-19 Correspondence between sectors of Japan's Energy Balance Table and those of the CRF (1.A.1)

| CRF | | General Energy Statistics | |
|---|---|---|---|
| 1A1 | Energy industries | | |
| 1A1a | Public electricity and heat production | Power generation | #240000 |
| | | Own use; Power generation | #301400 |
| | | District heat supply | #270000 |
| | | Own use; District heat supply | #301500 |
| | | Auto power generation; Production, transmission and distribution of electricity (until 2015) | #255330 |
| 1A1b | Petroleum refining | Oil products | #220000 |
| | | Own use; Oil products | #301200 |
| | | Auto power generation; Manufacture of petroleum products | #253171 |
| | | Auto steam generation, Manufacture of petroleum products | #263171 |
| | | Final energy consumption, Manufacture of petroleum products | #626510 |
| | | Non-energy and feedstock use; Manufacture of petroleum products | #951540 |
| 1A1c | Manufacture of solid fuels and other energy industries | Manufacture of coal products | #210000 |
| | | Own use; Coal products | #301100 |
| | | Auto power generation; Manufacture of coal products and miscellaneous | #253175 |
| | | Auto steam generation, Manufacture of coal products and miscellaneous | #263175 |
| | | Final energy consumption; Manufacture of coal products and miscellaneous | #626550 |
| | | Gas conversion and production | #230000 |
| | | Own use; Gas conversion and production | #301300 |

Note: #95xxxx items are subtracted as non-energy use activities.

- *Gross calorific value*

The gross calorific values used in *General Energy Statistics* are adopted. Table 3-20 shows the trends in gross calorific value for each fuel type. *General Energy Statistics* adopts actual calorific values calculated based on annual official statistics for some fuel types which can be recalculated. For other fuel types which cannot be recalculated and whose composition is stable, "standard calorific values" based on latest measurement data available at the time, relevant official statistics and documents are adopted. The "standard calorific values" are revised approximately once in every 5 years. The revision was conducted to the values of FY2000, 2005, 2013 and 2018.

The gross calorific value (GCV) trends for solid fuels are declining since 1990. From 1970 to 1990, Japanese steel manufacturers used conventional coking coal for feedstock for coke, but due to the shortage of coking coal and the increase of price, they developed a new coke making technology to use steam coal with pre-treatment as feedstock for coke instead. Similarly, they changed PCI coal from coking coal and steam coal mixture to steam coal with pre-treatment. The Japanese steel manufacturers have been trying to make high-quality coke from cheap coal for economic reasons. Because conventional coking coal has a higher carbon content and GCV than steam coal, and because the new technology was introduced gradually, the apparent GCV gradually decreased in these years.

## Table 3-20 Trends in gross calorific value of each fuel type

| Fuel | | | | Code | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solid fuels | Coal | | Steel making coal | $0110 | MJ/kg | 31.8 | 30.5 | 29.0 | 29.0 | 29.0 | 28.9 | 28.9 | 28.9 | 28.7 | 28.7 | 28.7 | 28.7 | 28.7 | 28.7 |
| | | | Coking coal | $0111 | MJ/kg | 31.8 | 30.5 | 29.1 | 29.1 | 29.1 | 29.1 | 29.1 | 29.1 | 28.9 | 28.9 | 28.9 | 28.9 | 28.9 | 28.9 |
| | | | Pulverized coal injection (PCI) coal | $0112 | MJ/kg | 31.8 | 30.5 | 28.2 | 28.2 | 28.2 | 28.2 | 28.2 | 28.2 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.3 |
| | | | Imported steam coal | $0121 | MJ/kg | 26.0 | 26.0 | 26.6 | 25.7 | 25.7 | 25.7 | 25.7 | 25.7 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.1 |
| | | | Imported steam coal for general use | $0122 | MJ/kg | 26.0 | 26.0 | 26.6 | 25.7 | 25.7 | 25.7 | 25.7 | 25.7 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.1 |
| | | | Imported steam coal for power generation use | $0123 | MJ/kg | 24.9 | 26.1 | 26.4 | 25.5 | 25.4 | 25.3 | 25.3 | 25.3 | 26.0 | 25.5 | 25.3 | 25.1 | 25.0 | 24.8 |
| | | | Indigenous produced steam coal | $0124 | MJ/kg | 24.3 | 24.3 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 25.3 | 25.3 | 25.3 | 25.3 | 25.3 | 24.2 |
| | | | Hard coal, anthracite & lignite | $0130 | MJ/kg | 27.2 | 27.2 | 27.2 | 26.9 | 26.9 | 26.9 | 26.9 | 26.9 | 27.8 | 27.8 | 27.8 | 27.8 | 27.8 | 27.8 |
| | Coal Products | | Coke | $0211 | MJ/kg | 30.1 | 30.1 | 30.1 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.2 | 29.2 | 29.2 | 29.2 | 29.2 | 29.0 |
| | | | Coal tar | $0212 | MJ/kg | 37.3 | 37.3 | 37.3 | 37.3 | 37.3 | 37.3 | 37.3 | 37.3 | 37.3 | 37.3 | 37.3 | 37.3 | 37.3 | 37.3 |
| | | | Coal briquette | $0213 | MJ/kg | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 |
| | | | Coke oven gas | $0221 | MJ/m$^3$ | 21.5 | 21.6 | 21.3 | 21.4 | 21.1 | 21.3 | 21.1 | 20.7 | 18.9 | 18.9 | 18.9 | 18.9 | 18.9 | 18.4 |
| | | | Blast furnace gas | $0222 | MJ/m$^3$ | 3.5 | 3.6 | 3.6 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| | | | Converter furnace gas | $0225 | MJ/m$^3$ | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |
| Liquid fuels | Oil | | Crude oil for refinery use | $0310 | MJ/L | 38.3 | 38.3 | 38.2 | 38.1 | 38.1 | 38.2 | 38.2 | 38.1 | 38.2 | 38.2 | 38.2 | 38.2 | 38.2 | 38.2 |
| | | | Crude oil for refinery use | $0311 | MJ/L | 38.3 | 38.3 | 38.2 | 38.1 | 38.1 | 38.2 | 38.2 | 38.1 | 38.2 | 38.2 | 38.2 | 38.2 | 38.2 | 38.2 |
| | | | Residual and straight run fuel oil for refinery use | $0312 | MJ/L | 38.3 | 38.3 | 38.2 | 38.1 | 38.1 | 38.2 | 38.2 | 38.1 | 41.3 | 40.9 | 40.6 | 40.8 | 40.3 | 40.2 |
| | | | Crude oil for power generation use | $0320 | MJ/L | 39.1 | 39.2 | 39.6 | 38.5 | 39.7 | 39.7 | 39.4 | 39.3 | 39.3 | 39.4 | 39.8 | 40.0 | 39.5 | 39.8 |
| | | | Bituminous mixture fuel | $0321 | MJ/kg | 30.1 | 30.3 | 29.9 | 22.4 | 22.4 | 22.4 | 22.4 | 22.4 | 22.4 | 22.4 | 22.4 | 22.4 | 22.4 | 22.4 |
| | | | Natural gas liquid (NGL) & condensate | $0330 | MJ/L | 35.7 | 35.5 | 35.4 | 35.0 | 34.8 | 34.8 | 36.9 | 34.8 | 34.8 | 34.7 | 34.6 | 34.8 | 34.5 | 34.5 |
| | | | NGL&condensate for refinery use | $0331 | MJ/L | 35.7 | 35.5 | 35.4 | 35.0 | 34.8 | 34.8 | 36.9 | 34.8 | 34.8 | 34.7 | 34.7 | 34.8 | 34.6 | 34.5 |
| | | | NGL&condensate for power generation use | $0332 | MJ/L | 35.7 | 35.5 | 35.4 | 35.0 | 34.8 | 34.8 | 36.9 | 34.8 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 |
| | | | NGL&condensate for petrochemical use | $0333 | MJ/L | 35.7 | 35.5 | 35.4 | 35.0 | 34.8 | 34.8 | 36.9 | 34.8 | 34.6 | 34.5 | 34.4 | 34.7 | 34.4 | 34.3 |
| | Oil Products | | Pure naphtha | $0420 | MJ/L | 33.6 | 33.6 | 33.6 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.3 | 33.3 | 33.3 | 33.3 | 33.3 | 33.3 |
| | | | Reformed feedstock Oil | $0421 | MJ/L | 35.1 | 35.1 | 35.1 | 35.1 | 35.1 | 35.1 | 35.1 | 35.1 | 33.7 | 33.7 | 33.7 | 33.7 | 33.7 | 33.7 |
| | | Fuel oil | Gasoline (crude oil origin)[1] | $0431 | MJ/L | 34.6 | 34.6 | 34.6 | 34.6 | 34.6 | 34.6 | 34.6 | 34.6 | 33.4 | 33.4 | 33.4 | 33.4 | 33.4 | 33.4 |
| | | | Gasoline (biofuel blended)[2] | | MJ/L | 34.6 | 34.6 | 34.6 | 34.6 | 34.6 | 34.5 | 34.5 | 34.5 | 33.3 | 33.3 | 33.2 | 33.2 | 33.2 | 33.2 |
| | | | Jet fuel oil | $0432 | MJ/L | 36.4 | 36.4 | 36.7 | 36.7 | 36.7 | 36.7 | 36.7 | 36.7 | 36.3 | 36.3 | 36.2 | 36.3 | 36.4 | 36.4 |
| | | | Kerosene | $0433 | MJ/L | 36.8 | 36.8 | 36.8 | 36.7 | 36.7 | 36.7 | 36.7 | 36.7 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 |
| | | | Gas oil or diesel oil (crude oil origin)[1] | $0434 | MJ/L | 38.1 | 38.1 | 38.2 | 37.8 | 37.9 | 38.1 | 38.0 | 37.9 | 38.0 | 38.0 | 38.0 | 38.0 | 38.0 | 38.0 |
| | | | Gas oil or diesel oil (biofuel blended)[2] | | MJ/L | 38.1 | 38.1 | 38.2 | 37.8 | 37.9 | 38.1 | 38.0 | 37.9 | 38.0 | 38.0 | 38.0 | 38.0 | 38.0 | 38.0 |
| | | | Fuel oil A | $0436 | MJ/L | 39.7 | 39.6 | 39.3 | 39.1 | 39.9 | 39.9 | 39.8 | 39.8 | 38.9 | 38.9 | 38.9 | 38.9 | 38.9 | 38.9 |
| | | | Fuel oil C | $0437 | MJ/L | 40.2 | 40.3 | 40.3 | 40.3 | 40.4 | 40.4 | 40.0 | 40.6 | 41.2 | 40.9 | 41.4 | 41.0 | 41.0 | 41.1 |
| | | | Fuel oil B | $0438 | MJ/L | 40.2 | 40.2 | 40.4 | 40.4 | 40.4 | 40.4 | 40.4 | 40.4 | 40.4 | 40.4 | 40.4 | 40.4 | 40.4 | 40.4 |
| | | | Fuel oil C for general use | $0439 | MJ/L | 40.2 | 40.3 | 40.3 | 40.3 | 40.4 | 40.4 | 40.0 | 40.6 | 41.2 | 40.9 | 41.4 | 41.0 | 41.0 | 41.1 |
| | | | Fuel oil C for power generation use | $0440 | MJ/L | 41.1 | 41.1 | 41.3 | 41.2 | 41.2 | 41.3 | 41.2 | 41.2 | 41.2 | 41.4 | 41.0 | 41.5 | 41.6 | 41.6 |
| | | Miscellaneous oil products | Lubricant oil | $0451 | MJ/L | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 |
| | | | Other heavy oil products | $0452 | MJ/kg | 39.2 | 39.3 | 39.4 | 39.4 | 39.5 | 39.4 | 39.0 | 39.6 | 40.2 | 39.9 | 40.4 | 40.0 | 40.0 | 40.1 |
| | | | Oil coke | $0455 | MJ/kg | 35.6 | 35.6 | 35.6 | 29.9 | 29.9 | 29.9 | 29.9 | 29.9 | 33.3 | 33.3 | 33.3 | 33.3 | 33.3 | 33.3 |
| | | | Galvanic furnace gas | $0456 | MJ/m$^3$ | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |
| | | | Refinery gas | $0457 | MJ/m$^3$ | 39.3 | 39.3 | 44.9 | 44.9 | 44.9 | 44.9 | 44.9 | 44.9 | 46.1 | 46.1 | 46.1 | 46.1 | 46.1 | 46.1 |
| | | | Liquefied petroleum gas (LPG) | $0458 | MJ/kg | 50.5 | 50.6 | 50.7 | 50.7 | 50.7 | 50.8 | 50.8 | 50.8 | 50.1 | 50.1 | 50.1 | 50.1 | 50.1 | 50.1 |
| Gaseous fuels | Natural Gas | | Liquefied natural gas (LNG) | $0510 | MJ/kg | 54.5 | 54.5 | 54.5 | 54.5 | 54.5 | 54.5 | 54.5 | 54.5 | 54.5 | 54.5 | 54.5 | 54.5 | 54.5 | 54.7 |
| | | | Indigenous natural gas | $0520 | MJ/m$^3$ | 42.1 | 42.4 | 42.6 | 42.9 | 44.8 | 44.7 | 44.7 | 44.8 | 39.6 | 39.6 | 39.6 | 39.6 | 39.6 | 38.4 |
| | | | Indigenous natural gas | $0521 | MJ/m$^3$ | 42.1 | 42.4 | 42.6 | 42.9 | 44.8 | 44.7 | 44.7 | 44.8 | 39.6 | 39.6 | 39.6 | 39.6 | 39.6 | 38.4 |
| | | | Coal mining gas | $0522 | MJ/m$^3$ | 36.0 | 36.0 | 16.7 | 16.7 | 16.7 | 16.7 | 16.7 | 16.7 | 15.1 | 15.1 | 15.1 | 15.1 | 15.1 | 15.1 |
| | | | Boil off gas from crude oil | $0523 | MJ/m$^3$ | 42.1 | 42.4 | 42.6 | 42.9 | 44.8 | 44.7 | 44.7 | 44.8 | 39.6 | 39.6 | 39.6 | 39.6 | 39.6 | 38.4 |
| | City gas | | City gas | $0610 | MJ/m$^3$ | 41.9 | 41.9 | 41.1 | 44.8 | 44.8 | 44.8 | 44.8 | 44.8 | 40.8 | 40.8 | 40.7 | 40.7 | 40.8 | 40.0 |
| | | | Small scale community gas | $0620 | MJ/m$^3$ | 105.4 | 103.6 | 102.3 | 101.5 | 102.0 | 101.1 | 101.2 | 101.0 | 96.0 | 95.7 | 95.3 | 95.3 | 95.0 | 94.8 |
| (Reference) | Biomass | | Woods | $N131 | MJ/kg | 15.4 | 15.4 | 15.4 | 19.9 | 18.6 | 17.4 | 17.7 | 17.9 | 17.6 | 17.2 | 17.0 | 13.1 | 12.9 | 13.6 |
| | | | Waste woods | $N132 | MJ/kg | 16.7 | 16.7 | 16.7 | 16.3 | 16.3 | 16.3 | 16.3 | 16.3 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 |
| | | | Bioethanol | $N134 | MJ/L | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.4 | 23.4 | 23.4 | 23.4 | 23.4 | 23.4 |
| | | | Biodiesel | $N135 | MJ/L | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.4 | 23.4 | 23.4 | 23.4 | 23.4 | 23.4 |
| | | | Thermal use of black liquor | $N136 | MJ/kg | 12.6 | 12.6 | 12.6 | 13.2 | 13.2 | 13.2 | 13.2 | 13.2 | 13.6 | 13.6 | 13.6 | 13.6 | 13.6 | 13.6 |
| | | | Gas biomass | $N137 | MJ/m$^3$ | 23.4 | 23.4 | 23.4 | 23.4 | 23.4 | 23.4 | 23.4 | 23.4 | 21.2 | 21.2 | 21.2 | 21.2 | 21.2 | 21.2 |

1) Used in the reference approach.

2) Used in the sectoral approach.

3) Until FY2012, in principle, the values of gases are indicated at 0°C and 1 atmosphere (normal condition), those of liquids are indicated at normal temperature, those of solids are indicated "with moisture and ash" state. After FY2013, in principle, the values of gases and liquids are indicated at 25°C and 1bar (standard ambient temperature and pressure (SATP)), and those of solids are indicated "with moisture and ash" state.

### c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties of emission factors are set by the upper and lower limits of 95% confidence intervals derived from the actual measurements of carbon emission factors. The upper and lower limits of uncertainties of activity data are set by the standard deviations of the statistical discrepancies [#400000] divided by domestic primary energy supply [#190000] from 1990 to 2017 for solid, liquid and gaseous fuels respectively, taking account of difficulty to set the uncertainties of energy consumption by each fuel and sector from the *General Energy Statistics*, or the reference of activity data. As a result, the uncertainty was determined to be −4% to +2% for $CO_2$ emissions from combustion of solid, liquid and gaseous fuels as a whole for the fuel combustion category. See section 7.4.3 for the uncertainty of $CO_2$ emissions from waste incineration for energy purposes and with energy recovery.

- ***Time-series Consistency***

The emissions were calculated in a consistent manner in all time-series.

The carbon emission factors of all energy sources have been calculated by a consistent estimation method in all time-series.

The activity data was used from data in the *General Energy Statistics* in all time-series, and the statistics were made by a consistent estimation method in all time-series.

The fossil fuel consumption of “Production, Transmission and Distribution of Electricity” [#255330] under “Auto power production” of the *General Energy Statistics* for the period of FY1990 through FY2015 are included in the activity data of Public electricity and heat production subcategory (1.A.1.a) in light of time-series consistency. See the Activity Data section under 3.2.4. b).

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### e) Category-specific Recalculations

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2013-FY2017 years were recalculated.

The amount $CO_2$ captured in 2017 was updated.

Updating the statistical data and improving the estimation methodology in the waste sector, $CO_2$ emissions from other fossil fuels for the period of FY2005-FY2017 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

It is necessary to consider the development of the carbon emission factor of petroleum coke with the sufficient number of samples because the number of samples are insufficient to reflect Japan’s circumstances during the development work of the calorific values and the carbon emission factors.

### 3.2.5. $CH_4$ and $N_2O$ Emissions from Energy Industries (1.A.1.: $CH_4$, $N_2O$)

#### *a) Category Description*

This section provides the methods for estimating $CH_4$ and $N_2O$ emissions from public electricity and heat production (1.A.1.a), petroleum refining (1.A.1.b), and manufacture of solid fuels and other energy industries (1.A.1.c).

$CH_4$ is generated as a result of incomplete combustion, and as such, if sufficient care is taken to ensure complete combustion, $CH_4$ will not be generated. $N_2O$ is generated through the reaction of NO, which is generated by combustion, with nitrogen-containing volatile components in fuels. Consequently, the higher the nitrogen content of the fuel used, the more likely it is that $N_2O$ will be generated. However, the reaction that produces $N_2O$ is also dependent on temperature, with $N_2O$ more likely to be generated at lower temperatures. More $N_2O$ will accordingly be generated by furnaces such as fluidized bed boilers that burn fuel at low temperatures (800–900°C). $N_2O$ can also be generated when $NO_X$ contacts catalysts for $NO_X$ removal.

The contribution of $CH_4$ and $N_2O$ emissions from this category relative to total GHG emissions is small in Japan. The $N_2O$ emissions from fluidized bed boilers are relatively large in this category. The $N_2O$ emissions from fluidized bed boilers contribute to the increase of GHG emissions from this category, since fluidized bed boilers have been introduced in Japan from 1990.

The $N_2O$ emissions from solid fuel in 1.A.1.a (Public electricity and heat production) increased between FY1994 and FY1995. The reason for the increase was that a new large sized fluidized-bed boiler for power generation was introduced in FY1995. As a result, the solid fuel consumption of fluidized-bed boilers for public power generation increased in FY1995, resulting in an increase of $N_2O$ emissions from solid fuels in this category.

$CH_4$ emitted in coke production is reported in this category. We have no measurements of the concentration of $N_2O$ in the gas leaking from coking furnace lids, but we decided that $N_2O$ emissions from this source are not applicable the reason being that experts say that $N_2O$ is likely not produced because the atmosphere in a coke oven is normally at least 1,000°C, and is reducing.

#### *b) Methodological Issues*

- ***Estimation Method***

➢ *Furnaces*

Because it is possible to use fuel-specific, sector-specific and furnace-specific activity data, and also to set country-specific emission factors by furnace, $CH_4$ and $N_2O$ emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2).

The estimation equation is as follows. The emissions were calculated by multiplying fuel-specific, furnace-specific and sector-specific activity data by fuel-specific and furnace-specific emission factors.

$$E = \sum_{ij} \left( EF_{ij} \times A_{ijk} \right)$$

$E$ : Emissions from combustion of fuel by stationary sources [kg-$CH_4$, kg-$N_2O$]
$EF_{ij}$ : Emission factor for fuel type $i$, furnace type $j$ [kg-$CH_4$/TJ, kg-$N_2O$/TJ]

$A_{ijk}$ : Fuel consumption for fuel type *i*, furnace type *j*, sector *k* [TJ]
*i* : Fuel type
*j* : Furnace type
*k* : Sector

➢ *Biomass boilers*

Because it is possible to use country-specific emission factors of power generation facility and heat utilization facility, $CH_4$ and $N_2O$ emissions from combustion in biomass boilers are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). However, $CH_4$ and $N_2O$ emissions of gas biomass are calculated by using Tier 1, as country-specific emission factors are not available.

➢ *Coke Production*

$CH_4$ emissions from coke production were calculated by multiplying coke production amount by Japan's country-specific emission factor, based on the method given in the *2006 IPCC Guidelines*.

➢ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3

● ***Emission Factors***

➢ *Furnaces*

Chimney flue $CH_4$, $N_2O$ and $O_2$ concentrations, theoretical (dry) exhaust gas volumes, theoretical air volumes, and higher heating values (gross calorific values (GCV)) shown in Table 3-21 were employed based on data obtained from surveys conducted in Japan (Table 3-22) to establish emission factors for each kind of facility using the following combustion calculation formula.

$$EF = C_{CH_4,N_2O} \times \{G_0' + (m-1) \times A_0\} \times MW/V_m/GCV$$

| | | |
|---|---|---|
| $EF$ | : | Emission factor [kg-$CH_4$/TJ, kg-$N_2O$/TJ] |
| $C_{CH4\ or\ N2O}$ | : | $CH_4$ or $N_2O$ concentration in exhaust gas [ppm] |
| $G_0$' | : | Theoretical exhaust gas volume for each fuel combustion (dry) [$m^3N$/ original unit] |
| $A_0$ | : | Theoretical air volume for each fuel combustion [$m^3N$/ original unit] |
| $m$ | : | Air ratio = actual air volume/ theoretical air volume [-] |
| $MW$ | : | Molecular weight of $CH_4$(constant)=16 [g/mol]<br>Molecular weight of $N_2O$(constant)=44 [g/mol] |
| $V_m$ | : | One mole ideal gas volume in standardized condition (constant)<br>=22.4 [$10^{-3}m^3$/mol] |
| $GCV$ | : | Gross calorific value for each fuel combustion [MJ/ original unit] |

However, the air ratio "*m*" is approximately provided with $O_2$ concentration in exhaust gas, as shown in the equation below.

$$m = \frac{21}{21 - C_{O_2}}$$

$C_{O_2}$ : $O_2$ concentration in exhaust gas [%]

$CH_4$ and $N_2O$ emission factors by each fuel and furnace types were averaged after dividing the emission factor of each kind of facilities according to fuel and furnace types (Table 3-23, Table 3-24). Anomalous values were excluded according to t-testing or expert judgment when calculating the average values. Please refer to MOE (2006a) for the actual measurement data to establish the emission factors.

- ***Emission Factors with Air-Intake Adjustment***

In Japan, until the GHG inventory was submitted in 2005, based on the results of past discussions (e.g., Japan Society for Atmospheric Environment (1997) relating to methodologies for calculating emissions, the non-$CO_2$ emission factors from stationary combustion were established after accounting for the differences between emission gas concentrations and intake gas concentrations (i.e., air-intake adjustment). With this methodology, it was possible to obtain negative emission factors for some emission sources if the measurement data showed that concentrations in emission gas were lower than those in intake gas, possibly because $CH_4$ and $N_2O$ present in the intake gas had been either oxidized or decomposed through the combustion process.

However, during the in-country review that was conducted in 2003, the Expert Review Team recommended Japan to replace negative emission factors by the corresponding positive ones, because, in the interest of enabling better international comparisons, the *Revised 1996 IPCC Guidelines* as well as *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (hereinafter referred to as *GPG (2000)*) indicate that positive emission factors should be used for calculations of emissions based on actual emissions of $CH_4$ and $N_2O$ in the flue gases, though air-intake adjustments might enable accurate determination of emissions. Thus, in the inventories submitted in 2006 and thereafter, the air-intake adjustments were not made, and emission factors were determined by using the actual measured $CH_4$ and $N_2O$ concentrations in emission gases.

Table 3-21 Theoretical exhaust gas and air volumes, and higher heating values for different fuels

| Fuel type | Original unit | Theoretical exhaust gas volume (dry) $G_0$' [1)] | Higher heating value $GCV$ [2)] | Theoretical air volume $A_0$ [1)] | Remarks |
|---|---|---|---|---|---|
| | | $m^3N$/L, kg, $m^3N$ | kJ/L, kg, $m^3N$, kWh | $m^3N$/L, kg, $m^3N$ | |
| Fuel oil A | L | 8.900 | 39,100 | 9.500 | a |
| Fuel oil B | L | 9.300 | 40,400 | 9.900 | a |
| Fuel oil C | L | 9.500 | 41,700 | 10.100 | a |
| Diesel oil | L | 8.800 | 38,200 | 9.400 | a |
| Kerosene | L | 8.400 | 36,700 | 9.100 | a |
| Crude oil | L | 8.747 | 38,200 | 9.340 | a |
| Naphtha | L | 7.550 | 34,100 | 8.400 | a |
| Other liquid fuels | L | 9.288 | 37,850 | 9.687 | b |
| Other liquid fuels (heavy) | L | 9.064 | 37,674 | 9.453 | b |
| Other liquid fuels (light) | L | 9.419 | 35,761 | 9.824 | b |
| Steam coal | kg | 7.210 | 26,600 | 7.800 | a |
| Coke | kg | 7.220 | 30,100 | 7.300 | a |
| Harvested wood | kg | 3.450 | 14,367 | 3.720 | b |
| Charcoal | kg | 7.600 | 30,500 | 7.730 | c |
| Other solid fuels | kg | 7.000 | 33,141 | 7.000 | b |
| City gas | $m^3$ | 9.850 | 46,047 | 10.949 | b |
| Coke oven gas (COG) | $m^3$ | 4.500 | 21,100 | 4.800 | a |
| Blast furnace gas (BFG) | $m^3$ | 1.460 | 3,410 | 0.626 | a |
| Liquefied natural gas (LNG) | kg | 11.766 | 54,500 | 13.093 | a |
| Liquefied petroleum gas (LPG) | kg | 11.051 | 50,200 | 12.045 | a |
| Converter furnace gas (CFG) (Linz-Donawitz gas: LDG) | $m^3$ | 2.200 | 8,410 | 1.500 | a |
| Refinery gas (off-gas) | $m^3$ | 11.200 | 44,900 | 12.400 | a |
| Other gaseous fuels | $m^3$ | 4.587 | 28,465 | 4.096 | b |
| Other gaseous fuels (petroleum) | $m^3$ | 7.889 | 40,307 | 7.045 | b |
| Other gaseous fuels (steel) | $m^3$ | 2.812 | 19,097 | 2.511 | b |
| Other gaseous fuels (mining) | $m^3$ | 3.396 | 38,177 | 3.032 | b |
| Other gaseous fuels (other) | $m^3$ | 4.839 | 23,400 | 4.321 | b |
| Pulping waste liquor | kg | 3.245 | 13,898 | 3.499 | b |
| Electricity | kWh | | 3,600 | | a |

Note:

1) Theoretical exhaust gas and air volumes are the standard values given in the *General Survey of the Emissions of Air Pollutants* (MOE), except for city gas, LNG, and LPG, for which values calculated from constituent data were used. For city gas, the constituents of city gas 13A were considered to be representative.
2) Regarding higher heating value, the standard calorific values given in the *General Energy Statistics* were used for items marked a, and the standard values given in *General Survey of the Emissions of Air Pollutants* (based on the 1992 survey) for items marked b in the Remarks column. The higher heating value for steam coal (imported) was used as the higher heating value of steam coal. The item marked c in the Remarks column was set by the 2005 Committee for the Greenhouse Gases Emissions Estimation Methods based on reference materials.

Table 3-22 References for measurement data used in the establishment of emission factors

| | References |
|---|---|
| 1 | Hokkaido Prefecture, Report of GHG Emissions Intensity from Stationary Combustion, 1991 |
| 2 | Hyogo Prefecture, Report of GHG Emissions Intensity from Stationary Combustion, 1991 |
| 3 | Osaka Prefecture, Study of GHG Emissions Intensity from Stationary Combustion, 1991 |
| 4 | Hokkaido Prefecture, Report of GHG Emissions Intensity from Stationary Combustion, 1992 |
| 5 | Hyogo Prefecture, Report of GHG Emissions Intensity from Stationary Combustion, 1992 |
| 6 | City of Kitakyushu, Report of GHG Emissions Intensity from Stationary Combustion, 1992 |
| 7 | Hyogo Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1993 |
| 8 | Hyogo Prefecture, Report of GHG Emissions Intensity from Stationary Combustion, 1994 |
| 9 | Kanagawa Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1995 |
| 10 | Niigata Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1995 |
| 11 | Osaka Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1995 |
| 12 | Hiroshima Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1995 |
| 13 | Fukuoka Prefecture, Report of GHG Emission Factors from Stationary Combustion, 1995 |
| 14 | City of Osaka, Study of GHG Emission Factors from Stationary Combustion, 1995 |
| 15 | City of Kobe, Study of GHG Emission Factors from Stationary Combustion, 1995 |
| 16 | Hokkaido Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1996 |
| 17 | Ishikawa Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1996 |
| 18 | Kyoto Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1996 |
| 19 | Osaka Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1996 |
| 20 | Hyogo Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1996 |
| 21 | Hiroshima Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1996 |
| 22 | Fukuoka Prefecture, Report of GHG Emission Factors from Stationary Combustion, 1996 |
| 23 | Kyoto Prefecture, Report of GHG Emission Factors from Stationary Combustion, 1997 |
| 24 | Hyogo Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1997 |
| 25 | Fukuoka Prefecture, Report of GHG Emission Factors from Stationary Combustion, 1997 |
| 26 | Japan Society for Atmospheric Environment, Report on Emission Factor Results for Combustion Facilities, 1997 |
| 27 | Osaka Prefecture, Study of GHG Emission Factors from Stationary Combustion, 1999 |
| 28 | Hyogo Prefecture, Report of GHG Emission Factors from Stationary Combustion, 2000 |
| 29 | The Institute of Applied Energy, Report for Trend of Fuel Quality in Lowering Environmental Atmospheric Quality, 2000 |
| 30 | MOE, Measurement Data prepared by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY1999, 1999 |
| 31 | Data prepared by the Federation of Electric Power Companies of Japan |
| 32 | IPCC, 2006 IPCC Guidelines, 2006 |
| 33 | Forestry Agency Wood Use Promotion Division, Promotion of Wood Use and Energy-saving and $CO_2$ Reduction Demonstration Project Fiscal Year 2014, 2015 |
| 34 | MOE, Survey on Grasp of the Actual Condition of Greenhouse Gas Emissions from Biomass Boilers Fiscal Year 2017, 2018 |

Table 3-23 $CH_4$ emission factors for different fuels and furnaces in GCV basis (unit: kg-$CH_4$/TJ)

| Fuel | | | Code | Boilers | Industrial furnaces | | | | | | | | | | Internal combustion engines | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Boiler | Sintering furnace for smelting of metals (except copper, lead, and zinc) | Pelletizing furnace (steel and non-ferrous metal) | Blast furnace, converter furnace and open-hearth furnace (steel and non-ferrous metal) | Metal rolling furnace, metal treating furnace, metal forging furnace | Petroleum and gas furnaces | Catalytic regenerator | Brick kiln, ceramic kiln, and other kiln | Aggregate drying kiln, cement raw material drying kiln, brick raw material drying kiln | Other drying kilns | Other industrial furnaces | Gas turbine | Diesel engine | Gas engine, petrol engine |
| Coal | Steel Making Coal | | $0110 | 0.13 | 31 | 1.7 | NA | 13 | 13 | NA | 1.5 | 29 | 6.6 | 13 | NA | NA | NA |
| | Coking Coal | | $0111 | | | | | | | | | | | | | | |
| | Pulverized Coal Injection Coal | | $0112 | | | | | | | | | | | | | | |
| | Imported Steam Coal | | $0121 | | | | | | | | | | | | | | |
| | Imported Coal for General Use | | $0122 | | | | | | | | | | | | | | |
| | Imported Coal for Power Generation | | $0123 | | | | | | | | | | | | | | |
| | Indigenous Produced Steam Coal | | $0124 | | | | | | | | | | | | | | |
| | Hard Coal, Anthracite & Lignite | | $0130 | | | | | | | | | | | | | | |
| Coal Products | Coke | | $0211 | 0.13 | 31 | 1.7 | NA | 13 | 13 | 0.054 | 1.5 | 29 | 6.6 | 13 | NA | NA | NA |
| | Coal Tar | | $0212 | | | | | | | | | | | | | | |
| | Coal Briquette | | $0213 | | | | | | | | | | | | | | |
| | Coke Oven Gas | | $0221 | 0.23 | | | | 0.43 | 0.16 | NA | | | | 2.3 | 0.81 | 0.70 | 54 |
| | Blast Furnace Gas | | $0222 | | | | | | | | | | | | | | |
| | Converter Furnace Gas | | $0225 | | | | | | | | | | | | | | |
| Oil | Crude Oil for Refinery | | $0310 | 0.10 | 31 | 1.7 | NA | 0.43 | 0.16 | NA | 1.5 | 29 | 6.6 | 0.83 | 0.81 | 0.70 | 54 |
| | Crude Oil for Power Generation | | $0320 | | | | | | | | | | | | | | |
| | Bituminous Mixture Fuel | | $0321 | | | | | | | | | | | | | | |
| | Natural Gas Liquid & Condensate | | $0330 | | | | | | | | | | | | | | |
| Oil Products | Pure Naphtha | | $0420 | 0.26 | 31 | 1.7 | NA | 0.43 | 0.16 | NA | 1.5 | 29 | 6.6 | 0.83 | 0.81 | 0.70 | 54 |
| | Reformed Feedstock Oil | | $0421 | | | | | | | | | | | | | | |
| | Gasoline | | $0431 | | | | | | | | | | | | | | |
| | Jet Fuel Oil | | $0432 | | | | | | | | | | | | | | |
| | Kerosene | | $0433 | | | | | | | | | | | | | | |
| | Gas Oil / Diesel Oil | | $0434 | | | | | | | | | | | | | | |
| | Fuel Oil A | | $0436 | | | | | | | | | | | | | | |
| | Fuel Oil C | | $0437 | 0.10 | | | | | | | | | | | | | |
| | Fuel Oil B | | $0438 | | | | | | | | | | | | | | |
| | Fuel Oil C for General Use | | $0439 | | | | | | | | | | | | | | |
| | Fuel Oil C for Power Generation | | $0440 | | | | | | | | | | | | | | |
| | Lublicant Oil | | $0451 | 0.26 | | | | | | | | | | | | | |
| | Other Heavy Oil Products | | $0452 | 0.13 | | | | 13 | 13 | 0.054 | | | | 13 | NA | NA | NA |
| | Petroleum Coke | | $0455 | | | | | | | | | | | | | | |
| | Galvanic Furnace Gas | | $0456 | 0.23 | | | | 0.43 | 0.16 | NA | | | | 2.3 | 0.81 | 0.70 | 54 |
| | Refinary Gas | | $0457 | | | | | | | | | | | | | | |
| | Liquified Petroleum Gas | | $0458 | | | | | | | | | | | | | | |
| Natural Gas | Liquefied Natural Gas | | $0510 | 0.23 | 31 | 1.70 | NA | 0.43 | 0.16 | NA | 1.5 | 29 | 6.62 | 2.29 | 0.81 | 0.70 | 54 |
| | Indigenous Natural Gas | | $0520 | | | | | | | | | | | | | | |
| | Indigenous Natural Gas | | $0521 | | | | | | | | | | | | | | |
| | Coal Mining Gas | | $0522 | | | | | | | | | | | | | | |
| | Boil Off Gas from Crude Oil | | $0523 | | | | | | | | | | | | | | |
| City Gas | City Gas | | $0610 | 0.23 | 31 | 1.7 | NA | 0.43 | 0.16 | NA | 1.5 | 29 | 6.6 | 2.3 | 0.81 | 0.70 | 54 |
| | Small Scale Community Gas | | $0620 | | | | | | | | | | | | | | |
| Biomass Energy | Woods | Power generation | $N131 | 0.2 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | | Heat utilization | | 16 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Waste Wood | Power generation | $N132 | 0.2 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | | Heat utilization | | 16 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Thermal Use of Black Liquor | | $N136 | 4.3 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Gas Biomass | | $N137 | 0.9 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Non Specified | Power generation | $N138 | 16 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

Table 3-24 $N_2O$ emission factors for different fuels and furnaces in GCV basis (unit: kg-$N_2O$/TJ)

| Fuel | | | Code | Boilers | | | Industrial furnaces | | | | | Internal-combustion engines | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Boiler (other than fluidized-bed boiler) | Normal pressure fluidized-bed boiler | Pressurized fluidized-bed boiler | Blast furnace | Petroleum and gas furnaces | Catalytic regenerator | Coke oven | Other industrial furnace | Gas turbine | Diesel engine | Gas engine, petrol engine |
| Coal | Steel Making Coal | | $0110 | 0.85 | 54 | 0.85 | NA | 1.1 | NA | NA | 1.1 | NA | NA | NA |
| | Coking Coal | | $0111 | | | | | | | | | | | |
| | Pulverized Coal Injection Coal | | $0112 | | | | | | | | | | | |
| | Imoorted Steam Coal | | $0121 | | | 5.2 | | | | | | | | |
| | Imported Coal for General Use | | $0122 | | | | | | | | | | | |
| | Imported Coal for Power Generation | | $0123 | | | | | | | | | | | |
| | Indigenous Produced Steam Coal | | $0124 | | | | | | | | | | | |
| | Hard Coal, Anthracite & Lignite | | $0130 | | | 0.85 | | | | | | | | |
| Coal Products | Coke | | $0211 | 0.85 | 54 | 0.85 | NA | 1.1 | 7.3 | NA | 1.1 | NA | NA | NA |
| | Coal Tar | | $0212 | | | | | | | | | | | |
| | Coal Briquette | | $0213 | | | | | | | | | | | |
| | Coke Oven Gas | | $0221 | 0.17 | 0.17 | 0.17 | 0.047 | 0.21 | NA | 0.14 | 1.2 | 0.58 | 2.2 | 0.85 |
| | Blast Furnace Gas | | $0222 | | | | NA | | | | | | | |
| | Converter Furnace Gas | | $0225 | | | | | | | | | | | |
| Oil | Crude Oil for Refinery | | $0310 | 0.22 | 0.22 | 0.22 | NA | 0.21 | NA | NA | 1.8 | 0.58 | 2.2 | 0.85 |
| | Crude Oil for Power Generation | | $0320 | | | | | | | | | | | |
| | Bituminous Mixture Fuel | | $0321 | | | | | | | | | | | |
| | Natural Gas Liquid & Condensate | | $0330 | | | | | | | | | | | |
| Oil Products | Pure Naphtha | | $0420 | 0.19 | 0.19 | 0.19 | NA | 0.21 | NA | NA | 1.8 | 0.58 | 2.2 | 0.85 |
| | Reformed Feedstock Oil | | $0421 | | | | | | | | | | | |
| | Gasoline | | $0431 | | | | | | | | | | | |
| | Jet Fuel Oil | | $0432 | | | | | | | | | | | |
| | Kerosene | | $0433 | | | | | | | | | | | |
| | Gas Oil / Diesel Oil | | $0434 | | | | | | | | | | | |
| | Fuel Oil A | | $0436 | | | | | | | | | | | |
| | Fuel Oil C | | $0437 | 0.22 | 0.22 | 0.22 | | | | | | | | |
| | Fuel Oil B | | $0438 | | | | | | | | | | | |
| | Fuel Oil C for General Use | | $0439 | | | | | | | | | | | |
| | Fuel Oil C for Power Generation | | $0440 | | | | | | | | | | | |
| | Lublicant Oil | | $0451 | 0.19 | 0.19 | 0.19 | | | | | | | | |
| | Other Heavy Oil Products | | $0452 | 0.85 | 54 | 0.85 | | 1.15 | 7.3 | | 1.1 | NA | NA | NA |
| | Petroleum Coke | | $0455 | | | | | | | | | | | |
| | Galvanic Furnace Gas | | $0456 | 0.17 | 0.17 | 0.17 | | 0.21 | NA | 0.14 | 1.2 | 0.58 | 2.2 | 0.85 |
| | Refinary Gas | | $0457 | | | | | | | | | | | |
| | Liquified Petroleum Gas | | $0458 | | | | | | | NA | | | | |
| Natural Gas | Liquefied Natural Gas | | $0510 | 0.17 | 0.17 | 0.17 | NA | 0.21 | NA | NA | 1.2 | 0.58 | 2.2 | 0.85 |
| | Indigenous Natural Gas | | $0520 | | | | | | | 0.14 | | | | |
| | Indigenous Natural Gas | | $0521 | | | | | | | | | | | |
| | Coal Mining Gas | | $0522 | | | | | | | | | | | |
| | Boil Off Gas from Crude Oil | | $0523 | | | | | | | | | | | |
| City Gas | City Gas | | $0610 | 0.17 | 0.17 | 0.17 | NA | 0.21 | NA | 0.14 | 1.2 | 0.58 | 2.2 | 0.85 |
| | Small Scale Community Gas | | $0620 | | | | | | | | | | | |
| Biomass Energy | Woods | Power generation | $N131 | 0.87 | 0.87 | 0.87 | NA | NA | NA | NA | NA | NA | NA | NA |
| | | Heat utilization | | 1.60 | 1.60 | 1.60 | NA | NA | NA | NA | NA | NA | NA | NA |
| | Waste Wood | Power generation | $N132 | 0.87 | 0.87 | 0.87 | NA | NA | NA | NA | NA | NA | NA | NA |
| | | Heat utilization | | 1.60 | 1.60 | 1.60 | NA | NA | NA | NA | NA | NA | NA | NA |
| | Thermal Use of Black Liquor | | $N136 | 0.17 | 0.17 | 0.17 | NA | NA | NA | NA | NA | NA | NA | NA |
| | Gas Biomass | | $N137 | 0.09 | 0.09 | 0.09 | NA | NA | NA | NA | NA | NA | NA | NA |
| | Non Specified | | $N138 | 1.60 | 1.60 | 1.60 | NA | NA | NA | NA | NA | NA | NA | NA |

➢ *Biomass boilers*

$CH_4$ and $N_2O$ emission factors by each fuel and each faciliy in biomass boilers are shown in Table 3-23 and Table 3-24.

The country-specific emission factors of woods, waste woods and non-specified biomass were established based on the actual measurements from MOE (2018) and Forestry Agency (2015), considering the utilization situation of woody biomass.

The emission factors of black liquor were established by using theoretical (dry) exhaust gas volumes, theoretical air volumes, and higher heating values shown in Table 3-21.

For the emission factors of gas biomass, the default values of the *2006 IPCC Guidelines* (Vol.2, page 2.16-2.23, table 2.2-2.5) were adopted. As the default values are based on net calorific values, they were converted to the GCV basis by multiplying them by 0.9 (for fuels with gaseous state) (*2006 IPCC Guidelines*, Vol.2, page 1.16).

➢ *Coke production*

$CH_4$ emissions from coke production come from two sources: $CH_4$ in combustion exhaust gas from gas leakage from the carbonization chamber to the combustion chamber, and $CH_4$ emitted from the coking furnace lid, the desulfurization tower, or the desulfurization recycling tower, in the carbonization process of coal.

- ***Combustion exhaust gas***

The concentration of $CH_4$ in the exhaust gas from coking furnaces operated by five companies at seven operating sites (surveyed by the Japan Iron and Steel Federation, actual results for FY1999) was weighted by the production amount of coke to derive a weighted average, which was established as the emission factor. The emission factor is 0.089 [kg-$CH_4$/t].

- ***Coking furnace lid, desulfurization tower, and desulfurization recycling tower***

The Japan Iron and Steel Federation has had a voluntary plan in place since fiscal year 1997 to manage noxious atmospheric pollutants, and $CH_4$ emissions have been estimated from emissions of other substances from the lid of coking furnaces. The emission factor has been established by taking a weighted average using this data and the amount of production of coke.

Table 3-25 Emission factor of $CH_4$ from coking furnace lids, desulfurization towers, and desulfurization recycling towers

| Item | Unit | 1990-1996 | 1997-1999 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ EFs | kg$CH_4$/t | 0.238 | 0.180 | 0.119 | 0.043 | 0.032 | 0.031 | 0.042 | 0.045 | 0.039 | 0.038 | 0.036 | 0.033 | 0.031 | 0.031 |

Reference: Japan Iron and Steel Federation data

Note: Emission factor change is assumed to be small for FY1990-1996. Therefore, actual data values for FY1995 is used for other years with no data. For FY1997-1999, it is assumed that values for 1998 and 1999 are the same as those of 1997. For FY2000 and on, actual data values are adopted.

- ***$CH_4$ emission factor for coke production***

The aforementioned Combustion Exhaust Gas and Coking Furnace Lids, Desulfurization Towers, and Desulfurization Recycling Towers have been added, and the resulting figure has been used as the emission factor.

- ***Activity Data***

➢ *Furnaces*

In the estimation of the activity data, data on the *General Survey of the Emissions of Air Pollutants* (see next page for the outline of this survey), which provides details of the fuel consumption for each type of furnace and fuel, and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries* (METI), *Structural Survey of Energy Consumption* (ANRE), *Electric Power Statistics* (ANRE), and *Current Survey of Production Concerning Gas Industry* (ANRE)) are used, because data on stationary combustion fuel consumption for each type of furnace are not available in the *General Energy Statistics*.

The fuel consumption by each sector (energy conversion, industry, commercial & others, and residential) for each type of fuels as presented in the *General Energy Statistics* was further divided among each furnace type proportionally to the fuel consumption ratio for each furnace type estimated from the *General Survey of the Emissions of Air Pollutants* and from fuel consumption statistics to obtain the activity data for each sector, each fuel type and each furnace type. However, because the data in the *General Survey of the Emissions of Air Pollutants* do not differentiate between pressurized fluidized-bed boilers, normal pressure fluidized-bed boilers, and other boilers, the fuel consumption of these fluidized-bed boilers is calculated separately. The fuel consumption data of pressurized fluidized-bed furnaces were provided by the Federation of Electric Power Companies. The fuel consumption data of normal pressure fluidized-bed furnaces were provided from companies which had past operation records of normal pressure fluidized-bed furnaces since 1990.

The data of solid fuel boilers excluding fluidized-bed furnaces were estimated by subtracting the data of fluidized-bed furnace from the data of whole solid fuel boilers.

The *General Survey of the Emissions of Air Pollutants* for all facilities emitting soot and smoke is exhaustively carried out approximately every three years. The fuel consumption ratio for each furnace type and each fiscal year is assumed as shown in Table 3-26.

Table 3-26 Setting method of fuel consumption ratio for each furnace type

| Fiscal year | Setting method |
|---|---|
| 1990 - 1991 | Set by linear interpolation using the FY1989 and FY1992 survey results |
| 1992 | FY1992 survey result is used |
| 1993 - 1994 | Set by linear interpolation using the FY1992 and FY1995 survey results |
| 1995 | FY1995 survey result is used |
| 1996 | FY1996 survey result is used |
| 1997 - 1998 | Set by linear interpolation using the FY1996 and FY1999 survey results |
| 1999 | FY1999 survey result is used |
| 2000 - 2007 | Set by linear interpolation using the FY1999 and FY2008 survey results |
| 2008 | FY2008 survey result is used |
| 2009 - 2010 | FY2008 survey result is intentionally used [1)] |
| 2011 | FY2011 survey result is used |
| 2012 - 2013 | Set by linear interpolation using the FY2011 and FY2014 survey results |
| 2014 | FY2014 survey result is used |
| 2015 - | FY2014 survey result is intentionally used |

Note:

1) The survey result of FY2011 is quite different from that of FY2008 because of the influence of the Great East Japan Earthquake which occurred on March 2011, thus the FY2008 data is intentionally used without interpolation.

The procedure for calculating activity data is as follows:

1) Fuel consumption data from the *General Survey of the Emissions of Air Pollutants* is collated respectively for each fuel type, furnace type and sector.

2) The percentage of fuel consumption accounted for by each furnace type is calculated for each fuel type and sector.

3) Fuel consumption for different fuel types and sectors provided in the *General Energy Statistics* is multiplied by the percentage calculated in (2) to obtain fuel-specific, furnace-specific, and sector-specific activity data.

$$A_{ijk} = A_{EB_{ik}} \times w_{ijk}$$

$$w_{ijk} = A_{MAP_{ijk}} / \sum_{m} A_{MAP_{ijk}}$$

$A_{EBik}$ : Fuel consumption for fuel type *i*, sector *k* from the *General Energy Statistics* [TJ]
$w_{ijk}$ : Ratio of furnace type *j* associated with consumption of fuel type *i* in sector *k*
*i* : Fuel type
*j* : Furnace type
*k* : Sector
$A_{MAPijk}$ : Fuel consumption for fuel type *i*, furnace type *j*, sector *k* according to the *General Survey of the Emissions of Air Pollutants* [TJ]

- ***Outline of the General Survey of the Emissions of Air Pollutants***

The *General Survey of the Emissions of Air Pollutants* is a statistical survey conducted to (1) promote a reasonable and effective atmospheric environmental policy, (2) obtain information on current activities within the context of the Air Pollutant Control Law (e.g., the current status of regulation of stationary sources that emit soot and smoke in facilities registered to a local government and in facilities emitting ordinary soot or particular soot, and the current status of air pollutant control), (3) develop the submitted data on facilities emitting soot and smoke, and (4) estimate the amounts of air pollutant emissions from facilities that emit soot and smoke. This survey is conducted in the form of questionnaires. The response sheets and this survey's explanations are distributed to the target facilities mentioned above.

- ***Influence of Great East Japan Earthquake on Fuel Consumption Ratio by Furnace Type***

The Great East Japan Earthquake which occurred on March 2011 largely influences the result of the *General Survey of the Emissions of Air Pollutants* in FY2011. It leads to the fluctuation of the fuel consumption ratio by furnace type in some categories in the previous and following fiscal years.

In the recommendation by UNFCCC inventory review on Japan's inventory submission in 2018 (FCCC/ARR/2018/JPN, paragraph E.12), the ERT noted that the IEFs of gaseous fuels for oil refinery category (1.A.1.b) largely reduced in $CH_4$ emissions from FY2010 (6.32 kg/TJ) to FY2011 (0.28 kg/TJ) and also in $N_2O$ emissions from FY2010 (0.42 kg/TJ) to FY2011 (0.20 kg/TJ). This is because the fuel consumption ratio by furnace type in this survey has been reflected in the activity data, and the gaseous fuel consumption by the furnaces with high emission factors such as "Gas Engine" ($CH_4$ EF: 54 kg/TJ, $N_2O$ EF: 0.85 kg/TJ) and "Other Industrial Furnaces" ($CH_4$ EF: 2.29 kg/TJ, $N_2O$ EF: 1.2 kg/TJ) is significantly reduced from FY2010 to FY2011.

On the other hand, in the same recommendation, the ERT also pointed out that the recalculated IEFs of gaseous fuels for the same category submitted in 2018 are larger than those in 2017 for FY2012-2015. Specifically, the $CH_4$ IEFs increased by 15.3% in FY2012, by 33.9% in FY2013, by 50.7% in FY2014 and by 36.5% in FY2015 respectively, and the $N_2O$ IEFs increased by 15.1% in FY2012, by 33.0% in

FY2013, by 49.4% in FY2014 and by 37.6% in FY2015 respectively. This is because, on the contrary to the former case, the fuel consumption ratio by furnace type in the *General Survey of the Emissions of Air Pollutants* in FY2014 has been adopted to the inventory in the same fiscal year. In FY2014 survey, the consumption of some gaseous fuels by furnaces with high emission factors such as "Gas Turbine" ($CH_4$ EF: 0.81 kg/TJ, $N_2O$ EF: 0.58 kg/TJ) and "Other Industrial Furnaces" (see above for EFs) have significantly increased from the FY2011 survey conducted right after the Earthquake. In the 2017 inventory submission, the fuel consumption ratio by furnace type in FY2011 survey was applied to the FY2011-2015 activity data. In the 2018 inventory submission, the fuel consumption ratio by furnace type in FY2014 survey has been reflected to the FY2014 activity data by furnace type at first, then the interpolation of fuel consumption ratio by furnace type has been adopted to FY2012-2013 activity data and FY2014 survey data has been used for FY2015 activity data. As a result of the recalculation, the emissions and the IEFs from FY2012 to FY2015 have largely increased.

➢ *Biomass boilers*

As the activity data of woods, waste woods, black liquor, gas biomass and non-specified biomass for the biomass boilers, the fuel consumption by each sector in the *General Energy Statistics* was used. It was assumed that woods and waste woods under "power generation sector" and "Auto power generation sector" of the *General Energy Statistics* were used in the power generation facilities, while those under the rest of the sectors were used in the heat utilization facilities.

➢ *Coke production*

As the activity data of $CH_4$ emissions from coke production, the coke production amount was given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

Table 3-27 Coke production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coke production | kt | 47,338 | 42,279 | 38,511 | 38,009 | 34,140 | 37,036 | 34,875 | 35,024 | 35,082 | 33,785 | 32,439 | 33,138 | 32,587 | 32,659 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

➢ *Furnaces (including biomass boilers)*

In case of using the default emission factor of the *2006 IPCC Guidelines*, the default uncertainties were applied. In case of using country specific emission factor, country specific uncertainties were established.

Since the uncertainty by fuel and sector of energy consumption in *the General Energy Statistics* were not available, upper value and lower value of uncertainty were established from standard deviation of the rate of statistics error of "Coal, Coal Products", "Oil, Oil Products", Natural Gas, LPG" and "Biomass Energy" from 1990 to 2016.

The uncertainties at furnaces were estimated to be −33% to +46% for $CH_4$ emissions and −33% to +33% for $N_2O$ emissions as a whole for the fuel combustion category.

➢ *Coke production*

For the uncertainty of the emission factor for coke production, the uncertainty of fuel combustion emissions from the coking furnace and coking furnace lids were estimated separately. The uncertainty

of fuel combustion emissions from the coking furnace and coking furnace lids was estimated as 98.5% and 61.8%, respectively. For the uncertainty of activity data, the standard value of 5% given by MOE (2006a) was used.

- *Incineration of waste for energy purposes and with energy recovery*

  See section 7.4.3

- ***Time-series Consistency***

- *Furnaces (including biomass boilers)*

The emissions were calculated in a consistent manner in all time-series.

The emission factors for $CH_4$ and $N_2O$ have been calculated by a consistent estimation method since FY1990.

The activity data was used from data in the *General Energy Statistics* in all time-series, and the statistics were made by a consistent estimation method in all time-series. For the activity data of "Production, Transmission and Distribution of Electricity" under "Auto power generation" of the *General Energy Statistics*, see 3.2.4. c) (1.A.1).

- *Coke production*

The activity data for coke production are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*, by a consistent method throughout the time-series from FY1990 to the most recent year. The emission factor is based on the information provided by the Japan Iron and Steel Federation estimated using a consistent methodology throughout the time-series. Therefore, $CH_4$ emissions from coke production have been estimated in a consistent manner throughout the time-series.

- *Incineration of waste for energy purposes and with energy recovery*

  See section 7.4.3

***d) Category-specific QA/QC and Verification***

- ***QA/QC***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

- ***Verification***

$N_2O$ emission factors of fuel combustion currently used are established based on the actual measurements conducted in 1990s. Since then, the change of combustion conditions due to the progress of energy saving may change the emission factors, and the necessity of periodical review of the emission factors were pointed out by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2009. In addition, the Expert Review Team strongly recommended that Japan provided additional information in its annual submission to transparently justify the appropriateness of the measurements to the current boiler types/technologies in the individual review of the 2013 submission. (FCCC/ARR/2013/JPN)

The actual measurement conducted in FY2009 is described here. The object of measurement was the $N_2O$ emission factor of fluidized-bed boilers combusting solid fuels. As a result, the validity of measurements in 1990s is confirmed because the result of the measurement in FY2009 is almost the same level of the emission factor based on the measurements in the 1990s.

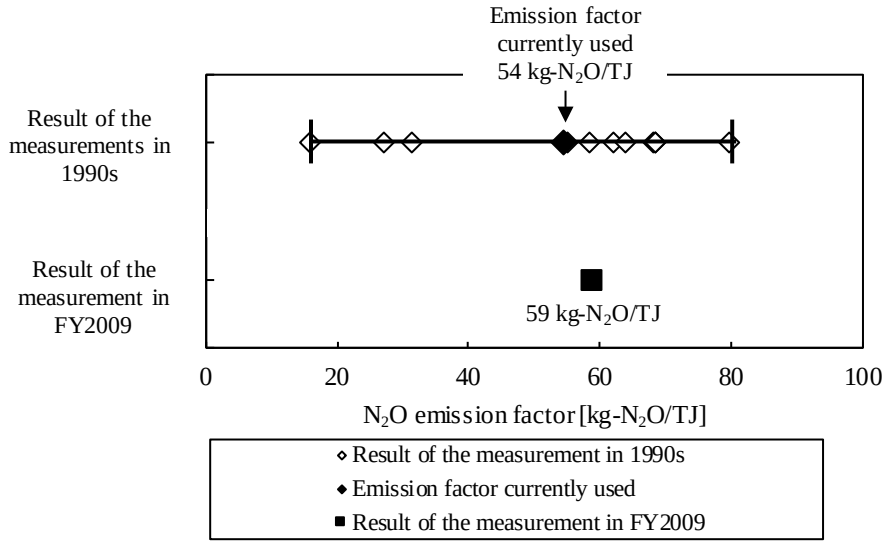


Figure 3-5 Comparison of the 1990s and FY2009 measurement results

Note: The result of the measurement in FY2009 in the figure is the average of three measurements in a boiler

### *e) Category-specific Recalculations*

Since the activity data for FY2013-2017 in the *General Energy Statistics* were revised, the $CH_4$ and $N_2O$ emissions in those years were recalculated.

Since the fuel consumption ratios for each furnace type of some fuels for FY2007, 2008-2013 were revised, the $CH_4$ and $N_2O$ emissions in those years were recalculated.

Since the coke production amount for FY2017 provided by the Japan Iron and Steel Federation was revised, the $CH_4$ emissions in that year were recalculated.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

## 3.2.6. $CO_2$ Emissions from Manufacturing Industries and Construction (1.A.2.: $CO_2$)

### *a) Category Description*

This section provides the estimation methods for determining $CO_2$ emissions from iron and steel (1.A.2.a); non-ferrous metals (1.A.2.b); chemicals (1.A.2.c); pulp, paper, and print (1.A.2.d); food processing, beverages, and tobacco (1.A.2.e); non-metallic minerals (1.A.2.f) and other (1.A.2.g).

In FY2018, $CO_2$ emissions from this category accounted for 262,837 kt-$CO_2$, and represented 21.2% of Japan's total GHG emissions (excluding LULUCF). The iron and steel (1.A.2.a) accounts for 51.8%, and is the largest source within the manufacturing industries and construction category in FY2018.

### *b) Methodological Issues*

- ***Estimation Method***

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2), as was the case for the energy industries (1.A.1). See Section 3.2.4. b) (1.A.1).

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as "other fossil fuels" and "biomass" in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The $CO_2$ emissions from biomass are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

- ***Emission Factors***

The emission factors elaborated in the energy industries (1.A.1) are also used in this category. See Section 3.2.4. b) (1.A.1).

- ***Activity Data***

The data presented in the *General Energy Statistics* were used for activity data, as was the case for the energy industries (1.A.1).

Table 3-28 Energy consumptions in Manufacturing Industries and Construction category (1.A.2) (unit: PJ)

| Fuel | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liquid fuels | 1,958 | 2,113 | 1,905 | 1,539 | 1,083 | 1,042 | 1,090 | 1,033 | 1,011 | 953 | 884 | 829 | 811 | 759 |
| Solid fuels | 2,130 | 2,053 | 2,034 | 2,051 | 1,861 | 2,043 | 1,990 | 2,031 | 2,087 | 2,051 | 2,000 | 1,889 | 1,863 | 1,828 |
| Gaseous fuels | 227 | 344 | 408 | 599 | 592 | 629 | 654 | 648 | 611 | 594 | 595 | 603 | 601 | 629 |
| Other fossil fuels | 86 | 99 | 115 | 174 | 196 | 202 | 202 | 208 | 212 | 219 | 222 | 219 | 226 | 226 |
| Biomass | 227 | 227 | 240 | 273 | 279 | 298 | 291 | 286 | 309 | 303 | 300 | 272 | 281 | 284 |
| Total | 4,628 | 4,835 | 4,701 | 4,637 | 4,011 | 4,214 | 4,228 | 4,206 | 4,231 | 4,120 | 4,001 | 3,811 | 3,782 | 3,726 |

The activity data for the manufacturing industry sectors were calculated by totaling the energy consumption from production activities in factories and offices (final energy consumption: #6xxxxx[10]), energy consumption related to non-utility power generation for use in one's own factories and offices (auto power generation: #25xxxx), and energy consumption related to steam production for use in own factories and offices (auto steam generation: #26xxxx) shown in the *General Energy Statistics*. Because the energy consumption for production activities in factories and offices contained a certain amount used as raw materials (non-energy and feedstock use: #95xxxx), this amount was subtracted.

The auto power generation and auto steam generation sectors are included in the energy transformation & own use sector in the *General Energy Statistics*. However, the *2006 IPCC Guidelines* allocates $CO_2$ emissions from energy consumption for power or steam generation to the sectors generating that power or steam. As such, these $CO_2$ emissions are added to those from each industry in the final energy consumption sector and are reported in 1.A.2.

Table 3-29 shows the correspondence between the sectors of Japan's Energy Balance Table and those

[10] x indicates any number.

of the CRF (1.A.2).

Table 3-29 Correspondence between sectors of Japan's Energy Balance Table and of the CRF (1.A.2)

| CRF | | General Energy Statistics | |
|---|---|---|---|
| 1A2 | Manufacturing industries and construction | | |
| 1A2a | Iron and steel | Auto power generation; Manufacture of iron and steel | #253250 |
| | | Auto steam generation; Manufacture of iron and steel | #263220 |
| | | Final energy consumption; Manufacture of iron and steel | #629100 |
| | | Non-energy and feedstock use; Manufacture of iron, steel and steel products | #951560 |
| 1A2b | Non-ferrous metals | Auto power generation; Manufacture of non-ferrous metals and products | #253230 |
| | | Auto steam generation; Manufacture of non-ferrous metals and products | #263260 |
| | | Final energy consumption; Manufacture of non-ferrous metals and products | #629300 |
| | | Non-energy and feedstock use; Primary smelting and refining of copper, lead, zinc and aluminium | #951570 |
| 1A2c | Chemicals | Auto power generation; Manufacture of chemical and allied products | #253160 |
| | | Auto steam generation; Manufacture of chemical and allied products | #263160 |
| | | Final energy consumption; Manufacture of chemical and allied products | #626100 |
| | | Non-energy and feedstock use; Manufacture of petrochemical, ammonia, soda products | #951530 |
| 1A2d | Pulp, paper and print | Auto power generation; Manufacture of pulp, paper and paper products | #253140 |
| | | Auto power generation; Printing and allied industries | #253150 |
| | | Auto steam generation; Manufacture of pulp, paper and paper products | #263140 |
| | | Auto steam generation; Printing and allied industries | #263150 |
| | | Final energy consumption; Manufacture of pulp, paper and paper products | #624000 |
| | | Final energy consumption; Printing and allied industries | #625000 |
| | | Non-energy and feedstock use; Manufacture of pulp, paper and paper products, large scale | #951520 |
| 1A2e | Food processing, beverages and tobacco | Auto power generation; Manufacture of food | #253090 |
| | | Auto power generation; Manufacture of beverages, tobacco and feed | #253100 |
| | | Auto steam generation; Manufacture of food | #263090 |
| | | Auto steam generation; Manufacture of beverages, tobacco and feed | #263100 |
| | | Final energy consumption; Manufacture of food, beverages, tobacco and feed | #621000 |
| 1A2f | Non-metallic minerals | Auto power generation; Manufacture of ceramic, stone and clay products | #253210 |
| | | Auto steam generation; Manufacture of ceramic, stone and clay products | #263210 |
| | | Final energy consumption; Manufacture of ceramic, stone and clay products | #628100 |
| | | Non-energy and feedstock use; Manufacture of ceramic, stone and clay products | #951550 |
| 1A2g | Other | Auto power generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#251010-#251040]) | #251000 |
| | | Auto power generation; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f) | #252000 |
| | | Auto steam generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#261010-#261040]) | #261000 |
| | | Auto steam generation; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f) | #262000 |
| | | Final energy consumption; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#611000]) | #610000 |
| | | Final energy consumption; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f) | #620000 |
| | | Non-energy and feedstock use; Agriculture, fishery, mining and construction (except for agriculture, forestry and fishery) | #951100 |
| | | Non-energy and feedstock use; Manufacturing industry, large scale (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f) | #951500 |
| | | Non-energy and feedstock use; Manufacturing industry, small and medium scale | #951700 |

Note: #95xxxx items are subtracted as non-energy use activities.

### *c) Uncertainties and Time-series Consistency*

See Section 3.2.4. c).

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY20013-FY2017 were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, $CO_2$ emissions from other fossil fuels in FY2005-FY2017 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

## 3.2.7. $CH_4$ and $N_2O$ Emissions from Manufacturing Industries and Construction (1.A.2.: $CH_4$, $N_2O$)

### *a) Category Description*

This section provides the estimation methods for determining $CH_4$ and $N_2O$ emissions from iron and steel (1.A.2.a); non-ferrous metals (1.A.2.b); chemicals (1.A.2.c); pulp, paper, and print (1.A.2.d); food processing, beverages, and tobacco (1.A.2.e); non-metallic minerals (1.A.2.f); and other (1.A.2.g).

This category also provides the estimation methods for determining $CH_4$ and $N_2O$ emissions from off-road vehicles, work ships and other machinery of manufacturing industries and construction.

### *b) Methodological Issues*

- ***Estimation Method***

➢ *Furnaces*

Same with Energy Industries (1.A.1), $CH_4$ and $N_2O$ emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). See 3.2.5. b) (1.A.1).

➢ *Biomass boilers*

See 3.2.5. b) (1.A.1).

➢ *Off-road vehicles and other machinery*

The emissions from off-road vehicles, work ships and other machinery of manufacturing industries and construction are estimated by Tier 1 in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 3.34, Fig. 3.3.1) and reported in each sub-category of manufacturing industries and construction (1.A.2).

➢ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3.

● ***Emission Factors***

➢ *Furnaces*

The emission factors which were established in Energy Industries (1.A.1) were used. See Table 3-23 and Table 3-24, See 3.2.5. b) (1.A.1).

➢ *Biomass boilers*

See 3.2.5. b) (1.A.1).

➢ *Off-road vehicles and other machinery*

The emission factors of fuel oil A of work ships were estimated using the default values of Ocean-going Ships which were provided in the *2006 IPCC Guidelines* (Vol.2, page 3.50, Table 3.5.3) after conversion to the gross calorific value by multiplying them by 0.95 (*2006 IPCC Guidelines*, Vol.2, page 1.16). The emission factors of gasoline, diesel oil and fuel oil A for other than work ships were estimated from the values of European Environment Agency (EEA, 2016) (Table 3-1, 1.A.2.g.vii) after conversion to the gross calorific value.

Table 3-30 Emission factors of $CH_4$ and $N_2O$ for off-road vehicles and other machinery in manufacturing industries and construction (1.A.2)

| Fuel | Unit | $CH_4$ emission factor | $N_2O$ emission factor | Reference |
|---|---|---|---|---|
| Gasoline | g/t | 665 | 59 | EEA (2016), Non-road mobile sources and machinery, Table 3-1 |
| Diesel oil (includes fuel oil A used for other than ships) | g/t | 83 | 135 | |
| Fuel oil A used for ships | kg/TJ(NCV) | 7 | 2 | *2006 IPCC Guidelines*, Vol.2, Table 3.5.3 |

● ***Activity Data***

➢ *Furnaces*

The fuel consumption of mobile combustion and stationary combustion are estimated by multiplying the fuel consumption of each category and each fuel type in the *General Energy Statistics* by the ratios of mobile and stationary combustion on the Table 3-31, which are the survey results executed by MOE in FY2014 and FY2015.

In addition, the fuel consumption, which is estimated by multiplying the fuel consumption of stationary combustion obtained as described above by the fuel consumption ratio of each furnace type, is assumed as the activity data for the stationary combustion (namely combustion in furnaces). Same with Energy Industries (1.A.1), the ratio of fuel consumption of each furnace type was estimated from data on the *General Survey of the Emissions of Air Pollutants* and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries*, *Structural Survey of Energy Consumption*, *Electric Power Statistics*, and *Current Survey of Production Concerning Gas Industry*). See 3.2.5. b) (1.A.1).

➢ *Biomass boilers*

As the activity data from the biomass boilers, the inventory used the fuel consumption for each sector, each fuel type in the *General Energy Statistics*. However, the consumption of non-specified biomass for each industry type before FY2001 under “Auto steam generation sector” in the *General Energy*

*Statistics* was not available because it was not investigated. Therefore, for this period, it was estimated on the assumption that it is proportional to the amount of steam generation for each industry type before FY2001, based on the amount of steam generation in FY2002.

- *Off-road vehicles and other machinery*

The fuel consumption, which is estimated by multiplying the fuel consumption of each category and each fuel type in the *General Energy Statistics* by the fuel consumption ratio in the Table 3-31, is assumed to be the activity data of the mobile combustion, namely the off-road vehicles and other machinery.

In relation to the Table 3-31, all fuel consumption of fuel oil A and diesel oil of construction in the *General Energy Statistics* were used for activity data of mobile combustion. According to Japan Federation of Construction Contractors, the fuel consumption of electric generator as stationary combustions is included in the value of fuel oil A and diesel oil of construction, however the emission factors of mobile combustion are applied for electric generator, because a combustion engine of electric generator is similar with diesel engine.

Table 3-31 Fuel consumption ratio of mobile combustion and stationary combustion in manufacturing industries and construction (1.A.2)

| CRF code | Category in General Energy Statistics | Gasoline | | Diesel oil | | Fuel oil A | | |
|---|---|---|---|---|---|---|---|---|
| | | Mobile combustion | Stationary combustion | Mobile combustion | Stationary combustion | Mobile combustion (ships) | Mobile combustion | Stationary combustion |
| 1A2a | Manufacture of iron and steel | 1% | 99% | 16% | 84% | | | |
| 1A2b | Manufacture of non-ferrous metals and products | 24% | 76% | 1% | 99% | | | |
| 1A2c | Manufacture of chemical and allied products | 100% | 0% | 1% | 99% | | | |
| 1A2d | Manufacture of pulp, paper and paper products | 74% | 26% | 10% | 90% | | | |
| | Printing and Allied Industries | | | 0% | 100% | | | |
| 1A2e | Manufacture of food, beverages, tobacco and feed | | | 1% | 99% | | | |
| 1A2f | Manufacture of Ceramic, Stone and Clay Products | 7% | 93% | 1% | 99% | | | |
| 1A2g | Manufacture of Fabricated Metal Products | | | 1% | 99% | | | |
| | Manufacture of Machinery | 2% | 98% | 1% | 99% | | | |
| | Mining, Quarrying of Stone and Gravel | | | 100% | 0% | 17% | 25% | 58% |
| | Manufacture of Lumber and Wood Products, except Furniture and Fixtures | | | 2% | 98% | | | |
| | Construction Work Industry | | | 100% | 0% | 0% | 100% | 0% |
| | Manufacture of Textile Mill Products | 100% | 0% | | | | | |
| | Manufacture of Leather Tanning, Leather Products and Fur Skins | | | 0% | 100% | | | |
| | Manufacture of Furniture and Fixtures | | | 0% | 100% | | | |
| | Manufacture of Rubber Products | | | 0% | 100% | | | |
| | Manufacture of Plastic Products, except Otherwise Classified | | | 0% | 100% | | | |
| | Miscellaneous Manufacturing Industry | | | 4% | 96% | | | |

Reference: Estimated based on MOE (2015b) and MOE (2016).

### *c) Uncertainties and Time-series Consistency*

- *Furnaces (including Biomass boilers)*

See 3.2.5. c).

The consumption of non-specified biomass for each industry type before FY2001 was not available because it was not investigated. Therefore, time-series consistency is ensured by estimating the consumption on the assumption that it is proportional to the amount of steam generation for each industry type before FY2001, based on the amount of steam generation in FY2002.

- *Off-road vehicles and other machinery*

The default values of the *2006 IPCC Guidelines* were substituted for the uncertainties of emission factors. The uncertainties of the activity data were established from the standard deviation of the rate of statistical discrepancy of liquid and gaseous fuels of the *General Energy Statistics*. For the activity data obtained from the fuel consumption ratio of mobile combustion, the uncertainties of the ratio were estimated from the survey conducted by MOE in FY2014 and FY2015 and they were combined by the error propagation formula. As a result, the uncertainties were determined to be −29% to +41% for $CH_4$ emissions and −23% to +91% for $N_2O$ emissions from off-road vehicles and other machinery as a whole for the fuel combustion category.

- *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since the activity data for FY2013-2017 in the *General Energy Statistics* were revised, the $CH_4$ and $N_2O$ emissions in those years were recalculated.

Since the activity data of one normal pressure fluidized-bed furnace for FY1997 and FY2010-2015 were revised, the $N_2O$ emissions in those years were recalculated.

Updating the statistical data in the waste sector, $CH_4$ and $N_2O$ emissions in FY2017 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

See section 3.2.5. f).

## 3.2.8. $CO_2$ Emissions from Transport (1.A.3.: $CO_2$)

### *a) Category Description*

This section provides the methods used to estimate $CO_2$ emissions from domestic aviation (1.A.3.a), road transportation (1.A.3.b), railways (1.A.3.c), domestic navigation (1.A.3.d), and other transportation

(1.A.3.e). The emissions from mobile sources that the main purpose is other than transport of passenger or freight (e.g. off-road vehicles, work ships and fishing boats) are included in manufacturing industries and construction (1.A.2) and other sectors (1.A.4).

In 2018, $CO_2$ emissions from this category accounted for 202,914 kt-$CO_2$, and represented 16.4% of Japan's total GHG emissions (excluding LULUCF). The road transportation (1.A.3.b) accounts for 89.4% and is the largest within the Transport category in FY2018.

### *b) Methodological Issues*

- ***Estimation Method***

➢ *Fuels such as gasoline and diesel oil*

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2), as was the case for the energy industries (1.A.1). See 3.2.4. b)). In the CRFs, the $CO_2$ emissions from biofuels are estimated from domestic supply [#190000] of biofuels from the *General Energy Statistics* and reported in Road transportation (1.A.3.b) as reference values. (The $CO_2$ emissions from biomass are not included in the national totals in accordance with the *2006 IPCC Guidelines*.)

➢ *Lubricants*

$CO_2$ is emitted by oxidation of lubricants in engines during use. According to the *2006 IPCC Guidelines* (Vol.3, page 5.6), in the case of 2-stroke (2-cycle) engines, where the lubricant is mixed with another fuel and thus on purpose co-combusted in the engine, the emissions should be estimated and reported as part of the combustion emissions in the energy sector. 2-stroke engine oil for automobile and marine diesel engine oil correspond to be reported in the energy sector. The emissions are estimated by the following equation. The emissions from 2-stroke engine oil are reported in 1.A.3.b and those from marine diesel oil are reported in 1.A.3.d.

$$E = \sum_i (LC_i \times CC_i \times ODU_i \times 44/12)$$

| | |
|---|---|
| $E$ | : $CO_2$ emissions from lubricants oxidized during use [kt-$CO_2$] |
| $LC_i$ | : Consumption of lubricant [TJ] |
| $CC_i$ | : Carbon content of lubricant [kt-C/TJ] |
| $ODU_i$ | : Oxidized During Use (ODU) factor |
| $i$ | : Lubricant type (2-stroke engine oil for automobile and marine diesel engine oil) |

- ***Emission Factors***

➢ *Fuels such as gasoline and diesel oil*

The emission factors elaborated in the energy industries (1.A.1) are also used in this category. See 3.2.4. b).

The carbon emission factor for liquid fuels (diesel oil) in 1.A.3.b (Road transportation) is the lowest in Annex I Parties for two reasons. One is because the quality standard for diesel oil in Japan is different from other countries. Crude oil with high sulfur content imported from the Middle East must be decomposed and go through ultra-deep desulfurization to become low-sulfur diesel oil (<10 ppm) according to Japanese automobile exhaust gas regulations. The other reason is because gas oil used for purposes other than road transport is called "fuel oil A" to distinguish it from diesel oil. The carbon balance of Japanese petroleum refineries including diesel oil and fuel oil A nearly matches according to statistics, so these carbon emission factors are not irregular.

Please refer to the quality standard for diesel oil in Japan provided in Annex 4 (A4.3).

➢ *Lubricants*

The carbon content *CC* is the carbon emission factor of lubricants elaborated in the energy industries (1.A.1). The ODU factor is 1.0 assuming that all lubricants are combusted.

● ***Activity Data***

Table 3-32 Energy consumptions in Transport (1.A.3.) (unit: PJ)

| Fuel | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liquid fuels | 2,966 | 3,569 | 3,729 | 3,510 | 3,272 | 3,286 | 3,215 | 3,228 | 3,135 | 3,065 | 3,048 | 3,023 | 3,001 | 2,965 |
| Solid fuels | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gaseous fuels | 0 | 0 | 1 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 2 | 2 |
| Other fossil fuels | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Biomass | NO | NO | NO | 0 | 1 | 9 | 9 | 9 | 10 | 12 | 15 | 18 | 19 | 20 |
| Total | 2,966 | 3,569 | 3,730 | 3,514 | 3,277 | 3,299 | 3,228 | 3,241 | 3,149 | 3,080 | 3,067 | 3,043 | 3,023 | 2,987 |

➢ *Fuels such as gasoline and diesel oil*

The data given in the *General Energy Statistics* were used for activity data.

The values subtracting final energy consumption reported under 'non-energy and feedstock use' [#953000] from energy consumption reported under 'air transport' [#815000] [#854000], 'road transport' [#811000] [#851000] [#811500] [#812000], 'railway transport' [#813000] [#852000] and 'water transport' [#814000] [#853000] in Japan's Energy Balance Table (*General Energy Statistics*) are used for activity data. Because energy consumption reported under 'non-energy and feedstock use' was used for purposes other than combustion and was considered not emitting $CO_2$, these values were deducted. (see Table 3-33)

Table 3-33 Correspondence between sectors of Japan's Energy Balance Table and those of the CRF (1.A.3)

| CRF | | | General Energy Statistics | |
|---|---|---|---|---|
| 1A3 | Transport | | | |
| | 1A3a Domestic aviation | | Final energy consumption; Passenger; Air passenger transport | #815000 |
| | | | Final energy consumption; Freight; Air freight transport | #854000 |
| | | | Non-energy and feedstock use; Transportation (air) | #953000 |
| | 1A3b Road transportation | | | |
| | | i Cars | Final energy consumption; Passenger; Passenger vehicle | #811000 |
| | | | Non-energy and feedstock use; Transportation (passenger vehicle) | #953000 |
| | | ii Light duty trucks | IE (1A3biii) | - |
| | | iii Heavy duty trucks and buses | Final energy consumption; Passenger; Bus | #811500 |
| | | | Final energy consumption, Freight; Freight truck and lorry | #851000 |
| | | | Non-energy and feedstock use; Transportation (bus, freight truck and lorry) | #953000 |
| | | iv Motorcycles | Final energy consumption; Passenger; Motorcycles | #812000 |
| | | | Non-energy and feedstock use; Transportation (Motorcycles) | #953000 |
| | | v Other | IE (1A3biii) | - |
| | 1A3c Railways | | Final energy consumption; Passenger; Railway passenger transport | #813000 |
| | | | Final energy consumption; Freight; Railway freight transport | #852000 |
| | | | Non-energy and feedstock use; Transportation (railways) | #953000 |
| | 1A3d Domestic navigation | | Final energy consumption; Passenger; Water passenger transport | #814000 |
| | | | Final energy consumption; Freight; Water freight transport | #853000 |
| | | | Non-energy and feedstock use; Transportation (water) | #953000 |
| | 1A3e Other transportation | | NO | - |

Note: #95xxxx items are subtracted as non-energy use activities.

➢ *Lubricants*

The sales of engine oils for automobiles and navigation are estimated from the total sales of lubricants, and then they are used to estimate the consumptions of total loss type engine oils.

The sales of engine oils for automobile (gasoline engine oil and diesel engine oil) and marine diesel engine oil in cubic volume basis are estimated by multiplying *DS*, or the domestic sales of all lubricants shown in *Yearbook of Mineral Resources and Petroleum Products Statistics* and *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, by $R_i$, or the proportion of each of engine oil to all lubricants sold to consumers, wholesalers and retailers[11] estimated from these yearbooks. They are multiplied by $R_{TLi}$, or the proportions of total loss type lubricants to each of engine oil, to obtain the consumptions of total loss type engine oils. $R_{TLi}$ is derived by dividing the productions and imports of 2-stroke engine oils and marine cylinder oil in fiscal year 2011 shown in Japan Lubricating Oil Society (2013) by the domestic sales of engine oils for automobiles and marine diesel engine oil estimated above, respectively (0.92% for engine oils for automobiles and 83% for marine diesel engine oil).

$LC_i$, or the consumptions of total loss type engine oils in quantity of heat basis, are obtained by converting the consumptions in cubic volume basis by using the gross calorific values of lubricants shown in the *General Energy Statistics*, and they are set as activity data.

$$LC_i = DS \times R_i \times R_{TLi} \times GCV$$

$LC_i$ : Consumption of each of engine oil [TJ]
$DS$ : Domestic sales of all lubricants [1,000 kL]
$R_i$ : Proportion of each of engine oil to all lubricants sold to consumers, wholesalers and retailers
$R_{TLi}$ : Proportions of total loss type lubricants to each of engine oil
$i$ : Lubricant type (engine oils for automobile and marine diesel engine oil)
$GCV$ : Gross calorific values of lubricants [GJ/kL]

Table 3-34 Consumption of total loss type engine oils

| Item | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Two stroke engine oil for automobiles | $LC_1$ | TJ | 207 | 215 | 210 | 194 | 183 | 183 | 172 | 157 | 158 | 154 | 142 | 135 | 137 | 149 |
| Cylinder oil for navigation | $LC_2$ | TJ | 5,318 | 5,503 | 7,144 | 6,250 | 4,972 | 4,627 | 4,016 | 3,638 | 3,502 | 3,301 | 3,124 | 2,843 | 2,766 | 3,094 |
| Total sales of lubricants | $DS$ | 1000 kL | 2,439 | 2,335 | 2,192 | 2,047 | 1,681 | 1,763 | 1,695 | 1,538 | 1,531 | 1,511 | 1,460 | 1,414 | 1,433 | 1,588 |
| Proportion of sales of engine oils for automobiles | $R_1$ | - | 23% | 25% | 26% | 26% | 30% | 28% | 28% | 28% | 28% | 28% | 26% | 26% | 26% | 26% |
| Proportion of sales of marine diesel engine oils | $R_2$ | - | 6.5% | 7.1% | 9.8% | 9.1% | 8.9% | 7.9% | 7.1% | 7.1% | 6.8% | 6.5% | 6.4% | 6.0% | 5.8% | 5.8% |
| Gross calorific value of lubricants | $GCV$ | GJ/kL | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 | 40.2 |

### *c) Uncertainties and Time-series Consistency*

See 3.2.4. c).

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2013-2017 were recalculated. In addition, due to the updates of the activity data based on the revision of the *Yearbook of Mineral Resources and Petroleum Products Statistics*, the emissions from lubricants for FY2017 were recalculated.

See Chapter 10 for impact on trend.

[11] Lubricants sold to consumers, for FY1990-2001.

### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

## 3.2.9. $CH_4$ and $N_2O$ Emissions from Transport (1.A.3.: $CH_4$, $N_2O$)

This section provides the estimation methods for $CH_4$ and $N_2O$ emissions from domestic aviation (1.A.3.a), road transportation (1.A.3.b), railways (1.A.3.c), domestic navigation (1.A.3.d), and other transportation (1.A.3.e). The emissions from mobile sources that the main purpose is other than transport of passenger or freight (e.g. off-road vehicles, work ships and fishing boats) are included in manufacturing industries and construction (1.A.2) and other sectors (1.A.4).

### 3.2.9.1. Domestic Aviation (1.A.3.a.)

#### *a) Category Description*

This section provides the estimation methods for $CH_4$ and $N_2O$ emissions from energy consumption in domestic aviation. Greenhouse gases associated with the domestic operation of Japanese airliners are mainly emitted from jet fuels. In addition, a small amount of aviation gasoline used by light aircraft and helicopters is also a source of $CH_4$ and $N_2O$ emissions.

#### *b) Methodological Issues*

- ***Estimation Method***

In accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.60, Fig. 3.6.1), the emissions from jet fuel for jet aircraft are estimated using the Tier 2 method by each operation phase: Landing/Take-Off (LTO) cycle and cruise. For LTO phase, the emissions by aircraft type are estimated by multiplying the emission factor per LTO 1 cycle by the number of LTO cycles for each aircraft type on domestic routes, and then they are aggregated. However, the emissions prior to FY2000 are estimated by multiplying the weighted average emission factor for all type of aircraft in FY2001 by the total activity data due to lack of activity data by aircraft type prior to FY2000. For cruise phase, the emissions are estimated from the total jet fuel consumption during cruising on domestic routes.

The emissions from aviation gasoline, which is used for light aircraft and helicopters, are estimated by the Tier 1 method from the total domestic fuel consumption.

$$E_{jet} = \sum_i (EF_{LTO,i} \times AD_{LTO,i}) + EF_{cruise} \times AD_{cruise}$$

| | |
|---|---|
| $E_{jet}$ | : $CH_4$ and $N_2O$ emissions from domestic airliners using jet fuel |
| $EF_{LTO,i}$ | : Emission factor per LTO 1 cycle by aircraft type of domestic airliner |
| $AD_{LTO,i}$ | : Number of LTO cycles by aircraft type on domestic routes |
| $EF_{cruise}$ | : Emission factor associated with jet fuel consumption |
| $AD_{cruise}$ | : Jet fuel consumption during cruising on domestic routes |
| $i$ | : Aircraft type |

$$E_{gasoline} = EF_{gasoline} \times AD_{gasoline}$$

| | |
|---|---|
| $E_{gasoline}$ | : $CH_4$ and $N_2O$ emissions associated with flight of gasoline-powered domestic aircraft |
| $EF_{gasoline}$ | : Emission factor associated with the consumption of aviation gasoline |
| $AD_{gasoline}$ | : Consumption of aviation gasoline by aircraft on domestic routes |

- ***Emission Factors***

➢ *Jet fuel*

The default values given in the *2006 IPCC Guidelines* (Vol. 2, page 3.70, Table 3.6.9) are used for the emission factors of $CH_4$ and $N_2O$ during LTO. As for during cruising, the default values given in the *2006 IPCC Guidelines* (Vol. 2, page 3.64, Table 3.6.5) are used. (See Table 3-35)

➢ *Aviation gasoline*

The default values given in the *2006 IPCC Guidelines* (Vol. 2, page 3.64, Table 3.6.5) are used for emission factors of $CH_4$ and $N_2O$ (see Table 3-35).

Table 3-35 $CH_4$ and $N_2O$ emission factors for aircraft

| Type of aircraft (fuel) | Flight phase | $CH_4$ | $N_2O$ |
|---|---|---|---|
| Jet aircraft (Jet fuel) | LTO | Varies per aircraft type (see Table 3-36) | |
| | Cruise | - [1)] | 2 [kg-$N_2O$/TJ(NCV)] |
| Other than jet aircraft (Aviation gasoline) | - | 0.5 [kg-$CH_4$/TJ(NCV)] | 2 [kg-$N_2O$/TJ(NCV)] |

Reference: *2006 IPCC Guidelines*, Volume 2, page 3.64, Table 3.6.5
Note:
LTO: Landing and take-off
1) Excluded from calculations, as the emissions are assumed as negligible in the guidelines.

Table 3-36 $CH_4$ and $N_2O$ emission factors and fuel consumption for major types of jet aircraft

| Aircraft type | $CH_4$ emission factor [kg/$CH_4$/LTO] [1)] | $N_2O$ emission factor [kg/$N_2O$/LTO] [1)] | Fuel consumption [kg/LTO] [1)] |
|---|---|---|---|
| B737-300/400/500 | 0.08 | 0.1 | 780 |
| B737-800 | 0.07 | 0.1 | 880 |
| B747SR (B747-100, -200, -300) | 4.84 [2)] | 0.4 [2)] | 3,440 [3)] |
| B747-400 | 0.22 | 0.3 | 3,240 |
| B767-300 | 0.12 | 0.2 | 1,780 |
| B777-200/300 | 0.07 | 0.3 | 2,560 |
| A320 | 0.06 | 0.1 | 770 |
| Average of emission factors of all aircraft types in FY 2001 (adopted for the emission factor of all types of aircraft before 2001) | 0.34 | 0.15 | — |

Reference: *2006 IPCC Guidelines*, Vol. 2, page 3.70, Table 3.6.9
Note:
1) LTO: Landing and take-off
2) Maximum value of B747-100, -200, and -300 is used
3) Average value of B747-100, -200, and -300 is used

- ***Activity Data***

➢ *Jet fuel*

The number of LTO (landing and take-off) by aircraft type given in the *PRTR Outside Notification Emissions Estimated Data* (MOE) is used as activity data for LTO. However, these data involve the international flights LTO, thus the number of international flights LTO is subtracted for each aircraft type used for both domestic and international flights in same ratio of domestic and international flights from total LTO, so as to keep the total number of domestic LTO in the *Airport Management Status Study Report* (MLIT).

The fuel consumption during LTO is calculated by multiplying the fuel amount consumed per one LTO, which is given in the 2006 *IPCC Guidelines* for each aircraft type, by the number of LTO given above.

The fuel consumption for cruising is estimated by subtracting the amount of jet fuel consumed during

LTO from the total jet fuel consumption in the *Statistical Yearbook of Air Transport* (MLIT).

➢ *Aviation gasoline*

The consumption of gasoline in the domestic aviation, which is taken from the *General Energy Statistics*, is used for activity data.

Table 3-37 Activity data used for emission estimates of aircraft

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of LTO cycle | 1000 LTO | 669 | 783 | 865 | 895 | 892 | 882 | 882 | 938 | 993 | 1,006 | 997 | 994 | 999 | 1,003 |
| Jet fuel comsumption during cruise | 1000 kL | 1,621 | 2,425 | 2,742 | 3,031 | 2,791 | 2,629 | 2,589 | 2,758 | 2,933 | 2,996 | 3,005 | 3,072 | 3,145 | 3,187 |
| Aviation gasoline comsumption | 1000 kL | 5.3 | 6.0 | 4.3 | 7.7 | 2.4 | 1.9 | 1.7 | 1.9 | 1.9 | 1.7 | 1.7 | 1.7 | 1.9 | 2.6 |

Table 3-38 Number of LTO cycle of major types of jet aircraft since FY2001

| Aircraft type | Unit | 2001 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B737-300/400/500 | 1000 LTO | 123 | 103 | 90 | 84 | 130 | 129 | 131 | 132 | 80 | 68 | 38 | 38 |
| B737-800 | | NO | NO | 59 | 97 | 89 | 97 | 118 | 130 | 166 | 165 | 178 | 179 |
| B747SR | | 43 | 30 | 2 | 3 | 2 | 1 | 1 | NO | 1 | 1 | NO | NO |
| B747-400 | | 56 | 54 | 36 | 22 | 15 | 16 | 14 | 8 | 5 | 7 | 5 | 5 |
| B767-300 | | 146 | 103 | 102 | 101 | 105 | 95 | 87 | 79 | 75 | 73 | 80 | 80 |
| B777-200/300 | | 69 | 76 | 87 | 89 | 86 | 91 | 93 | 87 | 78 | 74 | 71 | 71 |
| A320 | | 59 | 47 | 57 | 48 | 55 | 88 | 95 | 102 | 103 | 97 | 54 | 54 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

As for the uncertainty of emission factors, the default values by each aircraft type per one LTO given in the *2006 IPCC Guidelines* (Tier 2) are applied for the emission factors, and the estimation is considered to be more accurate than Tier 1. Therefore, the values of the Tier 1 default uncertainty in the guideline ($CH_4$: -57% to +100%, $N_2O$: -70% to +150%) are considered to be the upper limit, and are adopted. As for the uncertainty of activity data, because the *Airport Management Status Study Report* is a complete survey executed by MLIT, the values in the *2006 IPCC Guidelines* (-5% to +5%) are used. As a result, the uncertainty of the emissions from domestic aviation is evaluated as -57% to +100% for $CH_4$, and -70% to +150% for $N_2O$.

- ***Time-series Consistency***

For the emission factors per LTO, the same value is used for every fiscal year since FY2001 by each aircraft type. For the emission factors prior to FY2000, because the activity data by each aircraft type are not available, the average emission factor for all aircraft type is established from the FY2001 data, and it is used for the fiscal years back to FY1990. In addition, the jet fuel consumption in the *Statistical Yearbook of Air Transport* and the aviation gasoline consumption in the *General Energy Statistics* are used as activity data consistently from FY1990 to the nearest year.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

The $CH_4$ and $N_2O$ emissions from jet fuel for FY2017 were recalculated due to an update of the number of LTO in the *Airport Management Status Study Report.* See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

## 3.2.9.2. Road Transportation (1.A.3.b.)

This section provides the estimation methods for $CH_4$ and $N_2O$ emissions from the following vehicle categories:

Table 3-39 Reporting categories and definitions of emissions from automobiles

| Vehicle type | Definition | Fuel type for emission reporting | | | |
|---|---|---|---|---|---|
| | | Gasoline | Diesel | LPG | Natural gas |
| Light passenger vehicle | Light vehicle used for transportation of people. | Yes | - | - | - |
| Passenger vehicle | Regular vehicle or small vehicle used for transportation of people, with a capacity of 10 persons or less. | Yes | Yes | Yes | Yes |
| Bus | Regular vehicle or small vehicle used for transportation of people, with a capacity of 11 persons or more. | Yes | Yes | - | Yes |
| Light cargo truck | Light vehicle used for transportation of cargo | Yes | - | - | - |
| Small cargo truck | Small vehicle used for transportation of cargo. | Yes | Yes | - | Yes (Cargo truck) |
| Regular cargo truck | Regular vehicle used for transportation of cargo. | Yes | Yes | - | |
| Special-purpose vehicle | Regular, small or light vehicle used for special purposes, including flushers, advertising vans, hearses, and others. | Yes | Yes | - | Yes |
| Motorcycle | Two-wheeled vehicle | Yes | - | - | - |

Table 3-40 Correspondence between vehicle type and sectors of the CRF (1.A.3.b)

| CRF | Vehicle type, or notation key |
|---|---|
| 1A3b Road transportation | |
| i. Cars | Light passenger vehicle and passenger vehicle |
| ii. Light duty trucks | IE (included in iii. Heavy duty trucks and buses) |
| iii. Heavy duty trucks and buses | Bus, light cargo truck, small cargo truck, regular cargo truck, and special-purpose vehicle |
| iv. Motorcycles | Motorcycle |
| v. Other | IE (included in iii. Heavy duty trucks and buses) |

Different estimation methods are used between motorcycles and other road transportation vehicles, Road transportation vehicles other than motorcycles (3.2.4.2.a) and Motorcycles (3.2.4.2.b) are separately described in the following sections.

## 3.2.9.2.a. Road transportation: vehicles other than motorcycles

### *a) Category Description*

This section provides the estimation methods for $CH_4$ and $N_2O$ emissions from road transportation vehicles other than motorcycles, namely light passenger vehicles, light cargo trucks, passenger vehicles, buses, small cargo trucks, regular cargo trucks, and special-purpose vehicles.

### b) Methodological Issues

- ***Estimation Method***

The emissions are calculated by using the Tier 3 method, in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.14, Fig. 3.2.3).

$$E = \sum_i (EF_i \times AD_i)$$

$E$ : $CH_4$ and $N_2O$ emissions from road transportation (vehicles other than motorcycles)
$EF_i$ : Emission factor per distance traveled by vehicle type
$AD_i$ : Distance traveled by vehicle type
$i$ : Vehicle type

- ***Emission Factors***

The emission factors for $CH_4$ and $N_2O$ are established for each fuel type for each vehicle type, using the data shown in Table 3-41.

For "JAMA etc. data", the emission factors are established on the basis of the raw emission factors data provided by Japan Automobile Manufacturers Association (hereinafter referred to as JAMA) and other organizations[12]. For "JAMA data", the emission factors are established on the basis of the raw emission factors data provided by JAMA only. The raw emission factors are arranged as combined mode emission factors[13] by vehicle exhaust gas regulation[14] year. The emission factors are estimated by averaging the arranged emission factors weighted by the number of vehicles of each regulation year of each car type. The main reference of the number of vehicles is *Statistics of AIRIA/ Number of Motor Vehicle* compiled by the Automobile Inspection and Registration Information Association (AIRIA). (See Table 3-42, Table 3-43.)

For "Measured data", the emission factors are established on the basis of actual Japanese data. The emission factors are developed as weighted averages calculated from emission factors estimated by each class of running speed and proportion of distance traveled for each class of running speed given in *Road Transport Census* (MLIT). The emission factors reflect the actual operation of vehicles in Japan because the proportion of distance traveled by each class of running speed during rush hour was applied.

The $N_2O$ emission factors for natural gas trucks are established from actual measurement data. The emission factors are developed as weighted averages calculated from emission factors of each class of running speed based on actual measurements taken in Japan and the proportion of distance traveled for each class of running speed reported in the *Road Transport Census*. However, $N_2O$ emission factors for passenger vehicles, buses, and special-purpose vehicles, and $CH_4$ emission factors for special-purpose vehicles are established by the method indicated in Table 3-41, because of the absence of actual measurement data in Japan.

The detailed method for establishing the emission factors is described in the *GHGs Estimation Methods Committee Report Part 2 – Transportation* (MOE, August 2006).

[12] MOE, Bureau of Environment of Tokyo Metropolitan Government, NIES, National Traffic Safety and Environment Laboratory (NTSEL), and Japan Petroleum Energy Center (JPEC)
[13] The data were provided by test mode. The emission factors were calculated using "combined driving mode". "Combined JC08 driving mode" = "hot start driving mode" ×0.75 + "cold start driving mode" ×0.25
[14] The regulated gases include CO, non-methane hydrocarbons (NMHC), NOx and particulate matter (PM).

Table 3-41 Data source of the emission factors of vehicle

| Fuel / Vehicle type | Gasoline | | Diesel | | Natural gas | |
|---|---|---|---|---|---|---|
| | $CH_4$ | $N_2O$ | $CH_4$ | $N_2O$ | $CH_4$ | $N_2O$ |
| Light passenger vehicle | JAMA etc. data | JAMA etc. data | | | | |
| Passenger vehicle | JAMA etc. data | JAMA etc. data | JAMA etc. data | JAMA etc. data | JAMA data | The EF of small cargo truck is used considering the standard of vehicle type |
| Bus | 2006GL | 2006GL | Measured data | 2006GL | JAMA data | Established by correcting the EF of regular cargo truck by the equivalent inertial weight ratio considering vehicle weight. |
| Light cargo truck | JAMA etc. data | JAMA etc. data | | | | |
| Small cargo truck | JAMA etc. data | JAMA etc. data | JAMA etc. data | JAMA etc. data | | Established based on the actual measured data (classified as cargo truck) |
| Regular cargo truck | 2006GL | 2006GL | JAMA etc. data | JAMA etc. data | JAMA data | |
| Special-purpose vehicle | 2006GL | 2006GL | Measured data | 2006GL | Established using the corrected travel distance ratio by each running speed, considering the EFs by each speed of regular cargo truck and running pattern of special-purpose vehicle. | |

Note:
1) JAMA etc. data: Calculated by using driving mode test data provided by Japan Automobile Manufacturers Association (JAMA) and other organizations
2) JAMA data: Calculated by using driving mode test data provided by JAMA
3) Measured data: Using actual Japanese data other than the above JAMA data
4) 2006GL: Using the default values in the *2006 IPCC Guidelines*.
5) EFs of LPG vehicle are the same as those of gasoline passenger vehicle.

Table 3-42 $CH_4$ emission factors for road transportation

| Fuel | Vehicle type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | Light passenger vehicle | mg-$CH_4$/km | 8.3 | 8.3 | 8.2 | 6.9 | 5.4 | 5.0 | 4.8 | 4.5 | 4.2 | 4.0 | 3.8 | 3.6 | 3.5 | 3.3 |
| | Passenger vehicle (non-hybrid) | | 14.5 | 14.5 | 14.3 | 11.3 | 8.6 | 8.0 | 7.5 | 7.1 | 6.6 | 6.3 | 6.0 | 5.8 | 5.5 | 5.3 |
| | Passenger vehicle (hybrid) | | NO | NO | NO | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.3 |
| | Bus | | 14 | | | | | | | | | | | | | |
| | Light cargo truck | | 18.7 | 18.7 | 18.0 | 11.7 | 7.8 | 7.3 | 6.8 | 6.3 | 5.9 | 5.6 | 5.3 | 5.0 | 4.8 | 4.6 |
| | Small cargo truck | | 21.2 | 21.2 | 21.2 | 14.5 | 9.5 | 8.7 | 8.0 | 7.4 | 6.8 | 6.2 | 5.8 | 5.4 | 5.0 | 4.7 |
| | Regular cargo truck | | 14 | | | | | | | | | | | | | |
| | Special-purpose vehicle | | 14 | | | | | | | | | | | | | |
| Diesel | Passenger vehicle | | 11.3 | 12.2 | 12.6 | 12.8 | 12.8 | 12.8 | 12.7 | 12.8 | 12.9 | 12.7 | 12.5 | 12.2 | 12.1 | 11.9 |
| | Bus | | 19.0 | 18.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 |
| | Small cargo truck | | 9.6 | 10.7 | 10.1 | 8.7 | 8.3 | 8.3 | 8.2 | 8.1 | 7.9 | 7.8 | 7.7 | 7.6 | 7.5 | 7.4 |
| | Regular cargo truck | | 17.0 | 16.0 | 15.0 | 13.9 | 11.5 | 11.1 | 10.6 | 10.1 | 9.6 | 9.0 | 8.4 | 7.9 | 7.3 | 6.7 |
| | Special-purpose vehicle | | 17.0 | 15.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 |
| LPG | Passenger vehicle | | 14.5 | 14.5 | 14.3 | 11.3 | 8.6 | 8.0 | 7.5 | 7.1 | 6.6 | 6.3 | 6.0 | 5.8 | 5.5 | 5.3 |
| Natural gas | Passenger vehicle | | 13 | | | | | | | | | | | | | |
| | Bus | | 50 | | | | | | | | | | | | | |
| | Cargo truck | | 93 | | | | | | | | | | | | | |
| | Special-purpose vehicle | | 105 | | | | | | | | | | | | | |

Table 3-43 $N_2O$ emission factors for road transportation

| Fuel | Vehicle type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | Light passenger vehicle | mg-$N_2O$/km | 14.2 | 14.2 | 13.9 | 9.3 | 5.9 | 5.2 | 4.7 | 4.1 | 3.6 | 3.2 | 2.9 | 2.6 | 2.4 | 2.2 |
| | Passenger vehicle (non-hybrid) | | 23.7 | 23.7 | 20.3 | 12.2 | 7.2 | 6.3 | 5.6 | 5.0 | 4.4 | 4.0 | 3.7 | 3.4 | 3.2 | 3.0 |
| | Passenger vehicle (hybrid) | | NO | NO | NO | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | Bus | | 25 | | | | | | | | | | | | | |
| | Light cargo truck | | 23.7 | 23.7 | 21.7 | 12.8 | 8.0 | 7.4 | 6.8 | 6.3 | 5.8 | 5.4 | 5.1 | 4.8 | 4.5 | 4.3 |
| | Small cargo truck | | 21.1 | 21.6 | 21.8 | 13.1 | 8.5 | 7.8 | 7.2 | 6.6 | 6.1 | 5.6 | 5.2 | 4.9 | 4.6 | 4.3 |
| | Regular cargo truck | | 25 | | | | | | | | | | | | | |
| | Special-purpose vehicle | | 25 | | | | | | | | | | | | | |
| Diesel | Passenger vehicle | | 5.7 | 4.7 | 4.4 | 4.4 | 4.8 | 4.9 | 5.0 | 5.2 | 5.4 | 5.3 | 5.2 | 5.0 | 4.9 | 4.8 |
| | Bus | | 3 | | | | | | | | | | | | | |
| | Small cargo truck | | 9.3 | 10.3 | 11.1 | 11.7 | 12.1 | 12.2 | 12.3 | 12.4 | 12.5 | 12.6 | 12.7 | 12.8 | 12.8 | 12.9 |
| | Regular cargo truck | | 15.0 | 15.0 | 14.9 | 16.9 | 30.1 | 31.8 | 33.3 | 35.1 | 37.0 | 38.8 | 40.7 | 42.5 | 44.0 | 45.2 |
| | Special-purpose vehicle | | 3 | | | | | | | | | | | | | |
| LPG | Passenger vehicle | | 23.7 | 23.7 | 20.3 | 12.2 | 7.2 | 6.3 | 5.6 | 5.0 | 4.4 | 4.0 | 3.7 | 3.4 | 3.2 | 3.0 |
| Natural gas | Passenger vehicle | | 0.2 | | | | | | | | | | | | | |
| | Bus | | 38.4 | | | | | | | | | | | | | |
| | Cargo truck | | 12.8 | | | | | | | | | | | | | |
| | Special-purpose vehicle | | 14.5 | | | | | | | | | | | | | |

- ***Activity Data***

The estimates of annual distance traveled by each vehicle type and by each fuel type are used as activity data.

As for gasoline, diesel and LPG vehicles, the method of estimating the distance traveled by each vehicle type and by each fuel type up to FY2009 is to multiply the proportion of distance traveled for each fuel type, which is calculated from fuel consumption and fuel efficiency, by the distance traveled for each vehicle type given in *Statistical Yearbook of Motor Vehicle Transport* (MLIT). To separate out hybrid passenger vehicle (PV) from gasoline PV, the distance traveled by hybrid PV is estimated by multiplying the number of the vehicle by the annual distance traveled per vehicle. Before estimating the distance traveled, the values of *Statistical Yearbook of Motor Vehicle Transport* are converted to be consistent with the activity data since FY2010, using the overlap factors given by MLIT.

The annual distance traveled by vehicle type and by fuel type since FY2010 for gasoline, diesel and LPG vehicles is given in *Statistical Yearbook of Motor Vehicle Fuel Consumption* (MLIT). *Monthly Report of Motor Vehicle Transport Statistics* (MLIT) are also used supplementarily to estimate the annual distance for some vehicle types.

As for the natural gas vehicle, the annual distance traveled per vehicle type is determined by multiplying the number of natural gas-powered vehicles by the annual distance traveled per vehicle. From FY1990 to FY1996, the number of these vehicles is taken from the number of introduced natural gas-powered vehicles per type in the data compiled by the Japan Gas Association, and from FY1997, the number of registered natural gas-powered vehicles reported in the *Statistics of AIRIA/ Number of Motor Vehicle*. For the annual distance traveled per vehicle, the activity data are calculated using the annual total distance traveled by natural gas-powered vehicles, reported in the *Statistical Yearbook of Motor Vehicle Fuel Consumption*, the annual distance traveled by each vehicle type reported in the *Statistical Yearbook of Motor Vehicle Transport*, and the number of registered vehicle by each vehicle type reported in the *Statistics of AIRIA/ Number of Motor Vehicle*.

Table 3-44 Distance traveled of automobile

| Fuel | Vehicle type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | Light passenger vehicle | Million vehicle-km | 15,800 | 40,725 | 72,436 | 106,089 | 132,957 | 136,641 | 137,626 | 146,354 | 150,254 | 156,748 | 160,607 | 169,649 | 176,155 | 180,362 |
| | Passenger vehicle (non-hybrid) | | 272,902 | 304,297 | 342,901 | 348,524 | 325,115 | 318,911 | 322,697 | 315,837 | 302,713 | 281,922 | 272,858 | 266,825 | 260,401 | 255,328 |
| | Passenger vehicle (hybrid) | | NO | NO | NO | 2,560 | 9,809 | 14,333 | 19,549 | 29,419 | 38,353 | 48,023 | 58,258 | 67,183 | 77,866 | 88,399 |
| | Bus | | 90 | 30 | 20 | 43 | 81 | 314 | 234 | 181 | 188 | 193 | 212 | 212 | 213 | 221 |
| | Light cargo truck | | 90,707 | 89,828 | 79,560 | 78,333 | 76,812 | 75,073 | 73,153 | 75,164 | 77,421 | 77,724 | 75,876 | 76,331 | 75,192 | 72,936 |
| | Small cargo truck | | 28,972 | 20,286 | 19,582 | 20,853 | 20,437 | 22,228 | 23,058 | 23,162 | 23,172 | 23,176 | 22,994 | 21,467 | 21,365 | 21,342 |
| | Regular cargo truck | | 364 | 294 | 270 | 605 | 891 | 1,411 | 1,438 | 1,506 | 1,385 | 1,337 | 1,404 | 1,376 | 1,349 | 1,368 |
| | Special-purpose vehicle | | 662 | 693 | 1,283 | 1,272 | 1,503 | 2,841 | 2,728 | 2,714 | 2,604 | 2,474 | 2,461 | 2,415 | 2,476 | 2,513 |
| Diesel | Passenger vehicle | | 39,831 | 62,934 | 55,437 | 29,124 | 14,028 | 10,357 | 9,308 | 8,461 | 8,075 | 7,875 | 8,632 | 9,245 | 10,596 | 12,199 |
| | Bus | | 6,889 | 6,619 | 6,488 | 6,506 | 6,372 | 6,178 | 6,020 | 6,040 | 5,975 | 5,921 | 5,851 | 5,709 | 5,592 | 5,513 |
| | Small cargo truck | | 43,649 | 48,801 | 45,017 | 32,816 | 26,236 | 23,154 | 22,564 | 22,621 | 22,552 | 22,227 | 21,584 | 20,290 | 19,802 | 19,377 |
| | Regular cargo truck | | 57,824 | 68,143 | 72,434 | 69,361 | 65,292 | 62,856 | 61,156 | 59,395 | 59,091 | 58,976 | 59,368 | 59,124 | 59,539 | 59,778 |
| | Special-purpose vehicle | | 9,173 | 13,598 | 17,074 | 17,108 | 17,648 | 20,727 | 20,476 | 20,820 | 21,151 | 21,270 | 21,467 | 21,181 | 21,067 | 21,049 |
| LPG | Passenger vehicle | | 18,000 | 16,848 | 15,074 | 13,692 | 12,114 | 12,161 | 11,284 | 10,666 | 10,258 | 9,802 | 9,239 | 8,493 | 8,067 | 7,365 |
| Natural gas | Passenger vehicle | | 0 | 0 | 2 | 6 | 7 | 6 | 5 | 4 | 3 | 2 | 2 | 1 | 1 | 0 |
| | Bus | | NO | 2 | 15 | 48 | 56 | 52 | 49 | 47 | 39 | 34 | 28 | 22 | 15 | 11 |
| | Cargo truck | | 0 | 10 | 79 | 254 | 308 | 303 | 305 | 283 | 265 | 254 | 230 | 198 | 170 | 141 |
| | Special-purpose vehicle | | 0 | 2 | 18 | 57 | 69 | 67 | 66 | 65 | 62 | 56 | 49 | 39 | 33 | 27 |

- ***$N_2O$ emissions from gasoline passenger vehicles in Japan***

With the enhancement of the regulation of exhaust emissions of air pollutants on gasoline passenger vehicles in 1978, the under-floor type three-way catalyst started to be installed in Japan, leading to an increase in $N_2O$ emissions per distance traveled until around 1986 when the three-way catalyst became widely used. New emission regulations on gasoline passenger vehicles were not stipulated for the time being. Therefore, $N_2O$ emissions per distance traveled were stable from 1986 to 1997. From 1997, low emission vehicles were introduced. From 2000, with the stipulation of the "2000 Emission Regulation", $N_2O$ emissions per distance traveled started to decrease in response to the introduction of the close-coupled catalytic converter (or directly exhaust manifold type catalyst). Since 1997, the trend of $N_2O$ emissions per distance traveled is on the decrease.

The purification of toxic gas by catalyst does not start if the catalyst temperature has not exceeded a certain threshold level. Therefore, the early activation (or quick temperature raise) of catalyst at cold start has been projected, and the catalyst was relocated directly under the exhaust manifold, and this structure is introduced to close-coupled catalytic converter. $N_2O$ is produced at medium temperature range, however the temperature of close-coupled catalytic converter reaches over this range in a short time period, thus the $N_2O$ emissions can be reduced. (Goto et al., 2003; Yoda et al., 2010)

The figure below shows the $N_2O$ emissions from a vehicle with the under-floor type catalyst and a vehicle with the directly exhaust manifold type catalyst on the condition of the same test mode.

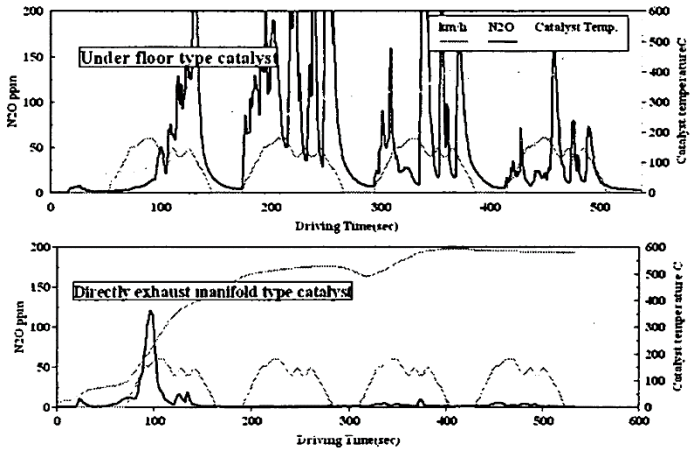


Figure 3-6 Difference of $N_2O$ emissions by catalyst fitting position

Test mode: 11 mode, (Reference) Goto et al. (2003)

- ***Completeness***

➢ *Biofuels*

Biofuels have been used in recent years, however the $CH_4$ and $N_2O$ emissions are estimated from activity data, which are not fuel consumption but mileage by vehicle type, and it is impossible to extract mileage only for biofuels. Therefore, $CH_4$ and $N_2O$ emissions from biofuels are reported as "IE", assuming those emissions are already included in the existing emissions from gasoline or diesel oil.

➢ *Methanol*

The number of methanol vehicles owned in Japan was only 9 at the end of March 2016 (data surveyed by AIRIA). Therefore, activity data is negligible, and is not reported, as it is assumed that the emissions are also negligible.

➢ *Lubricants*

Since $CH_4$ and $N_2O$ emissions from use of lubricants are very small in comparison to $CO_2$, these can be neglected for the greenhouse gas calculation according to the *2006 IPCC Guidelines* (Vol.3, page 5.7). Therefore, the emissions are reported as "NE".

***c) Uncertainties and Time-series Consistency***

- ***Uncertainties***

The emission factors of road transportation vehicle are established from the data provided by JAMA and other organizations. For the emission factors established from the samples more than five, the uncertainty is calculated from 95% confidence interval with the assumption of logarithmic standard deviation. For the emission factors established from the samples less than five, the default values of uncertainty in the *2006 IPCC Guidelines* are adopted. As for the uncertainty of activity data, because the *Statistical Yearbook of Motor Vehicle Fuel Consumption* is used for the activity data, the sample error rate of the Motor Vehicle Fuel Consumption Survey shown at the Service Statistics and Business Statistics Section Meeting by Cabinet Office, Government of Japan is used for the uncertainty. As a result, the uncertainty of emissions from road transportation vehicles including motorcycles is evaluated as -36% to +104% for $CH_4$, and -37% to +107% for $N_2O$.

- ***Time-series Consistency***

The emission factors are developed by using the same method throughout the time-series. The activity data of gasoline, diesel and LPG vehicles by FY2009 are estimated using the overlap factors given by MLIT, to be consistent with the activity data since FY2010. The activity data of natural gas vehicle are estimated based on the number of registered vehicles reported in the *Statistics of AIRIA/ Number of Motor Vehicle* after the accurate data has become available in 1997, and using the Japan Gas Association data for the total number of vehicles introduced before 1996 when the natural gas-powered vehicle was not popular. As for other activity data of natural vehicle, the data are estimated based on the *Statistical Yearbook of Motor Vehicle Transport* and the *Statistics of AIRIA/ Number of Motor Vehicle* by a consistent method throughout the time-series from FY1990 to the nearest year.

***d) Category-specific QA/QC and Verification***

- ***QA/QC***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission

factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

- ***Verification***

On the annual review in 2014 (FCCC/ARR/2014/JPN, paragraph 40), the ERT recommended to provide additional information on the annual number of vehicles by type, the annual mileage per vehicle and the fuel efficiency per vehicle type. The ERT also recommended to compare the annual mileage and fuel efficiency by vehicle category with the fuel consumption reported by the energy balance to ensure that no discrepancies occur.

The following tables show the annual number of vehicles by type, the annual mileage per vehicle and the fuel efficiency per vehicle type. Please note that not all these data are used for the estimation of the activity data as stated in the previous section.

Table 3-45 Annual number of vehicles by type

| Fuel | Vehicle type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | Light passenger vehicle | 1000 vehicles | 2,715 | 5,966 | 10,084 | 14,350 | 17,484 | 18,004 | 18,586 | 19,348 | 20,230 | 21,026 | 21,477 | 21,761 | 22,051 | 22,325 |
| | Passenger vehicle (non-hybrid) | | 29,140 | 33,891 | 37,794 | 40,104 | 38,142 | 37,594 | 37,099 | 36,178 | 35,023 | 33,793 | 32,685 | 31,733 | 30,688 | 29,525 |
| | Passenger vehicle (hybrid) | | NO | NO | NO | 253 | 971 | 1,404 | 2,017 | 2,851 | 3,823 | 4,685 | 5,559 | 6,544 | 7,513 | 8,453 |
| | Bus | | 8 | 3 | 2 | 5 | 8 | 9 | 10 | 11 | 13 | 14 | 15 | 16 | 16 | 17 |
| | Light cargo truck | | 12,312 | 11,377 | 9,958 | 9,548 | 9,171 | 8,923 | 8,873 | 8,784 | 8,708 | 8,624 | 8,520 | 8,421 | 8,345 | 8,322 |
| | Small cargo truck | | 2,820 | 2,144 | 1,901 | 1,988 | 1,857 | 1,826 | 1,813 | 1,788 | 1,772 | 1,760 | 1,750 | 1,750 | 1,747 | 1,742 |
| | Regular cargo truck | | 41 | 38 | 39 | 90 | 123 | 128 | 134 | 138 | 140 | 146 | 150 | 153 | 155 | 157 |
| | Special-purpose vehicle | | 141 | 198 | 393 | 330 | 291 | 287 | 287 | 290 | 291 | 293 | 297 | 299 | 302 | 304 |
| Diesel | Passenger vehicle | | 2,994 | 4,924 | 4,254 | 2,126 | 1,060 | 905 | 796 | 744 | 730 | 761 | 855 | 953 | 1,063 | 1,197 |
| | Bus | | 238 | 240 | 233 | 225 | 218 | 216 | 214 | 212 | 212 | 212 | 214 | 215 | 215 | 214 |
| | Small cargo truck | | 3,711 | 4,002 | 3,480 | 2,545 | 2,040 | 1,954 | 1,896 | 1,853 | 1,824 | 1,801 | 1,780 | 1,767 | 1,755 | 1,749 |
| | Regular cargo truck | | 2,164 | 2,544 | 2,534 | 2,350 | 2,142 | 2,105 | 2,091 | 2,086 | 2,100 | 2,116 | 2,130 | 2,151 | 2,169 | 2,197 |
| | Special-purpose vehicle | | 628 | 804 | 994 | 903 | 830 | 820 | 814 | 814 | 818 | 822 | 829 | 840 | 850 | 856 |
| LPG | All types | | 318 | 303 | 286 | 295 | 277 | 257 | 248 | 239 | 232 | 224 | 216 | 207 | 194 | 178 |
| Natural gas | Passenger vehicle | | 0.0 | 0.0 | 0.2 | 0.6 | 0.8 | 0.7 | 0.6 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 |
| | Bus | | NO | 0.0 | 0.3 | 1.1 | 1.3 | 1.2 | 1.2 | 1.1 | 0.9 | 0.8 | 0.7 | 0.6 | 0.4 | 0.3 |
| | Cargo truck | | 0.0 | 0.5 | 3.9 | 12.8 | 15.3 | 15.0 | 14.5 | 13.7 | 12.9 | 12.1 | 11.0 | 9.5 | 8.2 | 7.0 |
| | Special-purpose vehicle | | 0.0 | 0.2 | 1.5 | 4.8 | 5.8 | 5.6 | 5.4 | 5.2 | 4.9 | 4.4 | 3.9 | 3.3 | 2.8 | 2.3 |

Reference: *Statistics of AIRIA/ Number of Motor Vehicle* and Japan Gas Association

Table 3-46 Annual mileage per vehicle

| Fuel | Vehicle type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | Light passenger vehicle | 1000 km /vehicle | 5.8 | 6.8 | 7.2 | 7.4 | 7.6 | 7.6 | 7.4 | 7.6 | 7.4 | 7.5 | 7.5 | 7.8 | 8.0 | 8.1 |
| | Passenger vehicle (non-hybrid) | | 9.4 | 9.0 | 9.1 | 8.7 | 8.5 | 8.5 | 8.7 | 8.7 | 8.6 | 8.3 | 8.3 | 8.4 | 8.5 | 8.6 |
| | Passenger vehicle (hybrid)[1] | | NO | NO | NO | 10.1 | 10.1 | 10.2 | 9.7 | 10.3 | 10.0 | 10.3 | 10.5 | 10.3 | 10.4 | 10.5 |
| | Bus | | 11.9 | 9.3 | 9.0 | 8.6 | 9.9 | 34.7 | 22.8 | 15.8 | 14.9 | 14.2 | 14.5 | 13.6 | 12.9 | 12.7 |
| | Light cargo truck | | 7.4 | 7.9 | 8.0 | 8.2 | 8.4 | 8.4 | 8.2 | 8.6 | 8.9 | 9.0 | 8.9 | 9.1 | 9.0 | 8.8 |
| | Small cargo truck | | 10.3 | 9.5 | 10.3 | 10.5 | 11.0 | 12.2 | 12.7 | 13.0 | 13.1 | 13.2 | 13.1 | 12.3 | 12.2 | 12.3 |
| | Regular cargo truck | | 8.8 | 7.7 | 6.9 | 6.7 | 7.3 | 11.0 | 10.7 | 10.9 | 9.9 | 9.2 | 9.4 | 9.0 | 8.7 | 8.7 |
| | Special-purpose vehicle | | 4.7 | 3.5 | 3.3 | 3.9 | 5.2 | 9.9 | 9.5 | 9.4 | 8.9 | 8.4 | 8.3 | 8.1 | 8.2 | 8.3 |
| Diesel | Passenger vehicle | | 13.3 | 12.8 | 13.0 | 13.7 | 13.2 | 11.4 | 11.7 | 11.4 | 11.1 | 10.4 | 10.1 | 9.7 | 10.0 | 10.2 |
| | Bus | | 28.9 | 27.6 | 27.9 | 28.9 | 29.2 | 28.6 | 28.1 | 28.4 | 28.2 | 27.9 | 27.4 | 26.5 | 26.0 | 25.8 |
| | Small cargo truck | | 11.8 | 12.2 | 12.9 | 12.9 | 12.9 | 11.8 | 11.9 | 12.2 | 12.4 | 12.3 | 12.1 | 11.5 | 11.3 | 11.1 |
| | Regular cargo truck | | 26.7 | 26.8 | 28.6 | 29.5 | 30.5 | 29.9 | 29.2 | 28.5 | 28.1 | 27.9 | 27.9 | 27.5 | 27.4 | 27.2 |
| | Special-purpose vehicle | | 14.6 | 16.9 | 17.2 | 18.9 | 21.3 | 25.3 | 25.1 | 25.6 | 25.9 | 25.9 | 25.9 | 25.2 | 24.8 | 24.6 |
| LPG | All types | | 56.6 | 55.5 | 52.7 | 46.4 | 43.7 | 47.3 | 45.6 | 44.5 | 44.3 | 43.8 | 42.8 | 40.9 | 41.6 | 41.5 |
| Natural gas | Passenger vehicle | | 10.2 | 9.8 | 9.8 | 9.2 | 8.9 | 8.9 | 9.0 | 9.1 | 9.0 | 8.8 | 8.9 | 8.9 | 9.0 | 9.2 |
| | Bus | | NO | 47.6 | 45.9 | 44.9 | 43.8 | 43.3 | 42.0 | 42.5 | 41.9 | 41.3 | 39.9 | 38.3 | 37.2 | 36.7 |
| | Cargo truck | | 18.7 | 18.9 | 20.2 | 19.9 | 20.1 | 20.2 | 21.1 | 20.6 | 20.6 | 21.0 | 20.9 | 20.9 | 20.6 | 20.1 |
| | Special-purpose vehicle | | 11.1 | 11.2 | 12.0 | 11.8 | 11.9 | 12.0 | 12.3 | 12.5 | 12.7 | 12.7 | 12.6 | 11.8 | 11.7 | 11.6 |

Note: Estimated by dividing the distance traveled on Table 3-41 by number of vehicle on Table 3-42.
1) Due to absence of mileage statistical data, the values until FY2009 are assumed to be the mean value of FY2010-2014.

Table 3-47 Fuel efficiency per vehicle type

| Fuel | Vehicle type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | Light passenger vehicle | km/L | 14.2 | 12.9 | 12.0 | 12.6 | 12.3 | 12.6 | 12.8 | 13.0 | 13.3 | 13.5 | 13.7 | 14.0 | 14.1 | 14.4 |
| | Passenger vehicle (non-hybrid)[1] | km/L | 10.0 | 9.2 | 9.0 | 9.8 | 9.9 | 9.8 | 9.9 | 9.9 | 10.0 | 10.1 | 10.2 | 10.3 | 10.4 | 10.5 |
| | Passenger vehicle (hybrid) | km/L | NO | NO | NO | IE | IE | 16.3 | 16.1 | 16.2 | 15.7 | 15.5 | 16.0 | 16.2 | 16.5 | 16.9 |
| | Bus[2] | km/L | 4.1 | 3.9 | 4.1 | 4.3 | 4.5 | 5.8 | 6.0 | 6.2 | 6.5 | 6.7 | 6.8 | 7.1 | 7.3 | 7.6 |
| | Light cargo truck | km/L | 12.3 | 11.4 | 11.1 | 11.7 | 11.9 | 12.1 | 12.1 | 12.0 | 12.0 | 12.0 | 12.1 | 12.3 | 12.4 | 12.6 |
| | Small cargo truck[3] | km/L | 8.2 | 7.7 | 8.2 | 8.5 | 8.5 | 9.3 | 9.3 | 9.2 | 9.1 | 9.0 | 9.0 | 9.2 | 9.3 | 9.4 |
| | Regular cargo truck | km/L | 4.4 | 4.2 | 4.4 | 4.6 | 4.9 | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Special-purpose vehicle | km/L | 5.1 | 4.8 | 5.2 | 6.4 | 7.3 | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| Diesel | Passenger vehicle | km/L | 9.7 | 7.8 | 7.0 | 6.9 | 7.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.2 | 9.3 | 9.6 | 10.0 | 10.5 |
| | Bus | km/L | 3.6 | 3.4 | 3.4 | 3.6 | 3.7 | 3.6 | 3.6 | 3.5 | 3.5 | 3.5 | 3.6 | 3.5 | 3.6 | 3.6 |
| | Small cargo truck | km/L | 9.7 | 10.0 | 9.7 | 10.1 | 10.0 | 9.1 | 8.9 | 8.9 | 8.7 | 8.6 | 8.6 | 8.6 | 8.7 | 8.7 |
| | Regular cargo truck | km/L | 3.3 | 3.2 | 3.4 | 3.7 | 3.8 | 3.7 | 3.8 | 3.8 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 |
| | Special-purpose vehicle | km/L | 3.0 | 3.0 | 3.2 | 3.8 | 3.8 | 4.0 | 4.0 | 4.0 | 4.1 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| LPG | All types | km/L | 6.0 | 5.6 | 5.3 | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 | 5.3 | 5.4 | 5.4 | 5.5 | 5.5 | 5.6 |
| Natural gas | All types[4] | km/m$^3$ | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.2 | 4.1 | 4.2 | 4.2 | 4.2 | 4.2 | 4.1 | 4.1 |

Note: Mileage in *Statistical Yearbook of Motor Vehicle Fuel Consumption* and *Statistical Yearbook of Motor Vehicle Transport* are divided by fuel consumption in each statistics.

1) Hybrid passenger vehicle is included until FY2009.
2) Passenger car for business-noncargo-use and special-purpose car for private-noncargo-use are included since FY2010.
3) Regular cargo truck and special-purpose car for business cargo are included since FY2010.
4) Due to absence of fuel consumption statistical data, the values until FY2009 are assumed to be the same as the value of FY2010.

In regard to the relation between mileage and fuel consumption used for emission estimation, *Statistical Yearbook of Motor Vehicle Transport* and *Statistical Yearbook of Motor Vehicle Fuel Consumption* provide the annual total mileage, the fuel consumption (and the fuel efficiency derived from them). The annual total mileage from these statistics are used as a basis of the activity data to estimate $CH_4$ and $N_2O$ emissions. The $CO_2$ emissions are estimated by using *General Energy Statistics* (Japan's energy balance tables). *General Energy Statistics* uses the fuel consumption given in the above mentioned MLIT's statistics as primary statistics. Therefore, the same statistics are used as a basis in estimating both $CO_2$, $CH_4$ and $N_2O$ emissions.

### *e) Category-specific Recalculations*

New measurements of raw emission factors for vehicles were provided by JAMA. In response to the issue identified by QAWG in FY2017, additional measurements were provided by MOE, Bureau of Environment of Tokyo Metropolitan Government, NIES, NTSEL, and JPEC. The 2016 Regulation for diesel heavy-duty trucks and the 2018 Regulation for passenger vehicles were reflected into the estimation method. (However, the reflection of the 2018 Regulation is not regarded as the recalculation, because the regulation is applied for FY2018 onward.) Therefore, the emission factors were revised for gasoline hybrid passenger vehicles after FY2003, light passenger vehicles, gasoline passenger vehicles, gasoline small cargo trucks, diesel small cargo trucks and diesel regular cargo trucks after FY2005, and light cargo trucks after FY2007. In response to this revision, the $CH_4$ and $N_2O$ emissions for the period of FY2003-FY2017 were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

The emission factors will be reviewed, as appropriate, in order to represent Japan's circumstances more suitably.

## 3.2.9.2.b. Motorcycles

### *a) Category Description*

This section provides the estimation methods for $CH_4$ and $N_2O$ emissions from motorcycles.

### *b) Methodological Issues*

- ***Estimation Method***

The $CH_4$ and $N_2O$ emissions from motorcycles are established by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.14, Fig. 3.2.3). According to the Tier 3 method (Vol. 2, page 3.15, Equation 3.2.5), the equation indicates the aggregation of two types of emissions in different condition, one is the emissions in "hot" (running) condition when the engine is warm, and the other is "cold start" condition when the engine is cold at starting.

In Japan, the emission control regulation[15] for motorcycle has been established in 1999, and JAMA has collected the $CH_4$ and $N_2O$ emission data measured by test from "hot" and "cold start" condition engines of each type of emission controlled motorcycles. For these motorcycles, the emission factors are established from these measured data, and for emission uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used. The $CH_4$ and $N_2O$ emissions are estimated and aggregated by using the equations below.

$$E = \sum_{i,j} (EF_{hot,i,j} \times AD_{hot,i,j} + EF_{cold,i,j} \times AD_{cold,i,j})$$

| | |
|---|---|
| $E$ | : $CH_4$ and $N_2O$ emissions from motorcycles |
| $EF_{hot,i,j}$ | : Emission factor for vehicle-km by type of motorcycle and by emission control status |
| $AD_{hot,i,j}$ | : Total annual distance traveled by motorcycles by type and by emission control status |
| $EF_{cold,i,j}$ | : Emission factor per startup by type and by emission control status |
| $AD_{cold,i,j}$ | : Number of engine startups per year by each type of motorcycle and by emission control status |
| $i$ | : Vehicle type |
| $j$ | : Emission control status |

- ***Emission Factors***

➢ *"Hot" condition*

The $CH_4$ and $N_2O$ emission factors established by JAMA are used for the emission controlled motorcycles, and for uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used.

Table 3-48 $CH_4$ and $N_2O$ emission factors of motorcycle in "hot" condition [mg/km]

| Vehicle type (displacement) | 3rd Regulation[1)] | | 1st and 2nd Regulation[1)] | | Uncontrolled [2)] | |
|---|---|---|---|---|---|---|
| | $CH_4$ | $N_2O$ | $CH_4$ | $N_2O$ | $CH_4$ | $N_2O$ |
| Motor-driven cycles class 1 (50cc and under) | 2.1 | 0.18 | 13.3 | 2.64 | 53 | 4 |
| Motor-driven cycles class 2 (51cc-125cc) | 3.4 | 1.39 | 16.7 | 0.23 | | |
| Mini-sized motorcycles (126cc-250cc) | 6.7 | 0.18 | 12.5 | 0.85 | | |
| Small-sized motorcycles (Over 250cc) | 3.8 | 0.20 | 22.2 | 1.09 | | |

Note:
1) Data provided by JAMA
2) *2006 IPCC Guidelines*, Vol. 2, page 3.22, Table 3.2.3 Motorcycles/Uncontrolled/Running(hot)

➢ *"Cold start" condition*

The $CH_4$ and $N_2O$ emission factors established by JAMA are used for the emission controlled motorcycles, and for uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used.

[15] The regulated gases are CO, hydrocarbons (HC) and NOx.

Table 3-49 $CH_4$ and $N_2O$ emission factors for motorcycles in "cold start" condition [mg/start]

| Vehicle type (displacement) | 3rd Regulation 1) | | 1st and 2nd Regulation 1) | | Uncontrolled 2) | |
|---|---|---|---|---|---|---|
| | $CH_4$ | $N_2O$ | $CH_4$ | $N_2O$ | $CH_4$ | $N_2O$ |
| Motor-driven cycles class 1 (50cc and under) | 32.3 | 5.6 | 15.8 | 11.2 | 33 | 15 |
| Motor-driven cycles class 2 (51cc-125cc) | 41.7 | 18.9 | 18.3 | 4.2 | | |
| Mini-sized motorcycles (126cc-250cc) | 9.3 | 9.1 | 30.2 | 13.7 | | |
| Small-sized motorcycles (Over 250cc) | 35.0 | 11.8 | 26.1 | 6.9 | | |

Note:
1) Data provided by JAMA
2) *2006 IPCC Guidelines*, Vol. 2, page 3.22, Table 3.2.3 Motorcycles/Uncontrolled/cold start

- ***Activity Data***

➢ *"Hot" condition*

For the estimation of annual distance traveled by each vehicle type and by each emission control status, firstly and based on the number of owned vehicle by each vehicle type (*Monthly Report Statistics of Vehicle*s (JAMA)), the number of sold vehicle by each sales year and by each vehicle type (JAMA and Japan Light Motor Vehicle and Motorcycle Association) is multiplied by the survival ratio by each past year (Japan Automobile Research Institute, 2008), and then the ratio of number of owned vehicle of each year by each past year is obtained, and the number of owned vehicle by each sales year and by each vehicle type is calculated. Secondary, this number is multiplied by annual travel distance by each vehicle type per one vehicle (calculated from *Survey of Motorcycle Market Trends* (JAMA)) and multiplied by use factor by each vehicle type and by each past year (Japan Automobile Research Institute, 2007), then the annual travel distance by each sales year and by each vehicle type is obtained. The emission control status is judged by the sales year.

➢ *"Cold start" condition*

For the estimation of annual number of startup by each vehicle type and by emission control status, the number of owned vehicle by each vehicle type and by each emission control status, which is obtained through the calculation of "hot" condition activity data, is multiplied by annual number of startup by each vehicle type per one vehicle (calculated from *Survey of Motorcycle Market Trends*) and multiplied by use factor by each vehicle type and by each past year (Japan Automobile Research Institute, 2007), and then the annual number of startup by each sales year and by each vehicle type is obtained. The emission control status is judged by the sales year.

Table 3-50 Activity data of motorcycles

| Activity data | Vehicle type (Displacement) | Emission control by regulation | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Distance traveled | Motor-driven cycles class 1 (50cc and under) | 3rd regulation | Million vehicle-km | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 522 | 852 |
| | | 1st & 2nd regulation | | NO | NO | 1,773 | 4,165 | 3,919 | 3,643 | 3,182 | 3,092 | 3,325 | 3,248 | 2,829 | 2,646 | 1,905 | 1,428 |
| | | Uncontrolled | | 10,623 | 6,268 | 3,153 | 753 | 169 | 112 | 66 | 42 | 29 | 18 | 10 | 6 | 3 | 2 |
| | Motor-driven cycles class 2 (51cc-125cc) | 3rd regulation | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 531 | 1,081 |
| | | 1st & 2nd regulation | | NO | NO | 243 | 1,237 | 2,013 | 2,192 | 2,540 | 2,695 | 2,877 | 2,992 | 2,909 | 2,993 | 2,427 | 1,951 |
| | | Uncontrolled | | 2,060 | 1,853 | 1,568 | 686 | 238 | 172 | 131 | 91 | 61 | 39 | 23 | 14 | 8 | 5 |
| | Mini-sized motorcycles (126cc-250cc) | 3rd regulation | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 478 | 926 |
| | | 1st & 2nd regulation | | NO | NO | 565 | 2,664 | 3,194 | 3,127 | 3,025 | 3,053 | 3,141 | 3,208 | 3,268 | 3,277 | 2,494 | 2,131 |
| | | Uncontrolled | | 6,111 | 3,577 | 2,209 | 1,055 | 418 | 330 | 252 | 195 | 147 | 109 | 79 | 56 | 35 | 23 |
| | Small-sized motorcycles (over 250cc) | 3rd regulation | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 474 | 920 |
| | | 1st & 2nd regulation | | NO | NO | 317 | 1,662 | 2,637 | 2,751 | 2,781 | 2,952 | 2,883 | 3,037 | 3,471 | 3,568 | 2,896 | 2,552 |
| | | Uncontrolled | | 3,568 | 3,083 | 2,505 | 1,292 | 677 | 559 | 448 | 367 | 271 | 212 | 179 | 136 | 93 | 69 |
| Number of startup | Motor-driven cycles class 1 (50cc and under) | 3rd regulation | Million | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 110 | 179 |
| | | 1st & 2nd regulation | | NO | NO | 349 | 739 | 673 | 626 | 592 | 574 | 577 | 564 | 550 | 513 | 400 | 300 |
| | | Uncontrolled | | 1,838 | 1,131 | 621 | 134 | 29 | 19 | 12 | 8 | 5 | 3 | 2 | 1 | 1 | 0 |
| | Motor-driven cycles class 2 (51cc-125cc) | 3rd regulation | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 58 | 117 |
| | | 1st & 2nd regulation | | NO | NO | 31 | 140 | 209 | 228 | 245 | 259 | 274 | 285 | 325 | 334 | 264 | 212 |
| | | Uncontrolled | | 285 | 255 | 203 | 78 | 25 | 18 | 13 | 9 | 6 | 4 | 3 | 2 | 1 | 0 |
| | Mini-sized motorcycles (126cc-250cc) | 3rd regulation | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 28 | 54 |
| | | 1st & 2nd regulation | | NO | NO | 41 | 177 | 197 | 193 | 195 | 196 | 179 | 183 | 204 | 204 | 146 | 124 |
| | | Uncontrolled | | 361 | 223 | 159 | 70 | 26 | 20 | 16 | 13 | 8 | 6 | 5 | 4 | 2 | 1 |
| | Small-sized motorcycles (over 250cc) | 3rd regulation | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 10 | 20 |
| | | 1st & 2nd regulation | | NO | NO | 19 | 78 | 107 | 111 | 111 | 117 | 95 | 87 | 111 | 114 | 62 | 55 |
| | | Uncontrolled | | 187 | 177 | 154 | 60 | 28 | 23 | 18 | 14 | 9 | 6 | 6 | 4 | 2 | 1 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainty of the emissions from motorcycle is included and reported in "3.2.9.2.a Road transportation: vehicles other than motorcycles". Therefore, please refer to the description in the uncertainties of the section.

- ***Time-series Consistency***

The same estimation factors are used throughout the time-series. As for the activity data, the number of owned vehicle, travel distance per one vehicle, and number of startup per one vehicle are estimated using the data provided by JAMA, Japan Light Motor Vehicle and Motorcycle Association, and MOE by a consistent method throughout the time-series from FY1990 to the nearest year.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

The $CH_4$ and $N_2O$ emissions from motor-driven cycles for FY1999-2017 were recalculated, because the 3rd Regulation is reflected into the estimation method, the number of owned vehicle for FY2017 were obtained, the number of sold mini-sized motorcycles for FY2012 was updated, and the rounding of the emission factors of the 1st and 2nd Regulation was changed. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

## 3.2.9.3. Railways (1.A.3.c.)

### *a) Category Description*

This section provides the estimation methods for $CH_4$ and $N_2O$ emissions from railways. Emissions

from railways come mainly from diesel-engine railway cars. In addition, there are small amounts of emissions from coal-fired steam locomotives.

### *b) Methodological Issues*

- ***Estimation Method***

The emissions are calculated by using Tier 1 method in accordance with the *2006 IPCC Guidelines* (Vol. 2, page 3.41, Fig. 3.4.2).

$$E = \sum_i (EF_i \times AD_i)$$

$E$ : $CH_4$ and $N_2O$ emissions from railways
$EF_i$ : Emission factor of fuel consumption in railways by fuel type
$AD_i$ : Annual consumptions by fuel type
$i$ : Fuel type (diesel oil and coal)

- ***Emission Factors***

For emission factors for diesel-powered railway cars, the default values of "Diesel" shown in the *2006 IPCC Guidelines* are used after conversion to a per-liter value using the calorific value of diesel oil.

For the emission factors for steam locomotives, the default values of "sub-bituminous coal" shown in the *2006 IPCC Guidelines* are used after conversion to a per-weight value using the calorific value of imported steam coal.

Table 3-51 Default values for railway emission factors

| Gas | Unit | Diesel engines | Steam locomotives |
|---|---|---|---|
| $CH_4$ | kg-$CH_4$/TJ(NCV) | 4.15 | 2 |
| $N_2O$ | kg-$N_2O$/TJ(NCV) | 28.6 | 1.5 |

Reference: *2006 IPCC Guidelines*, Vol. 2, p. 3.43, Table 3.4.1

- ***Activity Data***

For the consumption of diesel oil by diesel engines in railways and coal consumption by steam locomotives, the diesel oil and coal consumption in the railway shown in the *General Energy Statistics* is used as activity data, respectively.

Table 3-52 Activity data used for estimation of emissions from railways

| Fuel type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diesel oil | 1000 kL | 356 | 313 | 270 | 248 | 225 | 218 | 211 | 211 | 205 | 199 | 198 | 189 | 189 | 189 |
| Coal | kt | 1.3 | 1.2 | 1.7 | 1.4 | 1.7 | 1.7 | 1.7 | 1.6 | 1.5 | 1.5 | 1.5 | 1.6 | 1.6 | 1.6 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

Since the default values in the *2006 IPCC Guidelines* are adopted for the emission factors of railways, the uncertainties indicated in the *2006 IPCC Guidelines* (-60% to +151% for $CH_4$ and -50% to +200% for $N_2O$) are adopted. Also, since the values in the *General Energy Statistics* are used for the activity data, the default values in the *2006 IPCC Guidelines* (-5% to +5%) are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions from railways is evaluated as -60% to +151% for $CH_4$ and -50% to +200% for $N_2O$.

- ***Time-series Consistency***

The same emission factors are used throughout the time-series. The data given in the *General Energy Statistics* are used as activity data consistently throughout the time-series.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

The emissions for FY2017 were recalculated due to a revision of the energy consumption of the *General Energy Statistics*. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

## 3.2.9.4. Domestic Navigation (1.A.3.d.)

### *a) Category Description*

This section provides the estimation methods for $CH_4$ and $N_2O$ emissions from domestic navigation of ships for passenger and freight transport.

### *b) Methodological Issues*

- ***Estimation Method***

The emissions were calculated by using Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.49, Fig. 3.5.1).

$$E = \sum_i (EF_i \times AD_i)$$

$E$ : $CH_4$ and $N_2O$ emissions associated with the navigation of domestic vessels
$EF_i$ : Emission factor of fuel consumption in domestic vessels
$AD_i$ : Consumption of each type fuel by domestic vessels
$i$ : Fuel type (diesel oil, fuel oil A, B and C)

- ***Emission Factors***

The default values for Ocean-Going Ships (diesel engines) given in the *2006 IPCC Guidelines* (see the following table) are converted to emission factors per liter using the calorific value for each type of fuel (diesel oil, fuel oil A, B and C).

Table 3-53 Default emission factors for navigation

| Gas | Emission factor |
|---|---|
| $CH_4$ | 7 [kg-$CH_4$/TJ(NCV)] |
| $N_2O$ | 2 [kg-$N_2O$/TJ(NCV)] |

Reference: *2006 IPCC Guidelines* Vol. 2, page 3.50, Table 3.5.3

- ***Activity Data***

The consumption of each fuel type in the domestic navigation taken from the *General Energy Statistics* is used for activity data.

Table 3-54 Activity data used for estimation of emissions from ships

| Fuel type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diesel oil | 1000 kL | 133 | 208 | 204 | 195 | 163 | 154 | 149 | 141 | 142 | 157 | 139 | 147 | 155 | 155 |
| Fuel oil A | 1000 kL | 1,602 | 1,625 | 1,728 | 1,324 | 946 | 1,007 | 969 | 1,006 | 994 | 984 | 980 | 1,010 | 1,005 | 991 |
| Fuel oil B | 1000 kL | 526 | 215 | 152 | 63 | 20 | 18 | 16 | 16 | 14 | 12 | 9 | 6 | 6 | 5 |
| Fuel oil C | 1000 kL | 2,446 | 3,002 | 3,055 | 2,873 | 2,420 | 2,482 | 2,460 | 2,517 | 2,487 | 2,482 | 2,386 | 2,361 | 2,332 | 2,360 |

- ***Completeness***

  According to the *2006 IPCC Guidelines* (Vol. 3, page 5.7), $CH_4$ and $N_2O$ emissions from use of lubricants are very small in comparison to $CO_2$, and these can be neglected for the greenhouse gas calculation. Therefore, the estimation is not done.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainties***

  Since the default values in the *2006 IPCC Guidelines* are adopted for the emission factors of domestic navigation, the uncertainties indicated in the *2006 IPCC Guidelines* (-50% to +50% for $CH_4$ and -40% to +140% for $N_2O$) are adopted. Also, since the values in the *General Energy Statistics* are used for the activity data, the default values in the *2006 IPCC Guidelines* (-13% to +13%) are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions from domestic navigation is evaluated as -52% to +52% for $CH_4$ and -42% to +141% for $N_2O$.

- ***Time-series Consistency***

  The same values for emission factors are throughout the time-series. The values given in the *General Energy Statistics* are used as activity data for domestic navigation consistently throughout the time-series from FY1990 to the nearest year.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

***e) Category-specific Recalculations***

The emissions for FY2017 were recalculated due to a revision of the energy consumption of the *General Energy Statistics*. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

There are no major planned improvements in this category.

### 3.2.9.5. Other Transportation (1.A.3.e.)

This subcategory is reported as “NO”, since fossil fuels are not combusted to transport materials by pipelines and no other activities to be reported are found.

## 3.2.10. $CO_2$ Emissions from Other Sectors and Other (1.A.4., 1.A.5: $CO_2$)

***a) Category Description***

This section provides the estimation methods for $CO_2$ emissions from the commercial/institutional

(1.A.4.a), residential (1.A.4.b), agriculture/forestry/fishing (1.A.4.c) and other (1.A.5) sectors. The emissions from fuel combustion for the national defense purpose are included in commercial/institutional (1.A.4.a).

In FY2018, $CO_2$ emissions from this category accounted for 139,247 kt-$CO_2$, and represented 11.2% of Japan's total GHG emissions (excluding LULUCF). The commercial/institutional (1.A.4.a) accounts for 51.5%, and is the largest subcategory within the "Other sectors" category in FY2018.

### *b) Methodological Issues*

- ***Estimation Method***

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2), as was the case for the energy industries (1.A.1). See 3.2.4. b).

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as "other fossil fuels" and "biomass" in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The $CO_2$ emissions from biomass are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

- ***Emission Factors***

The emission factors elaborated in the energy industries (1.A.1) were also used in this category. See 3.2.4. b).

- ***Activity Data***

The data given in the *General Energy Statistics* were used for activity data, as was the case for the energy industries (1.A.1).

The activity data for each sub-category were calculated by totaling the final energy consumption in the commercial industry (#650000), residential (#700000), and agriculture, forestry and fishery (#611000) sectors, energy consumption related to non-utility power generation for use in one's own offices (auto power generation: #25xxxx), and energy consumption related to steam production for use in own offices (auto steam generation: #26xxxx) shown in the *General Energy Statistics*. Because the final energy consumption above includes the amount of non-energy use which was used for purposes other than combustion (non-energy and feedstock use: #951100, #951800 and #952000), these values were deducted from the energy consumption in each category.

The energy consumption of each fuel in the agriculture, forestry and fishery (#611000) sector in the *General Energy Statistics* is classified to mobile combustion and stationary combustion according to the ratio in the Table 3-57, which is the survey results by MOE in FY2014 and FY2015. Please refer to the Table 3-56 for which category the emissions from mobile or stationary combustion to be allocated in the CRF table.

The auto power generation and auto steam generation sectors are included in the energy transformation

& own use sector in *General Energy Statistics*. However, the *2006 IPCC Guidelines* allocates $CO_2$ emissions from energy consumption for power or steam generation to the sectors generating that power or steam. As such, these $CO_2$ emissions are added to those from each office in the final energy consumption sector and are reported in 1.A.4.

Table 3-55 Energy consumptions in Other Sectors (1.A.4) (unit: PJ)

| Fuel | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liquid fuels | 1,939 | 2,093 | 2,200 | 2,231 | 1,568 | 1,581 | 1,515 | 1,423 | 1,451 | 1,356 | 1,299 | 1,286 | 1,293 | 1,174 |
| Solid fuels | 3 | 2 | 1 | 1 | 17 | 19 | 15 | 12 | 15 | 12 | 12 | 29 | 21 | 81 |
| Gaseous fuels | 418 | 537 | 649 | 731 | 835 | 835 | 847 | 826 | 836 | 832 | 846 | 850 | 909 | 862 |
| Other fossil fuels | 196 | 219 | 257 | 278 | 241 | 243 | 242 | 257 | 248 | 246 | 239 | 274 | 278 | 278 |
| Biomass | 15 | 18 | 22 | 44 | 52 | 59 | 62 | 63 | 65 | 73 | 84 | 64 | 68 | 72 |
| Total | 2,572 | 2,868 | 3,129 | 3,285 | 2,714 | 2,738 | 2,681 | 2,582 | 2,615 | 2,518 | 2,479 | 2,503 | 2,569 | 2,467 |

Table 3-56 Correspondence between sectors of Japan's Energy Balance Table and those of the CRF (1.A.4 and 1.A.5)

| CRF | | | General Energy Statistics | |
|---|---|---|---|---|
| 1A4 | Other sectors | | | |
| | 1A4a Commercial/institutional | | Auto power generation (except for Production, transmission and distribution of electricity [#255330] (until 2015), Agriculture, fishery, mining and construction [#251000] and Manufacturing [#252000]) | #255000 |
| | | | Auto steam generation (except for Agriculture, fishery, mining and construction [#261000] and Manufacturing [#262000]) | #265000 |
| | | | Final energy consumption; Commercial industry | #650000 |
| | | | Non-energy and feedstock use; Commercial | #951800 |
| | 1A4b Residential | | Final energy consumption; Residential | #700000 |
| | | | Non-energy and feedstock use; Household | #952000 |
| | 1A4c Agriculture/forestry/fishing | | | |
| | | i Stationary | Auto power generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery) | #251000 |
| | | | Auto steam generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery) | #261000 |
| | | | Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources (estimates) | |
| | | | Non-energy and feedstock use; Agriculture, fishery, mining and construction (agriculture, forestry and fishery) | #951100 |
| | | ii Off-road vehicles and other machinery | Final energy consumption; Agriculture [#611100]; mobile sources (estimates) | |
| | | | Final energy consumption; Forestry [#611200]; mobile sources (estimates) | |
| | | iii Fishing | Final energy consumption; Fishery, except aquaculture [#611300]; mobile sources (estimates) | |
| | | | Final energy consumption; Aquaculture [#611400]; mobile sources (estimates) | |
| 1A5 | Other | | NO | - |

Note: #95xxxx items are subtracted as non-energy use activities.

Table 3-57 Ratio of mobile and stationary combustion by fuel in the agriculture/forestry/fishing (1.A.4.c)

| Fuel | Agriculture | | Forestry | | Aquaculture | | | Fishery, except Aquaculture | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mobile com-bustion | Station-ary com-bustion | Mobile com-bustion | Station-ary com-bustion | Mobile com-bustion (ships) | Mobile com-bustion | Station-ary com-bustion | Mobile com-bustion (ships) | Mobile com-bustion | Station-ary com-bustion |
| Diesel oil | 99% | 1% | 100% | 0% | 0% | 100% | 0% | 0% | 100% | 0% |
| Fuel oil A | 5% | 95% | 0% | 100% | 100% | 0% | 0% | 100% | 0% | 0% |
| Kerosene | 2% | 98% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 100% |
| LPG and city gas | 5% | 95% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 100% |

Reference: MOE (2015a)

### *c) Uncertainties and Time-series Consistency*

See 3.2.4. c).

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2013-FY2017 years were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, $CO_2$ emissions from other fossil fuels for the period of FY2005-FY2017 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

## 3.2.11. $CH_4$ and $N_2O$ Emissions from Other Sectors and Other (1.A.4., 1.A.5: $CH_4$ and $N_2O$)

### *a) Category Description*

This section provides the estimation methods for $CH_4$ and $N_2O$ emissions from the commercial/institutional (1.A.4.a), residential (1.A.4.b), agriculture/forestry/fishing (1.A.4.c), and other (1.A.5) sectors.

This category also provides the estimation methods for determining $CH_4$ and $N_2O$ emissions from mobile combustion such as off-road vehicles, fishing boats and other machinery. The emissions from fuel combustion for the national defense purpose are included in commercial/institutional (1.A.4.a).

### *b) Methodological Issues*

- ***Estimation Method***

➢ *Furnaces*

For Commercial/institutional (1.A.4.a) and the stationary combustion in Agriculture/forestry/fishing (1.A.4.c), same with Energy Industries (1.A.1), $CH_4$ and $N_2O$ emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). See 3.2.5. b) (1.A.1).

➢ *Biomass boilers*

See 3.2.5. b) (1.A.1).

➢ *Residential*

For Residential (1.A.4.b), $CH_4$ and $N_2O$ emissions from fuel combustion in this category are calculated by using Tier 1 method, since furnace-specific activity data is not available.

➢ *Off-road vehicles and other machinery*

The emissions from mobile combustion in Agriculture/forestry/fishing (1.A.4.c) are estimated by Tier

1 in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 3.34, Fig. 3.3.1).

- ***Emission Factors***

➢ *Furnaces*

For Commercial/institutional (1.A.4.a) and the stationary combustion in Agriculture/forestry/fishing (1.A.4.c), the emission factors which were established in Energy Industries (1.A.1) were used. See Table 3-23 and Table 3-24 (1.A.1).

➢ *Biomass boilers*

See 3.2.5. b) (1.A.1).

➢ *Residential*

For Residential (1.A.4.b), the emission factors which were provided in the *2006 IPCC Guidelines* (Vol. 2, pages 2.22-2.23, Table 2.5) were used.

Table 3-58 $CH_4$ and $N_2O$ emission factors for residential (1.A.4.b)

| Furnace type | Fuel type | $CH_4$ Emission factor [kg-$CH_4$/TJ] | $N_2O$ Emission factor [kg-$N_2O$/TJ] |
|---|---|---|---|
| Household equipment | Liquid fuels | 9.5 | 0.57 |
| | Solid fuels | 290 | 1.4 |
| | Gaseous fuels | 4.5 | 0.090 |
| | Biomass fuels | 290 | 3.8 |

Note: Conversion to the GCV basis by multiplying the IPCC default values by 0.95 (liquid, solid and biomass fuels) or 0.9 (gaseous fuels) (*2006 IPCC Guidelines*, Vol.2, page 1.16)

➢ *Off-road vehicles and other machinery*

The emission factors of diesel oil used for the mobile combustion in agriculture, fishing and aquaculture were estimated from the values of "1.A.4.c.ii-Agriculture/ Diesel" in the Table 3-1 of EEA (2016). The emission factors of fuel oil A and kerosene used for agriculture were not shown in the guidebook but were applied the same value of diesel oil since most of the fuel oil A and kerosene are also used for tractors. The emission factors of LPG and city gas were estimated from the value of "LPG" in the same Table, and the emission factors of diesel oil for forestry were estimated from the values of "1.A.4.c.ii-Forestry/ Diesel" in the same Table.

The emission factors of fuel oil A used for fishing and aquaculture were estimated from the values on Table 3.5.3 "Default water-borne navigation $CH_4$ and $N_2O$ emission factors" in the *2006 IPCC Guidelines* vol. 2, page3.50.

Table 3-59 Emission factors of $CH_4$ and $N_2O$ for off-road vehicles and other machinery in agriculture/forestry/fishing (1.A.4.c)

| Fuel | Unit | $CH_4$ emission factor | $N_2O$ emission factor | Reference |
|---|---|---|---|---|
| Diesel oil, kerosene, fuel oil A used for other than ships | g/t | 87 | 136 | EEA (2016), Non-road mobile sources and machinery, Table 3-1 |
| Diesel oil for forestry | g/t | 49 | 138 | |
| LPG, city gas | g/t | 354 | 161 | |
| Fuel oil A for ships | kg/TJ(NCV) | 7 | 2 | *2006 IPCC Guidelines*, Vol.2, Table 3.5.3 |

- ***Activity Data***

➢ *Furnaces*

The fuel consumption, obtained by multiplying the fuel consumption of each sector and each fuel type in the *General Energy Statistics* by the ratio of stationary combustion in the Table 3-57 and the fuel consumption ratio by furnace type, is assumed to be the activity data for the stationary combustion namely combustion in furnaces. Same with Energy Industries (1.A.1), the fuel consumption ratios by furnace were estimated from data by furnace on the *General Survey of the Emissions of Air Pollutants* and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries, Structural Survey of Energy Consumption, Electric Power Statistics*, and *Current Survey of Production Concerning Gas Industry*). See 3.2.5. b) (1.A.1).

➢ *Biomass boilers*

See 3.2.5. b) (1.A.2).

➢ *Residential*

The fuel consumption by fuel type in the *General Energy Statistics* was used for the activity data of residential (1.A.4.b).

➢ *Off-road vehicles and other machinery*

The fuel consumption, estimated by multiplying the fuel consumption of each fuel type in Agriculture, Forestry and Fishery in the *General Energy Statistics* by the ratios of fuel consumption of mobile combustion (Table 3-57), were used for the activity data of mobile combustion namely off-road vehicles and other machinery.

### *c) Uncertainties and Time-series Consistency*

➢ *Furnaces (including biomass boilers)*

See 3.2.7. c).

➢ *Residential*

The uncertainties of the emission factors are set by the default values. The uncertainties of the activity data are set by the values established in section 3.2.4. c).

➢ *Off-road vehicles and other machinery*

See 3.2.7. c).

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since the activity data for FY2013-2017 in the *General Energy Statistics* were revised, the $CH_4$ and $N_2O$ emissions in those years were recalculated.

Updating the statistical data in the waste sector, $CH_4$ and $N_2O$ emissions in FY2017 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

See section 3.2.5. f).

## 3.2.12. Emissions from waste incineration with energy recovery

The three cases below in which waste is utilized as raw material or fuel meet the definition of emissions from waste incineration with energy recovery.

- Waste incineration with energy recovery
- Direct use of waste as alternative fuel
- Incineration of waste processed as fuel

The estimation method for emissions from these sources is applied for waste incineration (5.C) in accordance with the *2006 IPCC Guidelines*. The emissions are included in fuel combustion (1.A.) in accordance with the *2006 IPCC Guidelines.* Please refer to Chapter 7 for the details of the estimation methods.

The reporting category of the emissions for each type of waste is either “energy industries (category 1.A.1)”, “manufacturing industries and construction (1.A.2)” or “other sectors (1.A.4)” according to the use of waste as raw material or fuel. The fuel type is classified as “other fossil fuels” and “biomass”.

Greenhouse gas emissions during the direct use of waste as a raw material, such as plastics used as reducing agents in blast furnaces or as a chemical material in coking furnaces, or the use of intermediate products manufactured using the waste as a raw material, are also subject to the estimation of emissions.

Refuse-derived solid fuels (RDF: Refuse-Derived Fuel, RPF: Refuse Paper and Plastic Fuel) are also subject to the estimation of emissions as fuels produced from waste.

Table 3-60 Waste types whose emissions are estimated for "Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)"

| Category | Waste type | | | Fuel type to be allocated to CRF | Treatment type | | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|
| 1.A.1. (7.4.3.1)[7] | Municipal solid waste | Plastics | Fossil-fuel derived plastics | Other fossil fuels | Incineration with energy recovery | * Incinerator -continuous, -semi-continuous -batch type<br>* Gasification melting furnace | ○ | ○[2] | ○[2] |
| | | | Biomass-based plastics | Biomass[8] | | | NA[1] | | |
| | | Paper/ cardboard | Fossil-fuel derived fraction | Other fossil fuels[9] | | | ○ | | |
| | | | Biogenic fraction | Biomass | | | NA[1] | | |
| | | Nappy (Fossil-fuel derived fraction) | | Other fossil fuels | | | ○ | | |
| | | Textiles | Synthetic textile | Other fossil fuels | | | ○ | | |
| | | | Natural fiber | Biomass | | | NA[1] | | |
| | | Other (biogenic) | | Biomass | | | NA[1] | | |
| | Industrial solid waste | Waste oil | Fossil-fuel derived oil | Other fossil fuels | | Incinerator | ○ | ○ | ○ |
| | | | Animal and vegetable oil | Biomass | | | NA[1] | ○ | ○ |
| | | Plastics | Fossil-fuel derived plastics | Other fossil fuels | | | ○ | ○ | ○ |
| | | | Biomass-based plastics | Biomass[8] | | | NA[1] | IE[3] | IE[3] |
| | | Food waste [Animal and vegetable residues/animal carcasses] | | Biomass | | | NA[1] | ○ | ○ |
| | | Paper/ cardboard | Fossil-fuel derived fraction | Other fossil fuels[9] | | | ○ | IE[4] | IE[4] |
| | | | Biogenic fraction | Biomass | | | NA[1] | ○ | ○ |
| | | Wood | | Biomass | | | NA[1] | ○ | ○ |
| | | Textile | Synthetic textile | - | | | IE[5] | IE[5] | IE[5] |
| | | | Natural fiber | Biomass | | | NA[1] | ○ | ○ |
| | | Sludge | Sewage sludge | - | | | NO | NO | NO |
| | | | Other than sewage sludge | Biomass | | | NA[1] | ○ | ○ |
| | Specially controlled industrial waste | | | - | | | IE[5] | IE[5] | IE[5] |
| 1.A.1/2 (7.4.3.2)[7] | Municipal solid waste | Plastics | Fossil-fuel derived plastics | Other fossil fuels | Direct use as alternative fuel | | ○ | ○ | ○ |
| | | | Biomass-based plastics | Biomass[8] | | | NA[1] | IE[3] | IE[3] |
| | Industrial solid waste | Waste oil | Fossil-fuel derived oil | Other fossil fuels | | | ○ | ○ | ○ |
| | | | Animal and vegetable oil | Biomass | | | NA[1] | ○ | ○ |
| | | Plastics | Fossil-fuel derived plastics | Other fossil fuels | | | ○ | ○ | ○ |
| | | | Biomass-based plastics | Biomass[8] | | | NA[1] | IE[3] | IE[3] |
| | | Wood | | Biomass | | | NA[1] | ○ | ○ |
| | Waste tire | | Fossil-fuel derived fraction | Other fossil fuels | | | ○ | ○ | ○ |
| | | | Biogenic fraction | Biomass[8] | | | NA[1] | IE[6] | IE[6] |
| 1.A.1/2 (7.4.3.3)[7] | Refuse Derived Fuel (RDF) | | Fossil-fuel derived fraction | Other fossil fuels | Incineration of waste processed as fuel | | ○ | ○ | ○ |
| | | | Biogenic fraction | Biomass[8] | | | NA[1] | IE[6] | IE[6] |
| | Refuse Paper and Plastic Fuel (RPF) | | Fossil-fuel derived fraction | Other fossil fuels | | | ○ | ○ | ○ |
| | | | Biogenic fraction | Biomass[8] | | | NA[1] | IE[6] | IE[6] |

Note:

1) $CO_2$ emissions from the incineration of biomass-derived waste are not included in the total emissions; instead it is estimated as a reference value and reported as "Biomass" fuel in the CRF tables.
2) $CH_4$ and $N_2O$ emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported as "Other fossil fuels" in the CRF tables.
3) Included in fossil-fuel derived plastics in ISW
4) Included in biogenic fraction of paper/cardboard
5) Included in "Specially controlled industrial waste" incineration without energy recovery
6) Included in the fossil-fuel derived fraction
7) For details of categories to be reported in the CRF, see descriptions on each section.
8) For the biomass fraction in solid waste, etc. such as plastics, waste tire, RPF and RDF, it is difficult to distinguish the activity data on calorie basis for energy sector from the fossil-fuel derived fraction since there are no appropriate way to decompose calorimetric data of mixed solid waste. Hence, the activity data is reported as "IE", and is included in "other fossil fuels".
9) For the fossil-fuel derived fraction in "paper/cardboard", it is difficult to distinguish the activity data on calorie basis for energy sector from the biogenic fraction. Hence, the activity data is reported as "IE", and is included in "biomass".

Table 3-61 Reporting categories on the energy sector whose emissions are estimated for waste incineration and energy use

| Treatment type | Waste type | | Application breakdown | Major application | Reporting category on the energy sector | $CO_2$ [2] | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|
| Waste incineration with energy recovery | MSW | | (Unclassified) | Waste incineration with energy recovery | 1.A.4.a. Commercial/institutional | ○ | ○ | ○ |
| | ISW | | | | | ○ | ○ | ○ |
| Direct use of waste as alternative fuel | MSW Plastics | | Liquefaction | Fuel | 1.A.2.g. Other | ○ | ○ | ○ |
| | | | Blast furnace reducing agent | Reducing agent in blast furnace | 1.A.2.a. Iron & steel | ○ | NO[3] | NO[3] |
| | | | Coke oven chemical feedstock | Alternative fuel or raw material in coke oven | 1.A.1.c. Manufacture of solid fuels | ○ | IE[4] | NO[5] |
| | | | Gasification | Fuel | 1.A.2.g. Other | ○ | NE[6] | NE[6] |
| | Industrial waste | Waste oil | (Unclassified) | Fuel | 1.A.2.g. Other | ○ | ○ | ○ |
| | | Plastics | Blast furnace reducing agent | Blast furnace reducing agent | 1.A.2.a. Iron & steel | ○ | NO[3] | NO[3] |
| | | | Chemical industry | Boiler fuel | 1.A.2.c. Chemicals | ○ | ○ | ○ |
| | | | Paper industry | Boiler fuel | 1.A.2.d. Pulp, paper and print | ○ | ○ | ○ |
| | | | Cement burning | Cement burning | 1.A.2.f. Non-metallic minerals | ○ | ○ | ○ |
| | | | Automobile manufacturer | Boiler fuel | 1.A.2.g. Other | ○ | ○ | ○ |
| | | | Liquefaction | Fuel | 1.A.2.g. Other | ○ | ○ | ○ |
| | | | Gasification | Fuel | 1.A.2.g. Other | ○ | NE[6] | NE[6] |
| | | Wood | (Unclassified) | Fuel | 1.A.2.g. Other | NA | ○ | ○ |
| | Waste tire | | Cement burning | Cement burning | 1.A.2.f. Non-metallic minerals | ○ | ○ | ○ |
| | | | Boiler | Fuel | 1.A.2.g. Other | ○ | ○ | ○ |
| | | | Iron manufacture | Alternative fuel or raw materials in iron manufacturing | 1.A.2.a. Iron & steel | ○ | NO[3] | NO[3] |
| | | | Gasification | Fuel in iron manufacturing | 1.A.2.a. Iron & steel | ○ | ○ | ○ |
| | | | Metal refining | Fuel in metal refining | 1.A.2.b. Non-ferrous metals | ○ | ○ | ○ |
| | | | Tire manufacture | Fuel in tire manufacturing | 1.A.2.c. Chemicals | ○ | ○ | ○ |
| | | | Paper manufacture | Fuel in paper manufacturing | 1.A.2.d. Pulp, paper and print | ○ | ○ | ○ |
| | | | Power generation | Power generation | 1.A.4.a. Commercial/institutional | ○ | ○ | ○ |
| Incineration of waste processed as fuel | Refuse-derived fuel (RDF) | | (Unclassified) | Fuel use (including power generation) | 1.A.2.g. Other [1] | ○ | ○ | ○ |
| | Refuse paper and plastic fuel (RPF) | | Petroleum product manufacturer | boiler fuel | 1.A.1.b. Petroleum refining | ○ | ○ | ○ |
| | | | Chemical industry | boiler fuel | 1.A.2.b. Chemicals | ○ | ○ | ○ |
| | | | Paper industry | Fuel use in paper manufacturing | 1.A.2.d. Pulp, paper and print | ○ | ○ | ○ |
| | | | Cement manufacturer | Cement burning | 1.A.2.f. Non-metallic minerals | ○ | ○ | ○ |

Note:

1) Emissions from power generation and heat supply excluding in-house use should be included in the category 1.A.1.a. However, they are reported in the category 1.A.2.g., because the actual circumstances are not understood at the moment.
2) $CO_2$ emissions from the incineration of biomass-derived fraction are not included in the total emissions; instead it is estimated as a reference value and reported as "Biomass" fuel in the CRF tables. For detail, see Table 3-60.
3) Blast furnace gas generated from steel industry is entirely recovered.
4) These emissions are included in "solid fuels" in the same category 1.A.1.c.
5) $N_2O$ is likely not produced since the atmosphere in coke oven is normally at least 1,000 degree Celsius, and reducing.
6) Considering that small fraction of these sources is combusted as alternative fuel but these are mostly used to obtain feedstock for ammonia productions, the emissions are not estimated.

Table 3-62 shows the greenhouse gas emissions from waste incineration and energy use (reported on energy sector) (1.A.).

Table 3-62 GHG emissions from waste incineration and energy use (reported on energy sector) (1.A.)

| Gas | Item | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ [1)] | 1.A.1. Energy industries | a. Public electricity and heat production | kt-$CO_2$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | b. Petroleum refining | kt-$CO_2$ | NO | NO | 1 | 6 | 5 | 6 | 5 | 6 | 5 | 5 | 6 | 4 | 5 | 0 |
| | | c. Manufacture of solid fuels and other energy industries | kt-$CO_2$ | NO | NO | 15 | 241 | 206 | 242 | 232 | 235 | NO | 24 | 39 | 34 | 44 | 24 |
| | 1.A.2. Manufacturing industries and construction | a. Iron and steel | kt-$CO_2$ | NO | NO | 310 | 637 | 446 | 547 | 487 | 537 | 473 | 579 | 561 | 589 | 624 | 528 |
| | | b. Non-ferrous metals | kt-$CO_2$ | 119 | 63 | 51 | 17 | 2 | 2 | 2 | NO | NO | NO | NO | NO | NO | NO |
| | | c. Chemicals | kt-$CO_2$ | 14 | 64 | 89 | 67 | 67 | 73 | 72 | 84 | 82 | 65 | 68 | 63 | 65 | 63 |
| | | d. Pulp, paper and print | kt-$CO_2$ | NO | 56 | 114 | 998 | 1,662 | 1,726 | 1,747 | 1,772 | 1,853 | 1,905 | 1,952 | 2,001 | 2,065 | 2,091 |
| | | e. Food processing, beverages and tobacco | kt-$CO_2$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | f. Non-metallic minerals | kt-$CO_2$ | 197 | 492 | 879 | 1,088 | 1,391 | 1,324 | 1,355 | 1,359 | 1,455 | 1,639 | 1,593 | 1,714 | 1,780 | 1,965 |
| | | g. Other | kt-$CO_2$ | 3,870 | 4,464 | 4,425 | 5,768 | 5,237 | 5,526 | 5,379 | 5,625 | 5,508 | 5,257 | 5,648 | 5,305 | 5,339 | 5,145 |
| | 1.A.4 | a. Commercial/institutional | kt-$CO_2$ | 6,679 | 7,292 | 9,330 | 8,255 | 6,615 | 6,444 | 6,685 | 7,516 | 7,328 | 6,855 | 6,973 | 7,855 | 8,278 | 8,224 |
| | Total | | kt-$CO_2$ | 10,878 | 12,431 | 15,214 | 17,077 | 15,630 | 15,890 | 15,964 | 17,134 | 16,703 | 16,330 | 16,841 | 17,565 | 18,200 | 18,040 |
| $CH_4$ [2)] | 1.A.1. Energy industries | a. Public electricity and heat production | kt-$CH_4$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | b. Petroleum refining | kt-$CH_4$ | NO | NO | 1.7.E-06 | 1.8.E-05 | 1.3.E-05 | 1.6.E-05 | 1.3.E-05 | 1.5.E-05 | 1.3.E-05 | 1.4.E-05 | 1.7.E-05 | 1.2.E-05 | 1.4.E-05 | 8.6.E-07 |
| | | c. Manufacture of solid fuels and other energy industries | kt-$CH_4$ | NO | NO | IE | IE | IE | IE | IE | IE | NO | IE | IE | IE | IE | IE |
| | 1.A.2. Manufacturing industries and construction | a. Iron and steel | kt-$CH_4$ | NO | NO | NO | 7.7.E-04 | 1.4.E-03 | 1.4.E-03 | 1.3.E-03 | 1.3.E-03 | 1.2.E-03 | 1.4.E-03 | 1.4.E-03 | 1.4.E-03 | 1.6.E-03 | 1.7.E-03 |
| | | b. Non-ferrous metals | kt-$CH_4$ | 3.2.E-04 | 1.8.E-04 | 1.4.E-04 | 7.7.E-05 | 7.7.E-06 | 7.7.E-06 | 7.7.E-06 | NO | NO | NO | NO | NO | NO | NO |
| | | c. Chemicals | kt-$CH_4$ | 2.0.E-05 | 1.0.E-04 | 1.5.E-04 | 1.7.E-04 | 1.8.E-04 | 1.9.E-04 | 1.9.E-04 | 2.2.E-04 | 2.2.E-04 | 1.8.E-04 | 1.9.E-04 | 1.7.E-04 | 1.7.E-04 | 1.6.E-04 |
| | | d. Pulp, paper and print | kt-$CH_4$ | NO | 1.0.E-04 | 2.2.E-04 | 2.7.E-03 | 4.5.E-03 | 4.6.E-03 | 4.7.E-03 | 4.8.E-03 | 5.0.E-03 | 5.1.E-03 | 5.3.E-03 | 5.5.E-03 | 5.6.E-03 | 5.7.E-03 |
| | | e. Food processing, beverages and tobacco | kt-$CH_4$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | f. Non-metallic minerals | kt-$CH_4$ | 0.03 | 0.08 | 0.14 | 0.20 | 0.23 | 0.22 | 0.22 | 0.22 | 0.23 | 0.26 | 0.25 | 0.27 | 0.28 | 0.31 |
| | | g. Other | kt-$CH_4$ | 1.8 | 1.8 | 2.2 | 2.9 | 4.2 | 4.2 | 4.4 | 4.5 | 4.8 | 5.3 | 5.0 | 4.9 | 5.2 | 5.3 |
| | 1.A.4 | a. Commercial/institutional | kt-$CH_4$ | 0.54 | 0.54 | 0.60 | 0.15 | 0.14 | 0.14 | 0.17 | 0.17 | 0.15 | 0.15 | 0.14 | 0.15 | 0.15 | 0.15 |
| | Total | | kt-$CH_4$ | 2.3 | 2.4 | 3.0 | 3.3 | 4.6 | 4.6 | 4.8 | 4.9 | 5.2 | 5.7 | 5.4 | 5.4 | 5.7 | 5.8 |
| | | | kt-$CO_2$ eq. | 59 | 60 | 74 | 81 | 115 | 114 | 120 | 122 | 129 | 142 | 135 | 134 | 142 | 144 |
| $N_2O$ [2)] | 1.A.1. Energy industries | a. Public electricity and heat production | kt-$N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | b. Petroleum refining | kt-$N_2O$ | NO | NO | 1.1.E-05 | 1.2.E-04 | 8.3.E-05 | 1.0.E-04 | 8.3.E-05 | 1.0.E-04 | 8.1.E-05 | 9.0.E-05 | 1.1.E-04 | 8.0.E-05 | 9.1.E-05 | 5.6.E-06 |
| | | c. Manufacture of solid fuels and other energy industries | kt-$N_2O$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 1.A.2. Manufacturing industries and construction | a. Iron and steel | kt-$N_2O$ | NO | NO | NO | 9.1.E-04 | 1.6.E-03 | 1.6.E-03 | 1.5.E-03 | 1.5.E-03 | 1.5.E-03 | 1.7.E-03 | 1.6.E-03 | 1.7.E-03 | 1.9.E-03 | 2.0.E-03 |
| | | b. Non-ferrous metals | kt-$N_2O$ | 2.4.E-04 | 1.3.E-04 | 1.1.E-04 | 5.6.E-05 | 5.6.E-06 | 5.6.E-06 | 5.6.E-06 | NO | NO | NO | NO | NO | NO | NO |
| | | c. Chemicals | kt-$N_2O$ | 8.5.E-03 | 6.8.E-03 | 8.5.E-03 | 4.5.E-03 | 3.3.E-03 | 3.3.E-03 | 3.0.E-03 | 3.2.E-03 | 2.4.E-03 | 1.7.E-03 | 1.9.E-03 | 1.5.E-03 | 5.8.E-03 | 6.5.E-03 |
| | | d. Pulp, paper and print | kt-$N_2O$ | NO | 6.6.E-04 | 5.9.E-03 | 2.2.E-02 | 5.6.E-02 | 5.8.E-02 | 5.6.E-02 | 5.5.E-02 | 5.5.E-02 | 6.1.E-02 | 5.9.E-02 | 6.2.E-02 | 6.5.E-02 | 6.6.E-02 |
| | | e. Food processing, beverages and tobacco | kt-$N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | f. Non-metallic minerals | kt-$N_2O$ | 2.7.E-03 | 6.9.E-03 | 1.2.E-02 | 1.7.E-02 | 2.0.E-02 | 1.9.E-02 | 1.9.E-02 | 1.9.E-02 | 2.0.E-02 | 2.3.E-02 | 2.2.E-02 | 2.4.E-02 | 2.5.E-02 | 2.7.E-02 |
| | | g. Other | kt-$N_2O$ | 5.8.E-02 | 5.1.E-02 | 5.3.E-02 | 6.1.E-02 | 6.7.E-02 | 6.8.E-02 | 7.0.E-02 | 7.1.E-02 | 7.4.E-02 | 7.9.E-02 | 7.7.E-02 | 7.5.E-02 | 7.8.E-02 | 7.9.E-02 |
| | 1.A.4 | a. Commercial/institutional | kt-$N_2O$ | 1.2 | 1.3 | 1.6 | 1.2 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.1 | 1.0 |
| | Total | | kt-$N_2O$ | 1.3 | 1.4 | 1.7 | 1.3 | 1.1 | 1.1 | 1.1 | 1.2 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 |
| | | | kt-$CO_2$ eq. | 381 | 421 | 494 | 383 | 340 | 336 | 330 | 349 | 337 | 338 | 322 | 360 | 365 | 365 |

Note:

1) Include fossil-fuel derived component only.
$CO_2$ emissions from the incineration of biomass-derived waste (including biomass-based plastics and waste animal and vegetable oil) is not included in the total emissions in accordance with the *2006 IPCC Guidelines*; instead it is estimated as a reference value and reported under “Biomass” in CRF table 1.A(a).

2) Include both fossil-fuel derived component and biogenic component.

## 3.3. Fugitive Emissions from Fuels (1.B.)

The Fugitive Emissions subsector consists of intentional and unintentional GHG emissions from unburned fossil fuels during their mining, production, processing, refining, transportation, storage, and distribution, and from geothermal power plants.

There are two main source categories in this sector: solid fuels (1.B.1): emissions from coal mining and handling, and oil and natural gas (1.B.2): emissions from the oil and natural gas industries. The main source of emissions from solid fuels is $CH_4$ contained in coal bed, whereas fugitive emissions, venting, flaring, volatilization, and accidents are the main emission sources in the oil and natural gas industries. The emissions from geothermal power generation are also reported in 1.B.2.d.

In FY2018, GHG emissions from fugitive emissions from fuels were 1,155 kt-$CO_2$ eq. and accounted for 0.1% of Japan's total GHG emissions (excluding LULUCF). The emissions have decreased by 78% compared to 1990.

Table 3-63 Emission trends of the fugitive emissions subsector (1.B)

| Gas | CRF Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 1.B.1 Solid Fuels | a. Coal Mining | kt-$CH_4$ | 187.9 | 93.3 | 60.5 | 24.8 | 22.1 | 21.5 | 21.2 | 20.9 | 20.4 | 20.7 | 20.1 | 19.7 | 20.1 | 18.5 |
| | | b. Solid Fuel Transformation | | 2.5 | 2.5 | 2.0 | 1.3 | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 |
| | | c. Other (Uncontrolled Combustion and Burning Coal Dump) | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 1.B.2 Oil and Natural Gas | a. Oil | | 1.0 | 1.1 | 1.1 | 1.2 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 | 0.8 | 0.8 | 0.8 | 0.7 |
| | | b. Natural Gas | | 7.0 | 7.8 | 8.8 | 10.7 | 11.8 | 11.1 | 10.9 | 10.5 | 9.8 | 9.2 | 9.3 | 10.0 | 9.9 | 9.3 |
| | | c. Venting and Flaring | | 0.3 | 0.5 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | d. Other (Geothermal Generation) | | 0.2 | 0.8 | 0.7 | 0.7 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 |
| | Total | | kt-$CH_4$ | 198.9 | 105.9 | 73.4 | 39.1 | 36.7 | 35.4 | 34.7 | 34.0 | 32.6 | 32.2 | 31.5 | 31.8 | 32.0 | 29.6 |
| | | | kt-$CO_2$ eq. | 4,973 | 2,647 | 1,836 | 976 | 916 | 885 | 867 | 851 | 816 | 806 | 788 | 794 | 800 | 741 |
| $CO_2$ | 1.B.1 Solid Fuels | a. Coal Mining | kt-$CO_2$ | 5.3 | 2.4 | 1.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 |
| | | b. Solid Fuel Transformation | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| | | c. Other (Uncontrolled Combustion and Burning Coal Dump) | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 1.B.2 Oil and Natural Gas | a. Oil | | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | b. Natural Gas | | 0.6 | 0.7 | 0.8 | 1.0 | 1.1 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 | 0.8 | 0.9 | 0.9 | 0.8 |
| | | c. Venting and Flaring | | 81.2 | 109.1 | 122.6 | 164.3 | 258.2 | 221.7 | 224.0 | 232.2 | 221.6 | 209.8 | 223.3 | 245.2 | 264.7 | 242.3 |
| | | d. Other (Geothermal Generation) | | 104.4 | 409.2 | 386.6 | 341.9 | 241.0 | 251.2 | 251.9 | 256.5 | 215.2 | 237.9 | 200.1 | 210.5 | 170.0 | 170.0 |
| | Total | | kt-$CO_2$ | 192 | 521 | 512 | 508 | 501 | 475 | 477 | 490 | 438 | 449 | 425 | 457 | 436 | 414 |
| $N_2O$ | 1.B.1 Solid Fuels | a. Coal Mining | kt-$N_2O$ | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| | | b. Solid Fuel Transformation | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| | | c. Other (Uncontrolled Combustion and Burning Coal Dump) | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 1.B.2 Oil and Natural Gas | a. Oil | | IE,NA | IE,NA | IE,NA | IE,NA | IE,NA | IE,NA | IE,NA | IE,NA | IE,NA | IE,NA | IE,NA | IE,NA | IE,NA | IE,NA |
| | | b. Natural Gas | | | | | | | | | | | | | | | |
| | | c. Venting and Flaring | | 0.0004 | 0.0005 | 0.0004 | 0.0004 | 0.0004 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0002 |
| | | d. Other (Geothermal Generation) | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Total | | kt-$N_2O$ | 0.0004 | 0.0005 | 0.0004 | 0.0004 | 0.0004 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0002 |
| | | | kt-$CO_2$ eq. | 0.11 | 0.15 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 | 0.07 |
| | Total of all gases | | kt-$CO_2$ eq. | 5,165 | 3,169 | 2,347 | 1,484 | 1,417 | 1,359 | 1,345 | 1,341 | 1,255 | 1,255 | 1,212 | 1,251 | 1,236 | 1,155 |

### 3.3.1. Solid Fuels (1.B.1.)

### 3.3.1.1. Coal Mining and Handling (1.B.1.a.)

### 3.3.1.1.a. Underground Mines (1.B.1.a.i.)

#### *a) Category Description*

This category provides the estimation methods for $CH_4$ and $CO_2$ emissions from coal mining, post-mining process, and abandoned mines.

Coal contains $CH_4$ which was formed during the coalification process. Most will have been naturally released from the ground surface before mine development, but mining releases the $CH_4$ remaining in coal beds into the atmosphere. In addition, some of the coal mines still emit $CH_4$ after they have been

abandoned. Also, relatively low-density $CO_2$ is included in coal in comparison with $CH_4$, and is emitted to the air through the similar process with the $CH_4$.

The number of operational coal mines in Japan has decreased and coal production has decreased greatly as well. As a result, the amount of $CH_4$ emissions from coal mining has decreased year by year.

Furthermore, the coal mining practices have changed recently, resulting in the decreasing trend of $CH_4$ IEF. Specifically, coal is now mined in more shallow areas. Therefore, emitting less $CH_4$. This is because deep areas are costly to mine compared to coal in shallow areas. Additionally, areas which have been previously mined, thus already releasing $CH_4$, are re-mined for coal, using the latest technology. This contributes to low $CH_4$ emissions per amount of coal mined, even if compared with other countries.

***b) Methodological Issues***

- ***Estimation Method***

➢ *$CH_4$*

- ***Mining Activities***

$CH_4$ emissions from mining activities are drawn from actual measurements obtained from individual coal mines using the Tier 3 method, in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.11, Fig. 4.1.1).

- ***Post-Mining Activities***

$CH_4$ emissions from post-mining activities are estimated using the Tier 1 method, which uses default emission factors in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.11, Fig. 4.1.1). The emissions are estimated by multiplying the amount of coal mined from underground mines by the emission factor.

- ***Abandoned Underground Mines***

In accordance with the decision tree in the *2006 IPCC Guidelines* (Vol 2, page 4.1.1, Fig4.1.1) and by using the Tier 2 method, the $CH_4$ emissions from abandoned underground mines are estimated by multiplying the number of abandoned mines, which are not submerged, by emission factors which are established with consideration of types of coal and period of being abandoned as shown in the following equation.

$$E = N \times F \times ER \times EF \times CF, \quad EF = (1 + a \times T)^b$$

| | |
|---|---|
| *E* | : Amount of GHG fugitive emissions from abandoned coal mine [kt/year] |
| *N* | : Number of abandoned mines which was not submerged [sites] |
| *F* | : The percentage of mines that release fugitive emissions |
| *ER* | : GHG emissions from mines before mine closure [$m^3$/year] |
| *EF* | : Emissions reduction factor |
| *a*,*b* | : Parameters determining emission decline curve |
| *T* | : Time period of mine closure [year] |
| *CF* | : Gas density [kt/$m^3$] $CH_4$: $0.67\times10^{-6}$ |

➢ *$CO_2$*

- ***Mining Activities***

$CO_2$ emissions are estimated by multiplying the production amount of coal by $CO_2$ emission factor.

- ***Post-Mining Activities***

$CO_2$ emissions are estimated by multiplying the production amount of coal by $CO_2$ emission factor.

- ***Abandoned Underground Mines***

The estimation method of $CO_2$ emissions is similar to that of $CH_4$ described above, and the $CO_2$ emission factor is established based on $CH_4$ emission factor.

● ***Emission Factors***

➢ *$CH_4$*

- ***Mining Activities***

$CH_4$ emission factor for mining activities is established by dividing the total emissions of $CH_4$ gas identified in a survey by J-COAL (Japan Coal Energy Center), by the production volume of coal from underground mines.

From FY1991 to 1994, since actual measurement data cannot be obtained, the emission factors for those years are interpolated using FY1990 and 1995 values, which are established from actual measurements.

Table 3-64 Emission factors for mining activities –underground mines

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal production of underground mines | kt | 6,775 | 5,622 | 2,364 | 738 | 575 | 588 | 543 | 528 | 529 | 540 | 470 | 529 | 612 | 317 | Surveyed by J-COAL |
| $CH_4$ total emissions | 1000 $m^3$ | 262 | 92 | 57 | 4.2 | 2.1 | 2.0 | 1.8 | 1.8 | 1.9 | 2.3 | 2.4 | 2.4 | 2.9 | 1.5 | Surveyed by J-COAL |
| $CH_4$ total emissions | kt-$CH_4$ | 176 | 62 | 38 | 2.8 | 1.4 | 1.3 | 1.2 | 1.2 | 1.2 | 1.5 | 1.6 | 1.6 | 1.9 | 1.0 | =$CH_4$ [1000$m^3$] / 1000 × 0.67 [kt/$10^6m^3$] |
| Emission factor | kg-$CH_4$/t | 26 | 11 | 16 | 3.8 | 2.4 | 2.2 | 2.2 | 2.2 | 2.3 | 2.8 | 3.4 | 3.0 | 3.1 | 3.2 | $CH_4$ total emissions / coal production of underground mines |

- ***Post-Mining Activities***

Due to the lack of data for emissions from post-mining activities in Japan, the emission factors are calculated as 1.675 [kg-$CH_4$/t] by converting the average value (2.5 [$m^3$/t]) of the default values given in the *2006 IPCC Guidelines* with the density of $CH_4$ (0.67 [kt/$10^6m^3$]) at 20°C and 1 atmosphere.

- ***Abandoned Underground Mines***

To establish emission factor for abandoned underground mines, following values are used for the formula on the previous page;

The median of default values which is indicated in Table 4.1.5 in page 4.2.4 in the *2006 IPCC Guidelines* Vol.2 (1990-1925: 5%, 1926-1950: 26.5%, 1951-1975: 40%, 1976-2000: 54%, 2001-: 54.5%) are used for (*F*), the percentage of mines that release fugitive emissions.

The lower default value (1.3million cubic meter/year/site) indicated in Table 4.1.8 in page 4.27 in the *2006 IPCC Guidelines* Vol.2 is used for (*ER*), GHG emissions from mines before mine closure, by taking scale of mine into consideration.

The coefficients for sub-bituminous coal ($a$ = 0.27, $b$ = -1.00) indicated in Table 4.1.9 in page 4.27 in the *2006 IPCC Guidelines* Vol.2 are used for parameters to determine declining curve for emissions.

➢ *$CO_2$*

- ***Mining Activities***

$CO_2$ emission factor for mining activities is established by multiplying $CH_4$ emission factor (volume basis) by proportion of volume fraction of $CO_2$ in coalbed gas to that of $CH_4$ (0.0088), which is obtained

by using Hokkaido Development Agency (1965), and by $CO_2$ density (1.84kg/$m^3$).

- ***Post-Mining Activities***

In the same way as calculated for mining activities, the emissions factors for post-mining activities are established by multiplying $CH_4$ emission factor (volume basis) by 0.0088.

- ***Abandoned Underground Mines***

In the same way as calculated for mining activities, the emissions factors for post-mining activities are established by multiplying $CH_4$ emission factor (volume basis) by 0.0088.

● ***Activity Data***

- ***Mining Activities, Post-Mining Activities***

The values used for activity data for underground mining and post-mining activities are derived by subtracting the surface mining production from the total coal production as given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the data provided by J-COAL.

Table 3-65 Trends in coal production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total coal production | kt | 7,980 | 6,317 | 2,974 | 1,249 | 1,206 | 1,145 | 1,195 | 1,247 | 1,251 | 1,318 | 1,265 | 1,282 | 1,328 | 964 |
| Surface mines | | 1,205 | 695 | 610 | 511 | 631 | 557 | 652 | 719 | 721 | 778 | 795 | 753 | 716 | 647 |
| Underground mines | | 6,775 | 5,622 | 2,364 | 738 | 575 | 588 | 543 | 528 | 529 | 540 | 470 | 529 | 612 | 317 |

- ***Abandoned Underground Mines***

For activity data, the number of abandoned mines which were not submerged, estimated from the list of abandoned mine in J-COAL (2002).

Table 3-66 The number of abandoned mines which were not submerged

| Fiscal year of abandonment | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of abandoned coal mine without submergence | 39 | 34 | 28 | 48 | 12 | 32 | 91 | 103 | 61 | 46 | 33 | 42 | 21 | 42 | 29 |
| Fiscal year of abandonment | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1980 | 1987 | 1989 | 1992 | 1994 | 1995 | Total |
| Number of abandoned coal mine without submergence | 13 | 20 | 12 | 1 | 2 | 3 | 1 | 2 | 2 | 2 | 3 | 1 | 1 | 1 | 725 |

● ***Recovery and flaring***

- ***Mining Activities***

There is no flaring activity of $CH_4$ which has been emitted from the coal bed during mining in Japan, however there are activities of recovering $CH_4$ and using it as fuel. Therefore, the net amount of the emissions is estimated by subtracting the recovered value from the total $CH_4$ emissions. The values of recovery were provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* (1990-1997) and the data provided by J-COAL (since 1998).

Table 3-67 Trends in $CH_4$ recovery from mining activities

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Recovery | 1000 $m^3$ | 50,139 | 11,112 | 9,810 | 2,044 | 990 | 941 | 733 | 591 | 826 | 448 | 844 | 955 | 482 | 301 |

- ***Post-Mining Activities***

The $CH_4$ recovery/flaring are reported as “NE,” because the existence of such activities has not been confirmed,

- ***Abandoned Underground Mines***

Reported as "NO" since any activities for $CH_4$ recovery or flaring has not been implemented.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the uncertainties of $CH_4$ emissions during mining activities, the actual measurement values provided by J-COAL are used for reporting. However, it is difficult to evaluate the uncertainties of these data; therefore, for evaluating the uncertainties, the figures (combined the uncertainty due to measurement error and the uncertainty of error due to the change of flow rate, by using error propagation equation) given in the *2006 IPCC Guidelines* are used, and the uncertainties are established at -5% to +5%. For the uncertainties of $CO_2$ emissions during mining activity, the uncertainty of $CH_4$ emissions and the uncertainty of proportion of volume fraction of $CO_2$ in coalbed gas to that of $CH_4$, which is calculated using data provided by Hokkaido Development Agency are combined by error propagation equation, and the uncertainties are established at -19% to +19%.

For the uncertainties in $CH_4$ emission factors during post-mining activities, since the default values given in the *2006 IPCC Guidelines* are used for the estimation factors, the uncertainty values given in the *2006 IPCC Guidelines* (-33% to +300%) are used. For the uncertainties in $CO_2$ emission factors during post-mining activities, the uncertainty in $CH_4$ emission factors and the uncertainty in proportion of volume fraction of $CO_2$ in coalbed gas to that of $CH_4$, which is calculated using data provided by Hokkaido Development Agency are combined by error propagation equation, and the uncertainties are evaluated at -38% to +301%. For the uncertainties in activity data of $CH_4$ and $CO_2$, during post-mining activities, the actual measurement values provided by J-COAL are used for reporting. However, it is difficult to evaluate the uncertainties of these data; therefore, for evaluating the uncertainties, the figures given in the *2006 IPCC Guidelines* (-2% to +2%) are used, as a result, the uncertainties in emissions during post-mining activities are evaluated at -33% to +300% for $CH_4$ emissions and -38% to +301% for $CO_2$ emissions.

The uncertainties in $CH_4$ emissions from abandoned mines are established at -50% to +100% based on the description on the uncertainty in Tier 2 given in the *2006 IPCC Guidelines*. For the uncertainties in $CO_2$ emissions from abandoned mines, the uncertainties in $CH_4$ emissions and the uncertainties in proportion of volume fraction of $CO_2$ in coalbed gas to that of $CH_4$, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainties are evaluated at -53% to +102%.

- ***Time-series Consistency***

The $CH_4$ total emissions data for mining activities in underground mines are consistently derived from J-COAL statistics for FY1990 and since FY1995. From FY1991 to FY1994, time-series consistency is ensured by interpolating the emission factors.

The total coal production and coal production in surface mines are provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared from FY1990 to FY2000. Thereafter, they are provided by J-COAL, because the categories of surface mining production and total coal production in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* are no longer provided. The data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared until 2000 are provided by J-COAL. Therefore, the total coal production data from both of these sources are the same and are used in a consistent manner since FY1990.

The $CH_4$ recovery data for mining activities are consistent, as were the case for the total coal production and coal production in surface mines.

The numbers of abandoned coal mines, which are the activity data for the abandoned coal mines, are derived from the J-COAL (2002). The default values in the *2006 IPCC Guidelines* are used for the ratio of gas emitting coal mines, the amount of $CH_4$ emissions from the coal mine before the closure, and the parameters to determine the decreasing curve of the emissions. Also, the $CO_2$ emissions from the coal mine before closure are estimated from the $CH_4$ emissions by assuming the ratio of volume is constant, so that the time-series consistency is ensured.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

In order to ensure the safety of coal mine workers in Japan, monitoring the concentration of $CH_4$ and CO in coal mines is ordained by law. Under the law, mining companies must set rules on monitoring management. Mining companies monitor accurately under strict management and checks, and compile relevant reports. Furthermore, national authorities regularly check the monitoring measurements and safety reports.

***e) Category-specific Recalculations***

There have been no recalculations of emissions from this category.

***f) Category-specific Planned Improvements***

There are no major planned improvements in this category.

### 3.3.1.1.b. Surface Mines (1.B.1.a.ii.)

***a) Category Description***

This category provides the estimation methods for fugitive emissions of $CH_4$ and $CO_2$ occurring during coal mining and post-mining activities in surface mines. The emissions of $CH_4$ recovered/flared during coal mining in surface mines are reported as “NE,” because the existence of such activities has not been confirmed.

***b) Methodological Issues***

- ***Estimation Method***

➢ *$CH_4$*

- ***Mining Activities***

The $CH_4$ emissions from mining activities are calculated using the Tier 1 method and the default emission factor in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.18, Fig.4.1.2).

- ***Post-Mining Activities***

The $CH_4$ emissions from post-mining activities are calculated using the Tier 1 method and the default emission factor in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.18,

Fig.4.1.2).

Both are calculated by multiplying the amount of coal mined from surface mines by the relevant emission factor.

➢ *$CO_2$*

- ***Mining Activities***

$CO_2$ emissions are estimated by multiplying the production amount of coal by $CO_2$ emission factor.

- ***Post-Mining Activities***

$CO_2$ emissions are estimated by multiplying the production amount of coal by $CO_2$ emission factor.

● ***Emission Factors***

➢ *$CH_4$*

- ***Mining Activities***

The value of 0.804 kg-$CH_4$/t is used as emission factor for mining activities. It was derived by converting the average (1.2 $m^3$/t) of the default values given in the *2006 IPCC Guidelines*, using the concentration of $CH_4$ at one atmospheric pressure and 20°C (0.67 kt/$10^6m^3$).

- ***Post-Mining Activities***

The value of 0.067 kg-$CH_4$/t is used as emission factor for post-mining activities. It was derived by converting the average (0.1 $m^3$/t) of the default values given in the *2006 IPCC Guidelines*, using the concentration of $CH_4$ at one atmospheric pressure and 20°C (0.67 kt/$10^6m^3$).

➢ *$CO_2$*

- ***Mining Activities***

$CO_2$ emission factor for mining activities is established by multiplying $CH_4$ emission factor (volume basis) by proportion of volume fraction of $CO_2$ in coalbed gas to that of $CH_4$ (0.0088), which is obtained by using Hokkaido Development Agency (1965), and by $CO_2$ density (1.84 kg/$m^3$).

- ***Post-Mining Activities***

In the same way as calculated for mining activities, the $CO_2$ emissions factors for post-mining activities are established by multiplying $CH_4$ emission factor (volume basis) by 0.0088.

● ***Activity Data***

The figure for the surface production given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the data provided by the J-COAL were used as activity data for mining and post-mining activities (see Table 3-65).

***c) Uncertainties and Time-series Consistency***

● ***Uncertainties***

For the uncertainty in $CH_4$ emission factor during mining activities, since the default value given in the *2006 IPCC Guidelines* is used for emission factor, the uncertainty values given in the *2006 IPCC Guidelines* (-50% to +200%) are used. For the uncertainty in $CO_2$ emission factor during mining activities, the uncertainty in $CH_4$ emission factor and the uncertainty in proportion of volume fraction of $CO_2$ in coalbed gas to that of $CH_4$, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainty is calculated as

-53% to +201%. For the activity data of $CH_4$ and $CO_2$ during mining activities, the actually measured data provided by J-COAL are reported, however it is difficult to evaluate the uncertainty of the data. Therefore, the uncertainty values of -2% to +2% in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in emissions during mining were evaluated at -50% to +200% for $CH_4$ and -53% to +201% for $CO_2$.

For the uncertainty in $CH_4$ emission factor during post-mining activities, since the default value given in the *2006 IPCC Guidelines* is used for emission factor, the values given in the *2006 IPCC Guidelines* (-33% to +300%) are used. For the uncertainty in $CO_2$ emission factor during post-mining activities, the uncertainty in $CH_4$ emission factor and the uncertainty in proportion of volume fraction of $CO_2$ in coalbed gas to that of $CH_4$, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainties are evaluated at -38% to +301%. For activity data for $CH_4$ and $CO_2$ during post-mining activities, the actual measurement data provided by J-COAL are reported. However, it is difficult to evaluate the uncertainties in these data, the figures (-2% to +2%) given by the *2006 IPCC Guidelines* are used. As a result, the uncertainties in emissions during post-mining activities are evaluated at -33% to +300% for $CH_4$ and -38% to +301% for $CO_2$.

- ***Time-series Consistency***

The total coal production and coal production in surface mines were provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared from FY1990 to FY2000. Thereafter, they have been provided by J-COAL, because the categories of surface mining production and total coal production in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* are no longer provided. The data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared by METI until 2000 are provided by J-COAL. Therefore, the total coal production data from both of these sources are the same and have been used in a consistent manner since FY1990.

#### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

#### *e) Category-specific Recalculations*

There have been no recalculations of emissions from this category.

#### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

### 3.3.1.2. Solid Fuel Transformation (1.B.1.b.)

#### *a) Category Description*

This category provides the estimation methods for $CH_4$ emissions in the process of manufacturing charcoal in the oven; $CH_4$ emissions are released due to imperfect combustion of carbon contained wood material which is raw material of charcoal.

### b) Methodological Issues

- ***Estimation Method***

$CH_4$ emissions from manufacturing charcoal are estimated by multiplying production amount of charcoal by emission factor.

- ***Emission Factors***

The default value given in the *Revised 1996 IPCC Guidelines* (Vol.3, page 1.46, Table 1-14) is used since no default value for this category is provided in the *2006 IPCC Guidelines*. Because the production amount of charcoal is available as a statistical data, the emission factor (1000 kg/TJ) of emitted amount per produced amount in NCV is adopted.

- ***Activity Data***

The activity data is calculated by multiplying the production amount of charcoal by calorific value. The amount of charcoal production is obtained from *Basic Data for Special Forest Product* (Forestry Agency) and *Data for Charcoal* (Forestry Agency). For the calorific value, 30 MJ/kg quoted from the *Revised 1996 IPCC Guidelines* (Vol.3, page 1.46, Table 1-14) is adopted.

Table 3-68 The Production Amount of Charcoal

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Charcoal Production | t | 83,225 | 82,278 | 67,428 | 44,919 | 34,449 | 34,095 | 31,227 | 30,263 | 29,588 | 27,749 | 25,865 | 23,733 | 23,096 | 21,711 |

- ***Completeness***

$CO_2$ are also emitted by charcoal production, but the emissions are not estimated since they are bio-derived. The emissions by consuming charcoal are included in "1.A Fuel Combustion", however the $CO_2$ emissions are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

In Japan, the production of briquettes is considered to meet the description of the activity of solid fuel transformation. The process of coal briquette production includes introducing water to coal, and squeeze-drying it. Therefore, the process is not thought to involve any chemical reactions, but the emissions of $CO_2$, $CH_4$ or $N_2O$ cannot be denied. However, the emissions are not estimated as no actual measurement has been taken and no default value is provided.

### c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for emission factors, the default values given in the *Revised 1996 IPCC Guidelines* are used. However, since the uncertainties for emission factors for this category is not provided in the *Revised 1996 IPCC Guidelines*, the uncertainties (-67% to +233%, calculated by 95% confidence interval) for $CH_4$ emission factors for combustion of wood material provided in the *2006 IPCC Guidelines* are substituted.

As for activity data, the uncertainties are evaluated as -50% to +97% by synthesizing the uncertainties for charcoal production (weight base), which are not available in the *Basic Data for Special Forest Product* and then substituted by the uncertainties for coal production, and the uncertainties which are calculated by 95% confidence interval of charcoal calorific value provided in the *2006 IPCC Guidelines* with the error propagation method.

As a result, uncertainties for $CH_4$ emissions from charcoal production are evaluated as -84% to +252%.

- ***Time-series Consistency***

The reference of the charcoal production amount in FY1990, which is the *Data for Charcoal*, is different from the reference in and after FY1991, which is the *Basic Data for Special Forest Product*. However, both data are provided by the Forestry Agency and the data capturing ranges are set to be the same. The default values in the *Revised 1996 IPCC Guidelines* are used for the $CH_4$ calorific value and the emission factor throughout the time-series so that the consistency is ensured.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

***e) Category-specific Recalculations***

There have been no recalculations of emissions from this category.

***f) Category-specific Planned Improvements***

Surveys whether the default emission factors presented in the *Revised 1996 IPCC Guidelines* are suitable for Japan's circumstances, and studies of necessity in developing country-specific emission factors are necessary.

### 3.3.1.3. Others (Uncontrollable combustion and burning coal dumps) (1.B.1.c)

This category provides the estimation methods for $CO_2$ emissions generated by unintentional coal combustion due to mine fire.

As for FY1999, coal combustion was occurred by the fire in Ikejima Coal Mine. However, since the amount of combusted coal is not available, it is reported as "NE". As for other fiscal years, any fire resulted in coal combustion was not occurred; therefore, it is reported as "NO".

## 3.3.2. Oil, Natural Gas and Other Emissions from Energy Production (1.B.2.)

### 3.3.2.1. Oil (1.B.2.a.)

#### 3.3.2.1.a. Exploration (1.B.2.a.i.)

This category provides the estimation methods for fugitive emissions of $CO_2$, $CH_4$ and $N_2O$ from the exploratory drilling of oil fields.

In Japan, GHG emissions by the exploratory drilling of oil and natural gas fields are basically only from flaring. Therefore, the fugitive emissions associated with exploratory drilling are included in "1.B.2.c.Flaring.iii Flaring (Combined)".

"1.B.2.a.i. Exploration of Oil" and "1.B.2.b.1 Exploration of Natural Gas" are reported as "IE", because the fugitive emissions other than flaring are also conceptionally included in "1.B.2.c.Flaring.iii Flaring (Combined)" since the default emission factors in the *GPG (2000)*, which covers fugitive emissions other than flaring, are used in "1.B.2.c.Flaring.iii Flaring (combined)" as described later.

### 3.3.2.1.b. Production (1.B.2.a.ii.)

#### *a) Category Description*

This category provides the estimation methods for fugitive emissions of $CO_2$ and $CH_4$ occur at production of crude oil and in lowering measuring instrument into well at servicing of operating oil fields.

The emissions associated with fugitive emissions during oil production are estimated for offshore and onshore oil field. The emissions from operating oil fields occur in servicing are reported in "1.B.2.b.ii Production of Natural Gas" and not included in this category, because the activity data of number of wells in production is not able to be divided into the numbers of oil producing wells and natural gas producing wells.

#### *b) Methodological Issues*

- ***Estimation Method***

The fugitive emissions from oil production are estimated using the Tier 1 method, in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol. 2, page 4.39, Fig.4.2.2).

- ***Emission Factors***

- ***Production***

For emission factors for fugitive emissions from oil production, the default values for fugitive emissions of conventional oil from offshore and offshore oil fields, which are indicated in the *2006 IPCC Guidelines*, are used. As for emission factors for onshore fields, the medians of default values are used.

Table 3-69 Emission factors for fugitive emissions from oil production [$kt/10^3m^3$]

| | | $CH_4$ | $CO_2$ | $N_2O$ 3) |
|---|---|---|---|---|
| Conventional Oil | Fugitive emissions from offshore fields | $5.9\times10^{-7}$ | $4.3\times10^{-8}$ | NA |
| | Fugitive emissions from onshore fields | $1.8\times10^{-3}$ 1) | $1.3\times10^{-4}$ 2) | NA |

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.50, Table 4.2.4
Note:
1) The default value is $1.5\times10^{-6}$ - $3.6\times10^{-3}$
2) The default value is $1.1\times10^{-7}$ - $2.6\times10^{-4}$
3) Excluded from calculations, as the default value is "NA"

- ***Servicing***

As the fugitive emissions from the servicing of oil and natural gas wells are reported in "1.B.2.b.ii Production of natural gas", refer to that section for the emission factors as well.

- ***Activity Data***

- ***Production***

The amount of crude oil production by offshore and onshore oil field (excluding condensate[16]) is used for activity data.

The amount of condensate production in offshore gas field is estimated by multiplying the production amount of condensate by the percentage of production volume in offshore in total production volume of natural gas.

The estimated value above is deducted from total volume of domestic crude production in offshore oil

[16] Light, liquid hydrocarbon that is produced from natural gas wells associated with natural gas production

field to obtain the production amount of crude oil from offshore oil field (excluding condensate).
The production amount of crude oil in onshore oil field (excluding condensate) is estimated by deducting crude oil production in offshore (excluding condensate) from total amount of crude oil production (excluding condensate).

Total production volume of natural gas, crude oil, and condensate is obtained from the data given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*. The production amount of natural gas and crude oil from offshore is obtained from *Natural Gas Data Year Book* (Japan Natural Gas Association).

Table 3-70 Amount of oil production excluding condensate from offshore and onshore oil fields

| Item | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil production | offshore | 1000 kL | 175 | 391 | 167 | 76 | 91 | 78 | 76 | 72 | 70 | 82 | 76 | 67 | 70 | 70 |
| excluding condensate | onshore | 1000 kL | 245 | 232 | 218 | 295 | 218 | 215 | 208 | 209 | 195 | 180 | 164 | 152 | 141 | 125 |

- ***Servicing***

Because the fugitive emissions from the servicing of oil and natural gas wells are reported in "1.B.2.b.ii Production of natural gas", please refer to that section also for the activity data.

- ***Completeness***

In this category, the amount of crude oil production excluding condensate is used as activity data. The GHG emissions associated with condensate production are included in 1.B.2.b.ii and 1.B.2.b.iii, because emission factors of these categories include emission from condensate production.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainties for emission factors established in the *2006 IPCC Guidelines* (-100% to +100%) are used for emission factors for oil production, since the default values in the guidelines are used exclusively. For activity data, because the uncertainties of statistical data used as reference are not available, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used. As a result, the uncertainties for fugitive emissions of $CO_2$ and $CH_4$ from oil production are evaluated as -101% to +101% for each.

- ***Time-series Consistency***

Consistent values are used for emission factors from FY1990 to the nearest year, using the above-described method. The activity data for oil production are calculated by using the annual data from the *Yearbook of Mineral Resources and Petroleum Products*, the *Natural Gas Data Year Book* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* by the consistent estimation method throughout the time-series from FY1990 to the nearest year.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since the activity data for FY2017 in the *Natural Gas Data Year Book* were revised, the $CO_2$ and $CH_4$ emissions in that year were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

As for the fugitive emissions from the servicing of oil and natural gas wells, the correlative relationships between emissions and production volume of crude oil remains unclear when using estimation method in accordance with the *2006 IPCC Guidelines*, and it is likely that the result of the estimating dos not reflect the actual status. Therefore, the estimation method in the *GPG (2000)* is adopted. In the future, the background information regarding the *2006 IPCC Guidelines* estimation method will be collected, and if new information is obtained, the adoption of the estimation in the *2006 IPCC Guidelines* will be studied.

## 3.3.2.1.c. Transport (1.B.2.a.iii.)

### *a) Category Description*

This category provides the estimation methods for fugitive emissions of $CO_2$ and $CH_4$ occurring during the transportation of crude oil and condensate through pipelines, tank trucks, and tank cars to refineries.

### *b) Methodological Issues*

- ***Estimation Method***

The fugitive emissions from transport of crude oil and condensate are estimated using the Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.40, Fig.4.2.3) by multiplying the amount of crude oil and condensate production by the emission factors.

In this category, fugitive emissions from ocean transportation of crude oil which are produced at domestic offshore oil fields and are shipped from ocean to land, and the fugitive emissions from land transportation are estimated. Crude oil is transported on sea entirely by pipeline, and is not expected to generate any fugitive emissions from other transportation modes. Land transport includes a number of methods, including pipeline, tank trucks, and tank cars, but it is difficult to differentiate them statistically. For that reason, the emissions were estimated under the assumption that all of the produced oil is transported by tank trucks and rail cars.

- ***Emission Factors***

The default values given in the *2006 IPCC Guidelines* were used as emission factors.

Table 3-71 Emission factors for transportation of crude oil and condensate [$kt/10^3m^3$]

| Item | $CH_4$ | $CO_2$ | $N_2O$ |
|---|---|---|---|
| Oil Transport/ Tanker Trucks and Rail Cars | $2.5\times10^{-5}$ | $2.3\times10^{-6}$ | NA |
| Natural Gas Liquids Transport/ Condensate | $1.1\times10^{-4}$ | $7.2\times10^{-6}$ | ND |

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.50 and 4.53, Table 4.2.4
Note: $N_2O$ is excluded from calculations, as the default value is “NA” or “ND”.

- ***Activity Data***

The amount of oil and condensate production in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products*

*Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* are used as activity data for fugitive emissions from transport.

Table 3-72 Production of crude oil and condensate in Japan

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil production excluding condensate | 1000 kL | 420 | 623 | 386 | 370 | 310 | 293 | 284 | 281 | 265 | 262 | 240 | 219 | 210 | 195 |
| Condensate production | | 234 | 243 | 375 | 541 | 608 | 560 | 541 | 478 | 403 | 365 | 339 | 331 | 336 | 301 |
| Oil production (total) | | 655 | 866 | 761 | 911 | 917 | 853 | 824 | 759 | 668 | 626 | 578 | 549 | 546 | 496 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the uncertainty of emission factors for $CO_2$ and $CH_4$ fugitive emissions from transportation of crude oil and condensate, the values established in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values given in the guidelines are used exclusively. As for the uncertainty for activity data, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used since the uncertainties of statistical data used as reference are not available. As a result, the uncertainties for the $CO_2$ and $CH_4$ emissions from oil and condensate transport are evaluated to be -101% to +101% for each.

- ***Time-series Consistency***

For the emission factors, consistent values are used from FY1990 to the nearest year with the above-mentioned method. The activity data are calculated based on the annual data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* by a consistent method throughout the time-series from FY1990 to the nearest year.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

There have been no recalculations of emissions from this category.

### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

## 3.3.2.1.d. Refining / Storage (1.B.2.a.iv.)

### *a) Category Description*

This category provides the estimation methods for fugitive emissions of $CH_4$ occurring when crude oil is refined or stored at oil refineries.

The $CO_2$ emissions from this source are reported as “NE”. Refining/storage activities exist in Japan and

an extremely small amount of $CO_2$ is considered to be released into the atmosphere from these activities if $CO_2$ is included in crude oil. Because there are neither actual measurements of the $CO_2$ content of crude oil nor any default values for emission factors, $CO_2$ emissions from this source are not estimated.

### *b) Methodological Issues*

- ***Estimation Method***

- ***Oil Refining***

The fugitive emissions from oil refining are estimated using the Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol. 2, page 4.40, Fig. 4.2.3).

- ***Oil Storage***

For the fugitive emissions from oil storage, a country-specific emission factors can be used. Therefore, the emissions are estimated using these factors.

- ***Emission Factors***

- ***Oil Refining***

With respect to the emission factors for fugitive emissions during the refining process, the amount of $CH_4$ emitted during the crude oil refining process is considered to be negligible because no fugitive emission of $CH_4$ is likely to occur in Japan during crude oil refining at normal operation. For that reason, the lower limit of the default values shown in the *2006 IPCC Guidelines* is adopted.

Table 3-73 Emission factor during crude oil refining

| | Emission factor [kg-$CH_4/10^3m^3$] |
|---|---|
| Oil refining | $2.6\times10^{-6}$ |

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.53, Table 4.2.4
Note: The default value is $2.6\times10^{-6}$ - $41.0\times10^{-6}$

- ***Oil Storage***

Oil is stored in either corn-roof tanks or floating-roof tanks. All oil storage in Japan adopts floating-roof tanks, which means that the fugitive $CH_4$ emissions are considered to be very small. If fugitive $CH_4$ emissions were to occur, they could only occur by vaporization of oil left on the exposed wall wet with oil when the floating roof descends as the stored oil is removed; thus, the amount of fugitive $CH_4$ emissions would be small.

The Petroleum Association of Japan has conducted experiments relating to the evaporation of $CH_4$ from tank walls by making the model of floating-roof tank, and based on the result the $CH_4$ emissions are estimated.

The emission factor associated with the storage of crude oil is obtained by dividing the emissions estimated by the Petroleum Association (0.007 kt-$CH_4$/year as of 1998) by the amount of the crude oil put into the oil refining industry (from *General Energy Statistics*).

Table 3-74 Assumptions for calculation of emission factor during oil storage

| $CH_4$ emissions [kt-$CH_4$/year] | Input of crude oil to oil refining industry [$10^3$kL] | Emission factor [kt-$CH_4/10^3$kL] |
|---|---|---|
| $7\times10^{-3}$ | 242,861 | $2.9\times10^{-8}$ |

- ***Activity Data***

The values used for activity data during refining and storing are the values (in volume) of refined NGL (Natural Gas Liquids) and crude oil in the petroleum refining industry taken from the *General Energy*

*Statistics*.

Table 3-75 Amount of crude oil and NGL refined in Japan

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil and NGL refined | $10^6m^3$ | 204 | 241 | 242 | 241 | 210 | 209 | 197 | 197 | 200 | 189 | 188 | 191 | 184 | 177 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the uncertainties of emission factors for fugitive emissions of $CH_4$ from refining crude oil and NGL, the values shown in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. The uncertainties for activity data for the fugitive emissions from refining crude oil and NGL are evaluated to be -21% to +21% respectively by error propagation method using the uncertainties of the standard calorific value and statistics used for estimating consumption. However, since the uncertainties of statistical data used for estimating consumption (*Yearbook of Mineral Resources and Petroleum Products* and *Yearbook of the Current Survey of Energy Consumption*) are not available, the default values provided in the *2006 IPCC Guidelines* (the uncertainties associated with measurement of flow rate (excluding sales volumes)) are substituted. As a result, the uncertainties for $CH_4$ fugitive emissions associated with refining of crude oil and NGL are evaluated at -102% to +102% for each.

As for the uncertainties of emission factors for fugitive emissions of $CH_4$ during storage of crude oil and NGL, the country-specific values were used. However, it is difficult to evaluate uncertainties; therefore, the values evaluated in the *2006 IPCC Guidelines* (-100% to +100%) are applied. The uncertainties for activity data for the fugitive emissions during storage of crude oil and NGL are evaluated to be -21% to +21% respectively by error propagation method using the uncertainties of standard calorific value and statistics used for estimating consumption. However, since the uncertainties of statistical data used for estimating consumption (*Yearbook of Mineral Resources and Petroleum Products* and Y*earbook of the Current Survey of Energy Consumption*) are not available, the default values provided in the *2006 IPCC Guidelines* (the uncertainties associated with measurement of flow rate (excluding sales volumes)) are substituted. As a result, the uncertainties for $CH_4$ fugitive emissions associated with storage of crude oil and NGL are evaluated at -102% to +102% for each.

- ***Time-series Consistency***

Consistent values are used for emission factors from FY1990 to the nearest year by using above–mentioned method. The activity data for refining and storage are calculated using the data from the *General Energy Statistics*, by a consistent method throughout the time-series from FY1990 to the nearest year.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since the activity data for FY2017 in the *General Energy Statistics* were revised, the $CH_4$ emissions in that year were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

#### 3.3.2.1.e. Distribution of Oil Products (1.B.2.a.v.)

Petroleum products are distributed in Japan, and where $CO_2$ and $CH_4$ are dissolved, it is conceivable that either or both will be emitted as a result of the relevant activity. The level of $CO_2$ or $CH_4$ emitted by the activity is probably negligible in light of the composition of the petroleum products, but because there is no measurement of the $CO_2$ or $CH_4$ content in petroleum products, it is not currently possible to calculate emissions. The emissions are reported as “NE” due to the absence of default emission factors.

### 3.3.2.2. Natural Gas (1.B.2.b.)

The natural gas supply network and the inventory categorization of GHG fugitive emissions from each process of the network are shown in Figure 3-7.

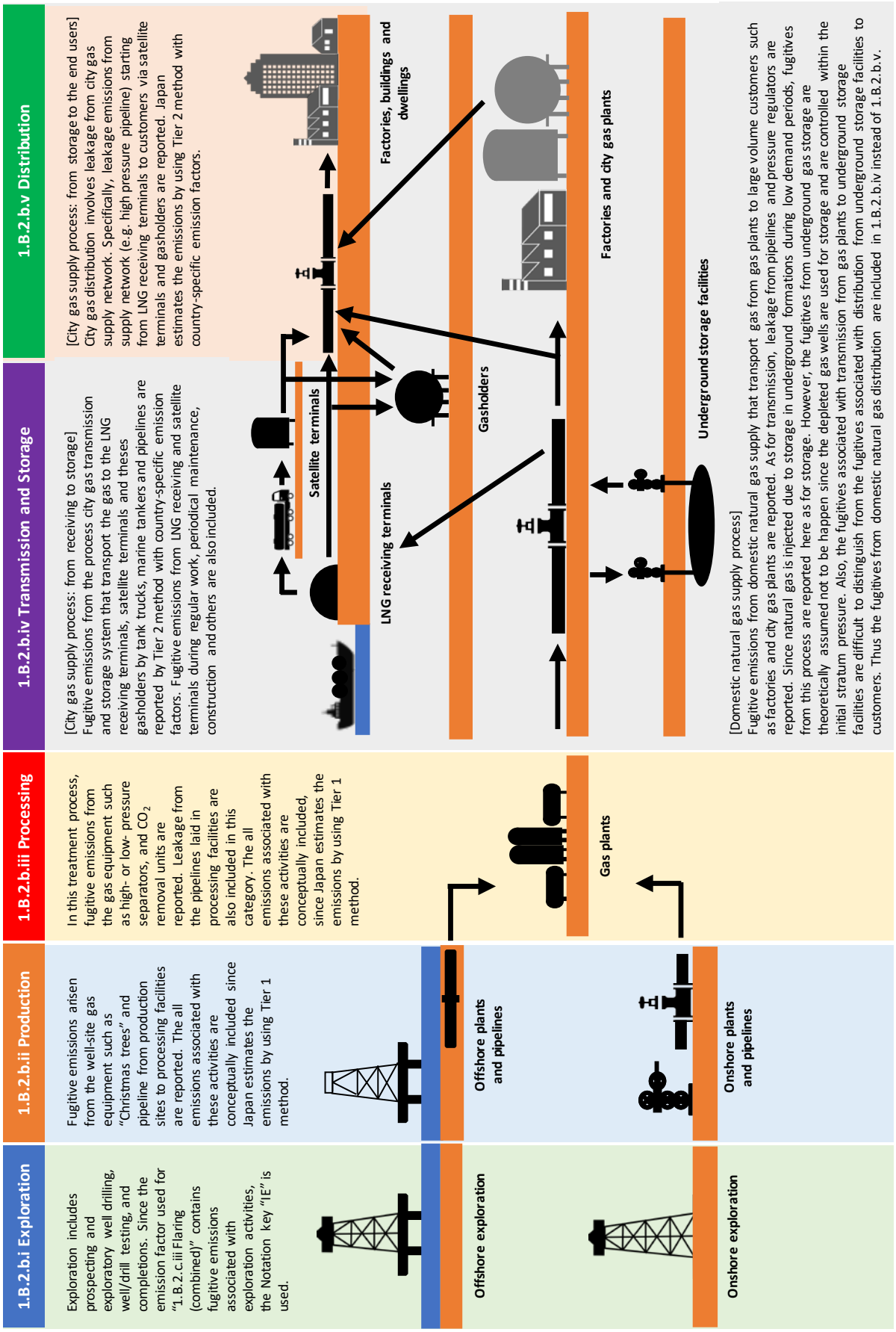


Figure 3-7 Supply network and inventory categorization of natural gas

### 3.3.2.2.a. Exploration (1.B.2.b.i.)

This category provides the estimation methods for fugitive emissions of $CO_2$, $CH_4$, and $N_2O$ from the explorative drilling of natural gas fields. As well as Exploration of oil (1.B.2.a.i), the emissions in this category are basically only from flaring. Also, it is difficult to distinguish between oil fields and gas fields prior to exploration. Therefore, the emissions are included in 1.B.2.c.Flaring.iii Flaring (combined). In addition, similar to the 1.B.2.a.1 Exploration of Oil, the fugitive emissions other than flaring would be also conceptually included in "1.B.2.c.Flaring.iii Flaring (Combined)". Therefore, the emissions from this category are reported here as "IE".

### 3.3.2.2.b. Production (1.B.2.b.ii.)

#### *a) Category Description*

This category provides the estimation methods for fugitive $CO_2$ and $CH_4$ emissions from natural gas production and from the lowering work of measuring instruments during the servicing of natural gas wells. The fugitive emissions from natural gas production are estimated by offshore oil fields and onshore oil fields.

#### *b) Methodological Issues*

- ***Estimation Method***

The fugitive emissions from the production of natural gas are estimated using Tier 1 method, in accordance with the *2006 IPCC Guidelines* (Vol. 2, page 4.38, Fig. 4.2.1).

For the fugitive emissions related to well servicing, the estimation method of multiplying the amount of crude oil production by emission factors is provided in the *2006 IPCC Guidelines*, however, in Japan, correlation between the amount of crude oil production and the emissions related to well servicing is not clear. Therefore, the Tier1 method provided in the *GPG (2000)* (the estimation method of multiplying the number of production wells by the emission factors), which is considered to be more appropriate for the actual status in Japan, is used

- ***Emission Factors***

- ***Production***

The default values given in the *2006 IPCC Guidelines* are used for the emission factors of fugitive emissions during the production of natural gas.

Table 3-76 Emission factors of fugitive emissions during production of natural gas [$kt/10^6m^3$]

| | | $CH_4$ | $CO_2$ | $N_2O$ |
|---|---|---|---|---|
| Natural gas production | Fugitive emissions from offshore field | $3.8\times10^{-4}$ | $1.4\times10^{-5}$ | NA |
| | Fugitive emissions from onshore field | $2.3\times10^{-3}$ | $8.2\times10^{-5}$ | NA |

Reference: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4
Note: $N_2O$ is excluded from calculations, as the default value is "NA".

- ***Servicing***

The default values for fugitive emissions during the servicing of natural gas production wells given in the *GPG (2000)* were used.

Table 3-77 Emission factors during servicing of natural gas production wells [kt/number of wells]

| | $CH_4$ | $CO_2$ | $N_2O$ |
|---|---|---|---|
| Production well (servicing) | $6.4\times10^{-5}$ | $4.8\times10^{-7}$ | 0 |

Reference : *GPG (2000)* Table 2.16
Note: $N_2O$ is excluded from calculations, as the default value is 0 (zero)

- ***Activity Data***

- ***Production***

The production volume of natural gas from offshore in the *Natural Gas Data Year book* is used for the production volume of natural gas from offshore gas field. The production volume of natural gas from onshore gas field is estimated by subtracting the production volume of natural gas from offshore gas field above from the total production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

- ***Servicing***

Because it is impossible to statistically differentiate between oil fields and natural gas fields in the time-series, the total number of oil fields and natural gas fields are used for the estimation. As for activity data for fugitive emissions from well servicing, the number of natural gas and oil wells in production provided in *Natural Gas Data Year Book* is used. As for the latest fiscal year, the values in the previous fiscal year are provisionally used.

Table 3-78 Natural gas production and the number of natural gas and oil wells in production

| Item | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Natural gas production | offshore | $10^6m^3$ | 342 | 374 | 350 | 361 | 191 | 188 | 190 | 196 | 196 | 197 | 190 | 176 | 148 | 148 |
| | onshore | | 1,724 | 1,863 | 2,149 | 2,779 | 3,364 | 3,155 | 3,144 | 2,981 | 2,744 | 2,549 | 2,525 | 2,621 | 2,777 | 2,508 |
| | total | | 2,066 | 2,237 | 2,499 | 3,140 | 3,555 | 3,343 | 3,334 | 3,177 | 2,940 | 2,746 | 2,715 | 2,797 | 2,926 | 2,657 |
| Number of gas and oil wells in production | | well | 1,230 | 1,205 | 1,137 | 1,115 | 1,049 | 1,046 | 1,047 | 1,038 | 1,059 | 1,046 | 1,034 | 1,019 | 1,001 | 1,001 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the uncertainties of emission factors for fugitive emissions of $CO_2$ and $CH_4$ from production of natural gas, the values provided in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties for statistical data used as reference are not available. As a result, the uncertainties of fugitive emissions of $CO_2$ and $CH_4$ from production of natural gas are evaluated to be -101% to +101% for each.

For the emission factors related to servicing of production well, the values established in the *GPG (2000)* (-25% to +25%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values established in the *2006 IPCC Guidelines* (-25% to +25% of the uncertainties associated with the factor of production facility number) are used, since the uncertainties for statistical data used as reference are not available. As a result, the uncertainties of fugitive emissions of $CO_2$ and $CH_4$ from servicing of production well are determined to be -35% to +35% for each.

- ***Time-series Consistency***

Consistent values are used for emission factors from FY1990 to the nearest year by using the above-mentioned method. The activity data are calculated by using the data on the production volume of natural gas from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* and on the number of oil/natural gas wells from the *Natural Gas Data Year Book.* A consistent method is used throughout the time-series from FY1990 to the nearest year.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since the activity data for FY2017 in the *Natural Gas Data Year Book* were revised, the $CO_2$ and $CH_4$ emissions in that year were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

## 3.3.2.2.c. Processing (1.B.2.b.iii.)

### *a) Category Description*

This category provides the estimation methods for fugitive $CO_2$ and $CH_4$ emissions from the processing of natural gas including adjustment of its constituent elements

### *b) Methodological Issues*

- ***Estimation Method***

The fugitive emissions associated with processing natural gas are estimated using Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.38, Fig.4.2.1).

- ***Emission Factors***

For the emission factors for the fugitive emissions during processing of natural gas, the median values between upper limit and lower limit indicated in the *2006 IPCC Guidelines* are used.

Table 3-79 Emission factors during natural gas processing [$kt/10^6m^3$]

| | | CH4 | CO2 | N2O [3)] |
|---|---|---|---|---|
| Natural gas processing | Fugitive emissions from sweet gas plant | $7.55\times10^{-4}$ [1)] | $2.35\times10^{-4}$ [2)] | NA |

Reference: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4
Note:
1) The default value of $CH_4$ is $4.8\times10^{-4}$ - $10.3\times10^{-4}$
2) The default value of $CO_2$ is $1.5\times10^{-4}$ - $3.2\times10^{-4}$
3) Excluded from calculations, as the default value is “NA”.

- ***Activity Data***

The production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand*

*of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* is used as activity data during processing. (Refer to Table 3-78).

***c) Uncertainties and Time-series Consistency***

- ***Uncertainties***

For the uncertainties of emission factors for fugitive emissions of $CO_2$ and $CH_4$ during natural gas processing, the values provided in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties of the statistical data used are not available. As a result, the uncertainties of fugitive emissions of $CO_2$ and $CH_4$ during natural gas processing are evaluated to be -101% to +101% for each.

- ***Time-series Consistency***

The default values are consistently used for emission factors from FY1990 to the nearest year. The activity data during natural gas processing are calculated by using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*. A consistent method is used throughout the time-series from FY1990 to the nearest year.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

***e) Category-specific Recalculations***

There have been no recalculations of emissions from this category.

***f) Category-specific Planned Improvements***

There are no major planned improvements in this category.

### 3.3.2.2.d. Transmission and Storage (1.B.2.b.iv.)

***a) Category Description***

This category provides the estimation methods for $CH_4$ emissions from transmission of domestically produced natural gas, such as the release of gas when relocating and building pipelines, and the release of gas used to operate pressure regulators, and provides the estimation methods for $CH_4$ emissions from storage facilities of natural gas, such as the emissions occurring by normal operation, regular maintenance, and construction works in receiving domestic LNG (liquefied natural gas) facilities, city gas production facilities, and satellite facilities.

The $CO_2$ emissions in this source are reported as “NA”. Approximately 90% of city gas is based on LNG and is free of $CO_2$. However, domestically produced natural gas from some of Japan’s natural gas

strata contains $CO_2$. Because nearly all of this $CO_2$ is removed at the natural gas production plants before the gas is sent to pipelines, thus almost no $CO_2$ in natural gas is emitted from natural gas pipelines, and the natural gas provided by city gas suppliers most likely contains no $CO_2$. The $CO_2$ emissions removed at natural gas production plants are included in venting (gas) (1.B.2.c.Venting.ii).

### *b) Methodological Issues*

- ***Estimation Method***

$CH_4$ emissions from transmission of natural gas are estimated by multiplying the sales volume of natural gas by the country-specific emission factors.

$CH_4$ emissions from storage facilities of natural gas are estimated by multiplying the amount of LNG and natural gas, which are utilized as raw material for city gas, by the country-specific emission factors.

- ***Emission Factors***

- ***Transmission***

$CH_4$ emissions associated with the release of gas from the facilities of Japan Natural Gas Association member companies in relocating and building of pipelines have been surveyed in FY2004, FY2008 and onward; and $CH_4$ emissions associated with the release of gas used to operate pressure regulators have been surveyed in FY2004, FY2011 and onward by Japan Natural Gas Association. To establish country-specific emission factors for Japan, the results of the surveys are used.

The emission factors for emissions from relocating and building of pipelines, and for emissions from the release of gas used to operate pressure regulators are estimated respectively as shown in the following Table 3-80 and the total values are applied to the emission factors. For the sales volume of natural gas which is used for establishing emission factors, the data are sourced from the member companies of Japan Natural Gas Association and provided by the association.

Table 3-80 The method of estimating emission factors of natural gas transmission

<table>
<tr><th>Fiscal year</th><th>Relocation and building work of pipeline</th><th>Release of gas used to operate pressure regulators</th></tr>
<tr><td>1990 - 2003</td><td colspan="2">The same value as FY2004 is consistently used.</td></tr>
<tr><td>2004</td><td colspan="2">Estimated by dividing the actual $CH_4$ emissions in FY2004 by the sales volume of natural gas in the same fiscal year.</td></tr>
<tr><td>2005 - 2007</td><td>Estimated by interpolating the emission factor in FY2004 and that in FY2008 which is estimated by the same method as FY2004.</td><td rowspan="2">Estimated by interpolating the emission factor in FY2004 and that in FY2011 which is estimated by the same method as FY2004.</td></tr>
<tr><td>2008 - 2010</td><td>Estimated by dividing the actual $CH_4$ emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.</td></tr>
<tr><td>2011 -</td><td colspan="2">Estimated by dividing the actual $CH_4$ emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.</td></tr>
</table>

As a result of the above estimation, the emission factors in each fiscal year are estimated as shown on the Table 3-81.

Table 3-81 The estimation result of emission factors of natural gas transmission [t-$CH_4/10^6m^3$]

| Item | -2004 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipeline relocation & installation | 0.220 | 0.190 | 0.100 | 0.071 | 0.037 | 0.073 | 0.062 | 0.070 | 0.115 | 0.217 | 0.077 | 0.129 |
| Gas for operating pressure regulators | 0.087 | 0.077 | 0.038 | 0.028 | 0.018 | 0.013 | 0.009 | 0.005 | 0.001 | 0.001 | 0.001 | 0.001 |
| Total | 0.306 | 0.267 | 0.138 | 0.099 | 0.056 | 0.087 | 0.071 | 0.075 | 0.116 | 0.218 | 0.078 | 0.131 |

- ***Storage***

The emission factor is calculated by dividing the $CH_4$ emissions actually measured during regular maintenance or construction in the major LNG receiving terminals, city gas production facilities, and satellite terminals in Japan, by the calorific value of the raw material input such as LNG and natural gas. The emission factor calculated using the FY1998 data is 905.41 [kg-$CH_4$/PJ], while that calculated using the FY2007 data is 264.07 [kg-$CH_4$/PJ]. The main reason of such change in emission factor is the reduction in $CH_4$ emissions, which is due to the progress in reduction measures such as the installation of new sampling and recovery lines used for gas analyses (changes to gas recovery lines from atmospheric dispersion) in LNG receiving terminals and city gas production facilities. Because the measures to reduce $CH_4$ emissions have been implemented gradually, the emission factors for the period from FY1999 to FY2006 are set by linear interpolation. At present, measures to reduce $CH_4$ emissions have been generally implemented, thereby affording little expectation of any major change in the emission factor for the time being. Therefore, the FY2007 emission factor value is kept for FY2008 and subsequent years.

- ***Activity Data***

- ***Transmission***

The sales volume of natural gas provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* is used for activity data.

Table 3-82 Sales amount of natural gas

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Natural gas sales amount | $10^6m^3$ | 2,067 | 2,339 | 2,617 | 3,329 | 3,918 | 4,020 | 4,208 | 3,928 | 3,790 | 3,792 | 3,709 | 3,806 | 4,000 | 3,980 |

- ***Storage***

The amount of LNG and natural gas used as raw material for city gas, provided in the *General Energy Statistics*, is used for activity data

Table 3-83 LNG and natural gas used for the feedstock of city gas

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LNG consumption with city gas production | PJ | 464 | 676 | 864 | 1,230 | 1,424 | 1,531 | 1,574 | 1,592 | 1,555 | 1,567 | 1,567 | 1,641 | 1,665 | 1,635 |
| Natural gas consumption with city gas production | PJ | 40 | 48 | 61 | 86 | 127 | 115 | 118 | 112 | 107 | 106 | 103 | 101 | 96 | 85 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

A country-specific emission factor is used for $CH_4$ emissions from transmission of natural gas, however, since it is difficult to assess the uncertainties, the established values in the *2006 IPCC Guidelines* (-100% to +100%) are applied. As for activity data, because the uncertainties of statistical data used as reference are not available, the established values in the *2006 IPCC Guidelines* (-2% to +2% of the uncertainties associated with measurement of flow rate (sales volumes)) are applied. As a result, the uncertainties of fugitive emissions of $CO_2$ and $CH_4$ from natural gas transmission are assessed to be -100% to +100%.

For the emission factors for fugitive $CH_4$ emissions associated with storage of natural gas, a country-

specific emission factor is used; however, since it is difficult to assess the uncertainties, the values established in the *2006 IPCC Guidelines* (-20% to +500%) are applied. As for the activity data, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties for statistical data used as reference are not available. As a result, the uncertainties of $CH_4$ fugitive emissions from natural gas storage are assessed to be -25% to +500%.

- ***Time-series Consistency***

Regarding emission factors for transmission of natural gas in and after FY2004, the values are established by dividing the measured emissions by corresponding natural gas production amount for the fiscal years when emission measurement was implemented. For fiscal years when emission measurement was not implemented, emission factors are established by interpolating. For emissions before FY2003, the established values for FY2004 are used for all fiscal years. In addition, the natural gas sales volume used for activity data is provided in the *Yearbook of Production Supply and Demand of Petroleum, Cool and Coke*, in the *Yearbook of Mineral Resources and Petroleum Products Statistics* and in the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

For emission factors for storage of natural gas, as described above and based on the emission factors established from the survey in FY1998 and FY2007, the emission factor for FY1998 is used for before FY1997, the emission factor for FY2007 is used for FY2008 and onward, and the emission factors for FY1999-2006 are established by interpolation using the FY1998 and FY2007 factors.

To ensure the consistency, the figures provided in the *General Energy Statistics* are adopted consistently for activity data of LNG and natural gas which are used as raw material of city gas.

#### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

#### *e) Category-specific Recalculations*

Since the activity data for FY2013-2017 in the *General Energy Statistics* were revised, the $CH_4$ emissions in those years were recalculated. See Chapter 10 for impact on trend.

#### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

### 3.3.2.2.e. Distribution (1.B.2.b.v.)

#### *a) Category Description*

This category provides the estimation methods for $CH_4$ emitted from city gas supply networks.

In Japan, liquefied petroleum gas, coal, coke, naphtha, crude oil, and natural gas are refined and blended at gas plants into gas, which, after being conditioned to produce a certain calorific value, is supplied to urban areas through gas lines. Such gas fuel is called “city gas”, of which more than 90% is LNG-based. As for detail of city gas, please refer to the explanation of city gas emission factor in 3.2.1.b.

Methodological issues (Figure 3-4 , Table 3-16, etc.).

The emissions from $CO_2$ in this source are reported as "NA". More than 90% of the city gas is based on LNG and is free of $CO_2$. However, domestically produced natural gas from some of Japan's natural gas strata contains $CO_2$. Because nearly all of this $CO_2$ is removed at the natural gas production plants before the gas is sent to pipelines, the natural gas provided by city gas suppliers most likely contains no $CO_2$. The emissions of $CO_2$ removed at natural gas production plants are included in the venting (gas) (1.B.2.c.Venting.ii).

### *b) Methodological Issues*

- ***Estimation Method***

$CH_4$ emissions from high-pressure pipelines, from medium- and low-pressure pipelines and holders, and from service pipes are calculated by multiplying the sales volume of city gas by the country-specific emission factors.

- ***Emission Factors***

The emission sources in the supply of domestically produced city gas are (i) high-pressure pipelines, (ii) medium- and low-pressure pipelines and holders, and (iii) service pipes. The $CH_4$ emissions from the city gas pipelines of general gas companies calculated from the actual data by each emission source are shown in Table 3-84. The value of $9.5\times10^{-6}$ kt-$CH_4$/$10^6m^3$, which is obtained by dividing the $CH_4$ emissions (292 t-$CH_4$) by the city gas amount sold by general gas companies in the same fiscal year of $30{,}696\times10^6m^3$ (Reference: *Current Survey of Production Concerning Gas Industry*), is used for the emission factor per sales amount.

Table 3-84 $CH_4$ emissions from city gas pipelines (FY2004 actual data)

| Emission sources | | $CH_4$ emissions[t/year] |
|---|---|---|
| High-pressure pipelines | New pipeline installation, and pipeline relocation | 180 |
| Medium- and low-pressure pipelines and holders | Construction, demolition, fugitive emissions, inspection of governor and others, holder construction, and overhauling | 93 |
| Service pipes | Installation of service pipes, post-installation purging, removal, change of meters, fugitive emissions, go around for opening valves and regular maintenance, and equipment repairs (mainly the emissions occur when the work is done at user sites (homes)) | 19 |

- ***Activity Data***

The city gas sales amount in calorific value in the *Current Survey of Production Concerning Gas Industry* is divided by the calorific value per volume in the *General Energy Statistics* to get the amount in volume, and the result is used for the activity data. The city gas sales amount is classified as industrial use, commercial use, residential use and other use. As the activity data include all of them, the emissions from city gas supplied to industrial plants are included in the estimation.

Table 3-85 The sales amount of city gas

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| The sales amount of city gas | PJ | 643 | 877 | 1,064 | 1,419 | 1,546 | 1,644 | 1,691 | 1,688 | 1,667 | 1,681 | 1,671 | 1,738 | 1,779 | 1,740 |
| Calorific value per volume | $MJ/m^3$ | 41.9 | 41.9 | 41.1 | 44.8 | 44.8 | 44.8 | 44.8 | 44.8 | 40.8 | 40.8 | 40.7 | 40.7 | 40.8 | 40.0 |
| The sales amount of city gas in volume | $10^6m^3$ | 15,367 | 20,952 | 25,899 | 31,684 | 34,516 | 36,705 | 37,738 | 37,686 | 40,894 | 41,226 | 41,073 | 42,721 | 43,607 | 43,521 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For emission factor in $CH_4$ fugitive emissions accompanied by city gas distribution, country-specific

figure is used. However, it is difficult to evaluate the uncertainties in this figure; therefore, values (-20% to +500%) provided in the *2006 IPCC Guidelines* are adopted. As for activity data, since it is unable to evaluate the uncertainties in statistical data used as reference, the setting values (-2% to +2% of the uncertainties associated with measurement of flow rate (sales volumes)) given in the *2006 IPCC Guidelines* are adopted. As a result, the uncertainties in $CH_4$ fugitive emissions accompanied by city gas distribution are evaluated at -20% to +500%.

- ***Time-series Consistency***

For the emission factor, the consistent value is used from FY1990 to the nearest year, by using the above-mentioned method. The activity data are calculated using the data from the *Current Survey of Production Concerning Gas Industry* with a consistent method throughout the time-series from FY1990 to the nearest year.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

***e) Category-specific Recalculations***

Since the activity data for FY2013-2017 in the *General Energy Statistics* were revised, the $CH_4$ emissions in those years were recalculated. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

There are no major planned improvements in this category.

### 3.3.2.2.f. Industrial plants and power station / residential and commercial sectors (1.B.2.b.vi.)

The conceivable sources of these $CH_4$ emissions include gas pipe work in buildings, but because these emissions are included in those of “Natural Gas Distribution” (distribution through the city gas network) (1.B.2.b.v), $CH_4$ emissions from this source are reported as “IE.” Additionally, because $CO_2$ is basically not included among the city gas constituents, the $CO_2$ emissions from this source are reported as “NA.”

### 3.3.2.3. Venting and Flaring (1.B.2.c.)

This section includes fugitive emissions of $CO_2$ and $CH_4$ occurring from venting during oil field development, crude oil transportation, refining processes, and product transportation in the petroleum industry, as well as during gas field development, natural gas production, transmission, and processing in the natural gas industry.

It also includes $CO_2$, $CH_4$ and $N_2O$ emissions from flaring during the above processes.

### 3.3.2.3.a. Venting (Oil) (1.B.2.c.Venting.i.)

***a) Category Description***

This category provides the estimation methods for $CO_2$ and $CH_4$ emissions from venting in the

petroleum industry.

### *b) Methodological Issues*

- ***Estimation Method***

The emissions from venting in the petroleum industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.39, Fig. 4.2.2) by multiplying the amount of crude oil production by the default emission factors.

- ***Emission Factors***

The default values for conventional oil given in the *2006 IPCC Guidelines* were used for the emission factors of oil field venting.

Table 3-86 Emission factors of oil field venting

| | | $CH_4$ | $CO_2$ | $N_2O$ |
|---|---|---|---|---|
| Oil production/ Conventional oil | Venting [kt/1000 $m^3$] | $7.2\times10^{-4}$ | $9.5\times10^{-5}$ | NA |

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.50, Table 4.2.4
Note: $N_2O$ is excluded from calculations, as the default value is "NA"

- ***Activity Data***

The production volume of oil in Japan given in its *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, *Yearbook of Mineral Resources and Petroleum Products Statistics* and *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* is used as activity data of the fugitive emissions from oil field venting. The production of condensate was excluded from the calculation (see Table 3-72).

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the uncertainties in emission factors for $CO_2$ and $CH_4$ fugitive emissions from venting (oil), since the default values given in the *2006 IPCC Guidelines* are used for emission factors, the uncertainty values (-50% to +50%) provided in the *2006 IPCC Guidelines* are used. As for activity data, it is unable to evaluate the uncertainties in statistical data used as reference, the setting values (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) provided in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in $CO_2$ and $CH_4$ fugitive emissions from venting (oil) are evaluated at -52% to +52% for each.

- ***Time-series Consistency***

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke,* the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics,* by a consistent method throughout the time-series from FY1990 to the nearest year.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

There have been no recalculations of emissions from this category.

### *f) Category-specific Planned Improvements*

There have been no major planned improvements in this category.

## 3.3.2.3.b. Venting (Gas) (1.B.2.c.Venting.ii.)

### *a) Category Description*

This category source deals with $CO_2$ emissions accompanied by separation and diffusion of $CO_2$ which is contained in natural gas produced in natural gas production facilities when $CO_2$ contents does not meet the standard of non-combustion gas content provided by users.

As for other emission source in this category, intentional $CO_2$ and $CH_4$ emissions during transmission of natural gas are considered to be included in this category, because their emission factors are provided in the *2006 IPCC Guidelines*. However, the intentional $CO_2$ emissions from pipeline of natural gas are reported as "NA" in transmission of natural gas (1.B.2.b.iv.) in case of Japan. Therefore, the emissions are not reported. As for $CH_4$ emissions, the emissions are reported as "IE", because they are included in emissions from transmission of natural gas (1.B.2.b.iv).

### *b) Methodological Issues*

- ***Estimation Method***

For the emissions from this category in FY1990, FY1995 and onward, actual measurement data of $CO_2$ emission provided by Japan Petroleum Development Association is used for reporting.

For FY1991-1994, the natural gas amount produced from gas field, where separation of $CO_2$ from natural gas has been implemented (Minami Nagaoka and Katagai gas fields), is used for the activity data, and the emissions are estimated by multiplying the activity data by emissions factors. As for the emission factors, nominal emission factors are estimated by dividing the emissions in FY1990 and FY1995 provided by Japan Petroleum Development Association by activity data in the same fiscal years, and the emission factors for FY1991-1994 are estimated by interpolation using the values for FY1990 and FY1995.

- ***Emission Factors***

For FY1990, FY1995 and onward, the values are estimated by dividing emissions data provided by Japan Petroleum Development Association by activity data. As for FY1991 – FY1994, the values are estimated by interpolation using the values for FY1990 and FY1995. (For emission estimating purpose, only emission factors for FY1991-1994 are used.)

Table 3-87 Emission factors of natural gas field venting

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emission factor | kg-$CO_2$/$m^3$ | 0.133 | 0.117 | 0.126 | 0.114 | 0.123 | 0.120 | 0.119 | 0.122 | 0.121 | 0.124 | 0.128 | 0.129 | 0.127 | 0.116 |

- ***Activity Data***

The total production amount of Minami Nagaoka gas field and Katagai gas field indicated in *Natural Gas Data Year Book* are used for activity data. (For emission estimating purpose, only activity data for FY1991-1994 are used.)

Table 3-88 Production amount of Natural gas from Minami-nagaoka and Katagai gas field

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Minami Nagaoka gas field | $10^6$ $m^3$ | 241 | 376 | 571 | 893 | 1,632 | 1,313 | 1,308 | 1,372 | 1,295 | 1,172 | 1,215 | 1,340 | 1,484 | 1,484 |
| Katagai gas field | $10^6$ $m^3$ | 191 | 281 | 219 | 336 | 279 | 346 | 395 | 358 | 369 | 370 | 384 | 421 | 460 | 460 |
| Total | $10^6$ $m^3$ | 432 | 657 | 789 | 1,229 | 1,911 | 1,660 | 1,704 | 1,731 | 1,664 | 1,542 | 1,598 | 1,761 | 1,944 | 1,944 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

As for emissions from venting (natural gas), actual measurement emission data provided by Japan Petroleum Development Association is used for reporting for FY1990, FY1995 and onward. However, it is difficult to evaluate the uncertainty for the data. Therefore, the standard value of uncertainty associated with measurement of flow rate (-15% to +15%) provided in the *2006 IPCC Guidelines* is adopted.

- ***Time-series Consistency***

For the emissions from this source, the emission data provided by *Japan Petroleum Development Association* are consistently used for FY1990, FY1995 and onward. As for FY1991-1994, the emissions are estimated from the FY1990 and FY1995 emission data provided by *Japan Petroleum Development Association*.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

There have been no recalculations of emissions from this category.

### *f) Category-specific Planned Improvements*

There have been no major planned improvements in this category.

## 3.3.2.3.c. Venting (Combined) (1.B.2.c.Venting.iii.)

Statistical data are reported for two categories of petroleum and natural gas in Japan. As a result, fugitive emissions from venting in the combined petroleum and natural gas industries were reported as “IE” since they were accounted for in the emissions from venting in the petroleum industry (1.B.2.c.i) and the natural gas industry (1.B.2.c.ii)

## 3.3.2.3.d. Flaring (Oil) (1.B.2.c.Flaring.i.)

### *a) Category Description*

This category provides the estimation methods for $CO_2$, $CH_4$, and $N_2O$ from flaring in the petroleum industry.

### b) Methodological Issues

- **Estimation Method**

The $CO_2$, $CH_4$, and $N_2O$ emissions from flaring in the petroleum industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines*, by multiplying the amount of crude oil production in Japan by the default emissions factors.

- **Emission Factors**

In the absence of actual measurement data or country-specific emission factors in Japan, the default values shown in the *2006 IPCC Guidelines* were used.

Table 3-89 Emission factors for flaring in the oil industry

| | Unit | $CH_4$ | $CO_2$ | $N_2O$ |
|---|---|---|---|---|
| Flaring (conventional oil) | kt/$10^3$ $m^3$ | $2.5\times10^{-5}$ | $4.1\times10^{-2}$ | $6.4\times10^{-7}$ |

Reference : *2006 IPCC Guidelines* Vol. 2, p 4.50, Table 4.2.4

- **Activity Data**

For the calculation of activity data for this emission source, the amounts of crude oil production shown in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Natural Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* are used. The production of condensate is excluded from the calculation (see Table 3-72).

### c) Uncertainties and Time-series Consistency

- **Uncertainties**

For emission factors for $CO_2$, $CH_4$, and $N_2O$ fugitive emissions from flaring (oil), since the default values given in the *2006 IPCC Guidelines* are used for the emission factors, the setting values (-50% to +50%) provided in the *2006 IPCC Guidelines* are used. As for activity data, it is unable to evaluate the uncertainties in statistical data used as reference, the setting values (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) provided in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in $CO_2$ $CH_4$, and $N_2O$ fugitive emissions from flaring (oil) are evaluated at -52% to +52% for each.

- **Time-series Consistency**

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data of the flaring in oil industry are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics,* by a consistent method throughout the time-series from FY1990 to the nearest year.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

### *f) Category-specific Planned Improvements*

There have been no major planned improvements in this category.

## 3.3.2.3.e. Flaring (Gas) (1.B.2.c.Flaring.ii.)

### *a) Category Description*

This category provides the estimation methods for $CO_2$, $CH_4$, and $N_2O$ from flaring in the natural gas industry.

### *b) Methodological Issues*

- ***Estimation Method***

The $CO_2$, $CH_4$, and $N_2O$ emissions associated with flaring in the natural gas industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.38, Fig. 4.2.1). The emissions were calculated by multiplying the amount of natural gas production by the emission factors. The total emissions associated with flaring both during gas production and processing were reported as the emissions from flaring in the natural gas industry.

- ***Emission Factors***

The default values for fugitive emissions from flaring in the natural gas industry given in the *2006 IPCC Guidelines* are used.

Table 3-90 Emission factors for flaring in the natural gas industry

| | | Unit | $CH_4$ | $CO_2$ | $N_2O$ |
|---|---|---|---|---|---|
| Flaring in the natural gas industry | Gas production | $kt/10^6m^3$ | $7.6\times10^{-7}$ | $1.2\times10^{-3}$ | $2.1\times10^{-8}$ |
| | Gas processing/Sweet gas plant | $kt/10^6m^3$ | $1.2\times10^{-6}$ | $1.8\times10^{-3}$ | $2.5\times10^{-8}$ |

Reference: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4

- ***Activity Data***

For the calculation of activity data for this emission source, the amounts of domestic production of natural gas shown in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Natural Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* were used (see Table 3-78).

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the uncertainty of $CO_2$, $CH_4$, and $N_2O$ emission factors for flaring (natural gas), the default values given in the *2006 IPCC Guidelines* are used for the emission factors exclusively. Therefore, the uncertainty of -25% to +25% in the *2006 IPCC Guidelines* is applied. For the activity data, the uncertainty of the statistics used is not clear. Therefore, the value in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) is used. As a result, the uncertainty of $CO_2$, $CH_4$, and $N_2O$ emissions from flaring (natural gas) are evaluated to be -29% to +29% for each.

- ***Time-series Consistency***

For the emission factors, consistent values as described above are used from FY1990 to the nearest year.

The activity data of flaring in natural gas industry are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*, by a consistent method throughout the time-series from FY1990 to the nearest year.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

***e) Category-specific Recalculations***

There have been no recalculations of emissions from this category.

***f) Category-specific Planned Improvements***

There have been no major planned improvements in this category.

### 3.3.2.3.f. Flaring (Combined) (1.B.2.c.Flaring.iii.)

***a) Category Description***

In Japan, the statistical data are reported for two categories of oil and natural gas. Therefore, the fugitive emissions which can be distinguished of their category are reported in Flaring (Oil) (1.B.2.c.Flaring.i) or in Flaring (Natural gas) (1.B.2.c.Flaring.ii) respectively. In this category, $CO_2$, $CH_4$, and $N_2O$ emissions accompanied by exploration and test before production of oil and natural gas, which are unable to be distinguished of their categories of oil industry or natural gas industry, are reported.

***b) Methodological Issues***

- ***Estimation Method***

For the fugitive emissions accompanied by exploration and test before production of oil and natural gas, the emission factors, which are established using the crude oil production as activity data, are indicated as default values in the *2006 IPCC Guidelines*.

However, in case of Japan, the correlation between $CO_2$, $CH_4$, and $N_2O$ emissions, which are accompanied by exploratory drilling and pre-production testing, and crude oil production, and the correlation between the GHG emissions, which are accompanied by the production during exploration and testing, and the production amount from commercial plants are not clear, thus there is a possibility of deviation between the estimated result and the actual condition, if the estimation method of using the crude oil production as activity data, which is indicated in the *2006 IPCC Guidelines*, is adopted. Therefore, the Tier 1 method in *GPG (2000)*, which is considered to be closer to actual condition, is used in this category. The method used is to multiply the activity data of number of exploratory drilling well or testing well by the default emission factor.

- ***Emission Factors***

The default values indicated in the *GPG (2000)* are adopted.

Table 3-91 Emission factors for exploratory drilling and testing wells [kt/number of wells]

| | $CH_4$ | $CO_2$ | $N_2O$ |
|---|---|---|---|
| Drilling | $4.3\times10^{-7}$ | $2.8\times10^{-8}$ | 0 |
| Testing | $2.7\times10^{-4}$ | $5.7\times10^{-3}$ | $6.8\times10^{-8}$ |

Reference: *GPG (2000)*, page 2.86, Table 2.16

- ***Activity Data***

The values described in *Natural Gas Data Year Book* are used for the number of exploratory dilled wells. As for the number of tested wells, it is difficult to grasp statistically, and the tested wells don't always become the succeeded wells. Therefore, the median of the number of wells drilled and the number of wells tested in the *Natural Gas Data Year Book* is used as the number of wells tested. For the most recent year, the data of the previous year are provisionally used.

Table 3-92 Number of wells

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of wells drilled | well | 8 | 7 | 7 | 10 | 4 | 2 | 1 | 4 | 5 | 1 | 2 | 2 | 0 | 0 |
| Number of wells succeeded | | 1 | 3 | 4 | 5 | 2 | 0 | 1 | 2 | 3 | 1 | 1 | 0 | 0 | 0 |
| Number of wells tested | | 5 | 5 | 6 | 8 | 3 | 1 | 1 | 3 | 4 | 1 | 2 | 1 | 0 | 0 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the uncertainty of $CO_2$, $CH_4$, and $N_2O$ emission factors for flaring (combined), the default values given in the *GPG (2000)* are used for the emission factors exclusively. Therefore, the uncertainty of -25% to +25% in *GPG (2000)* is applied. For the activity data, the uncertainty of the statistics used is not clear. Therefore, the value in the *2006 IPCC Guidelines* (-25% to +25%: uncertainty accompanied with the factor for number of production facilities) is used. As a result, the uncertainty of $CO_2$, $CH_4$, and $N_2O$ emissions from flaring (combined) are evaluated to be -35% to +35% for each.

- ***Time-series Consistency***

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data are calculated using the data from the *Natural Gas Data Year Book* by a consistent method throughout the time-series from FY1990 to the nearest year.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since the activity data for FY2017 in the *Natural Gas Data Year Book* were revised, the $CO_2$, $CH_4$ and $N_2O$ emissions in that year were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

There have been no major planned improvements in this category.

### 3.3.2.4. Other (Fugitive Emissions Associated with the Geothermal Power Generation) (1.B.2.d.)

#### *a) Category Description*

This category deals with the $CO_2$ and $CH_4$ emissions in the geothermal power plants, where the $CO_2$ and $CH_4$ from the steam production well are emitted from cooling tower into the atmosphere.

#### *b) Methodological Issues*

- ***Estimation Method***

The emissions from this category are estimated by multiplying the amount of steam production (weight base) in each geothermal power plant by mass concentration rate of $CO_2$ and $CH_4$, since any descriptions for estimation methods for this category are not provided in the *2006 IPCC Guidelines*. However, as for $CO_2$ and $CH_4$ in the steam produced in production well, even though there is a possibility that the steam dissolves in water during transmitting in condenser, it is difficult to estimate the dissolved amount. Therefore, the emissions are estimated assuming that the total amount of $CO_2$ and $CH_4$ in the produced steam is emitted into the air.

- ***Emission Factors***

Mass concentration rate of $CO_2$ in steam is estimated by using volume concentration of non-condensable gas in steam and volume concentration of $CO_2$ in non-condensable gas in each geothermal power plant (Japan Geothermal Energy Association, 2000).

Mass concentration rate of $CH_4$ is estimated by using volume concentration of non-condensable gas in steam in each geothermal power plant (Japan Geothermal Energy Association, 2000) and concentration of $CH_4$ in non-condensable gas (Geothermal Energy Association, 2012).

- ***Activity Data***

The amount of steam production in each geothermal power plant is estimated by multiplying an amount of steam production per hour in each plant provided in *Trend of Geothermal Power in Japan* (JGEA) and *Current Status and Trend of Geothermal Power* (Thermal and Nuclear Power Engineering Society), by operating time of production well which is assumed as the same as the power generating time of each power plant in *Current Status and Trend of Geothermal Power*.

Each emission factor for $CO_2$ and $CH_4$ for geothermal power plants in Japan and the trend of the produced amount of steam are indicated in the Table 3-93.

Table 3-93 Emission factor and produced amount of steam of geothermal power plants

| Power plant name | Emission factor | | Production amount of steam [kt] | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $CO_2$ [t-$CO_2$/kt] | $CH_4$ [t-$CH_4$/kt] | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Matsukawa | 12.2 | 0.025 | 1,884 | 1,493 | 1,708 | 1,115 | 1,083 | 813 | 777 | 745 | 872 | 857 | 666 | 412 | 610 | 610 |
| Otake | 3.1 | 0.006 | 1,173 | 995 | 995 | 774 | 817 | 789 | 677 | 770 | 937 | 885 | 867 | 935 | 1,013 | 1,013 |
| Onuma | 0.6 | 0.002 | 694 | 682 | 535 | 651 | 610 | 600 | 590 | 518 | 537 | 521 | 489 | 521 | 510 | 510 |
| Onikobe | 2.6 | 0.008 | 1,018 | 1,015 | 1,035 | 982 | 1,026 | 1,185 | 456 | 348 | 357 | 381 | 334 | 402 | NO | NO |
| Hatchobaru 1 | 6.5 | 0.013 | 2,883 | 2,366 | 2,598 | 2,602 | 2,783 | 2,287 | 2,468 | 2,353 | 2,347 | 1,887 | 1,963 | 2,097 | 1,729 | 1,729 |
| Hatchobaru 2 | 5.8 | 0.011 | 2,514 | 2,686 | 2,532 | 2,452 | 2,215 | 2,291 | 1,943 | 2,219 | 2,342 | 2,264 | 2,209 | 1,848 | 2,107 | 2,107 |
| Kakkonda 1 | 0.3 | 0.001 | 3,498 | 3,126 | 1,966 | 2,021 | 1,476 | 1,535 | 1,537 | 1,276 | 1,374 | 1,400 | 1,362 | 1,455 | 1,371 | 1,371 |
| Kakkonda 2 | 0.4 | 0.001 | NO | 209 | 1,823 | 2,004 | 1,002 | 1,440 | 1,521 | 1,255 | 1,269 | 1,225 | 1,142 | 1,058 | 1,286 | 1,286 |
| Suginoi | 8.5 | 0.019 | 220 | 284 | 203 | 144 | 146 | 129 | 139 | 170 | 147 | 136 | 140 | 137 | 110 | 110 |
| Mori | 28.1 | 0.053 | 1,367 | 1,990 | 1,981 | 1,501 | 1,065 | 1,068 | 888 | 1,182 | 1,001 | 1,105 | 934 | 1,015 | 1,121 | 1,121 |
| Kirishima international hotel | 1.1 | 0.003 | 48 | 97 | 70 | NO | NO | 30 | 81 | 58 | 68 | 38 | NO | NO | NO | NO |
| Uenotai | 6.5 | 0.014 | NO | 1,882 | 2,070 | 1,601 | 1,801 | 482 | 1,480 | 1,846 | 1,784 | 1,717 | 1,512 | 1,521 | 1,449 | 1,449 |
| Yamakawa | 5.8 | 0.012 | NO | 1,451 | 1,336 | 639 | 973 | 1,026 | 1,151 | 1,026 | 989 | 702 | 744 | 1,031 | 1,047 | 1,047 |
| Sumikawa | 1.4 | 0.004 | NO | 3,234 | 2,846 | 2,908 | 2,593 | 2,611 | 2,145 | 1,853 | 2,038 | 2,903 | 2,903 | 2,676 | 2,334 | 2,334 |
| Yanaizunishiyama | 68.8 | 0.130 | NO | 3,912 | 3,425 | 3,197 | 1,872 | 2,229 | 2,266 | 2,203 | 1,626 | 1,998 | 1,537 | 1,691 | 1,064 | 1,064 |
| Ogiri | 0.4 | 0.001 | NO | 219 | 2,373 | 2,306 | 2,117 | 2,286 | 2,079 | 1,983 | 1,969 | 2,073 | 1,928 | 1,910 | 1,457 | 1,457 |
| Takigami | 1.9 | 0.004 | NO | NO | 2,111 | 2,075 | 2,242 | 2,239 | 2,358 | 2,251 | 2,374 | 2,087 | 2,422 | 2,299 | 2,239 | 2,239 |
| Hachijojima | 18.1 | 0.041 | NO | NO | 187 | 156 | 179 | 152 | 171 | 142 | 149 | 151 | 147 | 153 | 165 | 165 |
| Kujyu | 8.5 | 0.019 | NO | NO | 10 | 136 | 129 | 124 | 56 | 26 | 120 | 58 | 108 | 108 | 108 | 108 |
| Waita | 8.5 | 0.019 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 148 | 174 | 181 | 181 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

As for the emission factors, because the emissions were estimated from the concentration of non-condensable gas in the steam and the concentration of GHG in the non-condensable gas, the uncertainty was estimated at -7% to +7% based on the uncertainty of measurement of gas concentration given in the *2006 IPCC Guidelines*. As for the activity data, because the uncertainty of the referred statistics was not available, the values given in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) were used. As a result, the uncertainty of $CO_2$ and $CH_4$ emissions from the steam generated in production well in geothermal production was evaluated as -17% to +17%.

- ***Time-series Consistency***

For the emission factors, consistent values are used from FY1990 to the nearest year, by using the above-mentioned method. The activity data are calculated by a consistent method throughout the time-series from FY1990 to the nearest year, based on the *Current Status and Trend of Geothermal Power*.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since the activity data for FY2013, 2014 and 2017 in the *Current Status and Trend of Geothermal Power* were revised, the $CO_2$ and $CH_4$ emissions in those years were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

There have been no major planned improvements in this category.

## 3.4. $CO_2$ transport and storage (1.C.)

$CO_2$ transport and storage sector provides the $CO_2$ emissions associated with the carbon dioxide capture and storage (CCS). CCS is the technology or methodology that captures the $CO_2$ which would be emitted to the atmosphere and stores it underground or under seabed.

This sector consists of three categories; transport of $CO_2$ (1.C.1): emissions in the stage of $CO_2$ transport, injection and storage (1.C.2): emissions in the stage of $CO_2$ injection and storage, and Other (1.C.3). There are five projects of $CO_2$ injected underground in the past in Japan. $CO_2$ Emissions in the stage of transport and injection can occur during the period of injection, and $CO_2$ emissions in the stage of storage can have occurred continuously since $CO_2$ is injected. Table 3-94 shows the emissions from $CO_2$ transport and storage (1.C).

Table 3-94 Past projects of $CO_2$ underground injection in Japan

| Injection site | Period of injection |
|---|---|
| Kubiki | March 1991 – June 1993 |
| Sarukawa | September 1997 – September 1999 |
| Nagaoka | July 2003 – January 2005 |
| Yubari | November 2004 – October 2007 |
| Tomakomai | April 2016 – |

Table 3-95 $CO_2$ emissions from $CO_2$ transport and storage (1.C)

| IPCC Category | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.C.1 Transport of $CO_2$ | a. Pipelines | NE | NO | NO | NE | NO | NO | NO | NO | NO | NO | NO | NA | NA | NA |
| | b. Ships | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | c. Other | NE | NO | NO | NE | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| 1.C.2 Injection and storage | a. Injection | NE | NO | NO | NE | NO | NO | NO | NO | NO | NO | NO | NA | NA | NA |
| | b. Storage | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| 1.C.3 Other | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

### 3.4.1. Transport of $CO_2$ (1.C.1)

#### 3.4.1.1. Pipelines (1.C.1.a.)

This category provides the fugitive emissions of $CO_2$ in the stage of $CO_2$ transport by pipeline.

According to the interview to the entities of the projects shown in Table 3-94, the fugitive emissions in the stage of $CO_2$ transport by pipeline do not occur basically or the amount is quite small even if the fugitive emissions occur. Especially in the case of Tomakomai injection site, the pipeline is structurally designed to allow no gas leaks, and the assurance of airtightness is confirmed by execution of airtightness test. In addition, the approximate results of emissions estimated using the default emission factor of the *2006 IPCC Guidelines* (vol. 2, page 5.10, Table 5.2) are less than three thousand t-$CO_2$, which is a criterion to include the emissions in the national totals established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE in the year $CO_2$ injection was conducted (but reported as NA in the year $CO_2$ injection was conducted only in Tomakomai site where the airtightness is assured) and reported as NO in the other years. The treatment of insignificant NE is described in Annex 5.

#### 3.4.1.2. Ships (1.C.1.b.)

This category provides the fugitive emissions of $CO_2$ in the stage of $CO_2$ transport by ships. The emissions are reported as NO, because ships were not used in the past projects in Japan.

#### 3.4.1.3. Other (1.C.1.c.)

This category provides the fugitive emissions of $CO_2$ in the stage of liquefied $CO_2$ transport by a lorry from a plant to an injection site or from a storage tank of liquefied $CO_2$. It is hard to consider the annual fugitive emissions become larger than three thousand t-$CO_2$ for following reasons: First, according to the interview to the entities of the projects shown in Table 3-94, the fugitive emissions shown above do not occur basically or the amount is quite small even if the fugitive emissions occur. Second, the maximum amount of annual injection is about six thousand t-$CO_2$. Therefore, the emissions from this category are reported as insignificant NE. (The emissions are reported as NE in the year $CO_2$ injection was conducted and reported as NO in the other years.) The treatment of insignificant NE is described in Annex 5.

### 3.4.2. Injection and Storage (1.C.2)

#### 3.4.2.1. Injection (1.C.2.a.)

This category provides the fugitive emissions of $CO_2$ in the stage of a compressor or an injection well at an injection site.

According to the interview to the entities of the projects shown in Table 3-94, the fugitive emissions in the stage of injection do not occur basically or the amount is quite small even if the fugitive emissions occur. In addition, the approximate results of emissions estimated using the emission factors shown in Koornneef *et al*. (2008) are less than three thousand t-$CO_2$, which is a criterion to include the emissions in the national total established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE in the year $CO_2$ injection was conducted (but reported as NA in the year $CO_2$ injection was conducted only in Tomakomai site where the airtightness is assured) and reported as NO in the other years. The treatment of insignificant NE is described in Annex 5.

#### 3.4.2.2. Storage (1.C.2.b.)

This category provides the fugitive emissions from a storage site.

According to the interview to the entities of the projects shown in Table 3-94, the fugitive emissions from a storage site do not occur basically or the amount is quite small even if the fugitive emissions occur. In addition, the approximate results of emissions estimated using the ratio of stored $CO_2$ in a storage reservoir to the injected $CO_2$ shown in the *IPCC (2005)* are less than three thousand t-$CO_2$, which is a criterion to include the emissions in the national total established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE through all reporting years. The treatment of insignificant NE is described in Annex 5.

### 3.4.3. Other (1.C.3)

This category provides any other emissions from CCS not reported in transport of $CO_2$ (1.C.1) and injection and storage (1.C.2). The emissions are reported as NO, because there are no emissions to be reported in this subcategory.

### 3.4.4. Information item

This section provides the amount of $CO_2$ captured for geological storage. Although there is 'Total amount captured for storage' in 'Information item' of CRF table 1.C, it should be noted that amount of $CO_2$ captured is subtracted from $CO_2$ emissions not from 1.C but from categories $CO_2$ captured.

The amount of $CO_2$ captured is considered to be nearly equal to that of $CO_2$ injected in the past projects of geological injection of $CO_2$ conducted in Japan. Thus, the amount of $CO_2$ injected that was provided by the entities of the projects is reported as the amount of $CO_2$ captured in the fiscal years when the injections were conducted. The captured amount is reported in 1.A.1.b Petroleum refining or 2.B.1 Ammonia production in accordance with the source of $CO_2$ used in each project.

Table 3-96 Amount of $CO_2$ captured for geological storage

| Injection site | Unit | 1990 | 1991 | 1992 | 1993 | 1997 | 1998 | 1999 | 2003 | 2004 | 2005 | 2006 | 2007 | 2016 | 2017 | 2018 | Reported under |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kubiki | kt | 0.23 | 3.93 | 4.46 | 1.17 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 2.B.1 Ammonia production |
| Sarukawa | kt | NO | NO | NO | NO | 2.37 | 4.87 | 2.71 | NO | NO | NO | NO | NO | NO | NO | NO | 2.B.1 Ammonia production |
| Nagaoka | kt | NO | NO | NO | NO | NO | NO | NO | 3.98 | 6.43 | NO | NO | NO | NO | NO | NO | 2.B.1 Ammonia production |
| Yubari | kt | NO | NO | NO | NO | NO | NO | NO | NO | 0.04 | 0.12 | 0.36 | 0.37 | NO | NO | NO | 1.A.1.b Petroleum refining |
| Tomakomai | kt | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 29.22 | 126.80 | 79.58 | 1.A.1.b Petroleum refining |

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# Chapter 4. Industrial Processes and Product Use (CRF sector 2)

## 4.1. Overview of Sector

Chemical and physical transformation in industrial processes releases GHGs into the atmosphere. This chapter describes the methodologies of estimating industrial process and product use emissions shown in Table 4-1. The estimation methods, emission factors, activity data, etc of each source are considered and approved by the breakout groups on Energy and Industrial Processes, and F-gases, of the Committee for Greenhouse Gas Emissions Estimation Methods, consisting of experts from various fields. (See Chapter 1)

Emissions have been estimated for all years, with zero emissions for some years and sources. To the extent that space and confidentiality concerns allow, relative indices are shown in the tables under each sub-category. Emissions by each sub-category and by gas are shown in the first table of each category.

Table 4-1 Categories in the industrial processes and product use sector

| Source categories | | | | $CO_2$ | $CH_4$ | $N_2O$ | HFCs | PFCs | $SF_6$ | $NF_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.A Mineral Industry | 2.A.1 | Cement Production | | ○ | | | | | | |
| | 2.A.2 | Lime Production | | ○ | | | | | | |
| | 2.A.3 | Glass Production | | ○ | | | | | | |
| | 2.A.4 | Other Process Uses of Carbonates | Ceramics | ○ | | | | | | |
| | | | Other Uses of Soda Ash | ○ | | | | | | |
| | | | Non-metallurgical Magnesia Production | IE | | | | | | |
| | | | Other | ○ | | | | | | |
| 2.B Chemical Industry | 2.B.1 | Ammonia Production | | ○ | NE | NA | | | | |
| | 2.B.2 | Nitric Acid Production | | | | ○ | | | | |
| | 2.B.3 | Adipic Acid Production | | NA | | ○ | | | | |
| | 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | Caprolactam | | | ○ | | | | |
| | | | Glyoxal | | | ○ | | | | |
| | | | Glyoxylic Acid | | | ○ | | | | |
| | 2.B.5 | Carbide Production | Silicon Carbide | ○ | ○ | | | | | |
| | | | Calcium Carbide | ○ | NA | | | | | |
| | 2.B.6 | Titanium Dioxide Production | | ○ | | | | | | |
| | 2.B.7 | Soda Ash Production | | IE | | | | | | |
| | 2.B.8 | Petrochemical and Carbon Black Production | Methanol | NO | NO | | | | | |
| | | | Ethylene | ○ | ○ | | | | | |
| | | | Ethylene Dichloride and Vinyl Chloride Monomer | ○ | ○ | | | | | |
| | | | Ethylene Oxide | ○ | ○ | | | | | |
| | | | Acrylonitrile | ○ | NA | | | | | |
| | | | Carbon Black | ○ | ○ | | | | | |
| | | | Styrene | | ○ | | | | | |
| | | | Phthalic Anhydride | ○ | | | | | | |
| | | | Maleic Anhydride | ○ | | | | | | |
| | | | Hydrogen | ○ | | | | | | |
| | 2.B.9 | Fluorochemical Production | By-product Emissions: Production of HCFC-22 | | | | ○ | | | |
| | | | Fugitive emissions | | | | ○ | ○ | ○ | ○ |
| 2.C Metal Production | 2.C.1 | Iron and Steel Production | Steel | IE | NA | | | | | |
| | | | Use of Electric Arc Furnaces in Steel Production | ○ | ○ | | | | | |
| | | | Pig Iron | IE | NA | | | | | |
| | | | Limestone and dolomite use in Iron and Steel Production | ○ | | | | | | |
| | | | Direct Reduced Iron | NO | NO | | | | | |
| | | | Sinter | IE | IE | | | | | |
| | | | Pellet | IE | IE | | | | | |
| | 2.C.2 | Ferroalloys Production | | IE | ○ | | | | | |
| | 2.C.3 | Aluminium Production | By-product Emissions | IE | | | | ○ | | |
| | | | F-gases Used in Foundries | | | | | | NO | |
| | 2.C.4 | Magnesium Production | | | | | ○ | | ○ | |
| | 2.C.5 | Lead Production | | IE | | | | | | |
| | 2.C.6 | Zinc Production | | IE | | | | | | |
| 2.D Non-energy Products from Fuels and Solvent Use | 2.D.1 | Lubricant Use | | ○ | | | | | | |
| | 2.D.2 | Paraffin Wax Use | | ○ | | | | | | |
| | 2.D.3 | Other | Urea-based Catalysts | ○ | | | | | | |
| | | | NMVOC Incineration | ○ | | | | | | |
| | | | Road Paving with Asphalt | | | | | | | |
| | | | Asphalt Roofing | | | | | | | |
| 2.E Electronics Industry | 2.E.1 | Integrated Circuit or Semiconductor | | | | | ○ | ○ | ○ | ○ |
| | 2.E.2 | TFT Flat Panel Display | | | | | ○ | ○ | ○ | ○ |
| | 2.E.3 | Photovoltaics | | | | | | IE | | |
| | 2.E.4 | Heat Transfer Fluid | | | | | | IE | | |

Table 4-1 Categories in the industrial processes and product use sector (continued)

| Source categories | | | | | | $CO_2$ | $CH_4$ | $N_2O$ | HFCs | PFCs | $SF_6$ | $NF_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.F Product Uses as Substitutes for ODS | 2.F.1 | Refrigeration and Air-Conditioning | Domestic Refrigeration | | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | ○ | NO | NO | NO |
| | | | | | disposal | | | | ○ | NO | NO | NO |
| | | | Commercial Refrigeration | Commercial Refrigeration | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | ○ | NO | NO | NO |
| | | | | | disposal | | | | ○ | NO | NO | NO |
| | | | | Automatic Vending Machines | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | IE | NO | NO | NO |
| | | | | | disposal | | | | IE | NO | NO | NO |
| | | | Transport Refrigeration | | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | ○ | NO | NO | NO |
| | | | | | disposal | | | | ○ | NO | NO | NO |
| | | | Industrial Refrigeration | | manufacturing | | | | IE | NO | NO | NO |
| | | | | | stocks | | | | IE | NO | NO | NO |
| | | | | | disposal | | | | IE | NO | NO | NO |
| | | | Stationary Air-Conditioning (Household) | | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | ○ | NO | NO | NO |
| | | | | | disposal | | | | ○ | NO | NO | NO |
| | | | Mobile Air-Conditioning (Car Air Conditioners) | | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | ○ | NO | NO | NO |
| | | | | | disposal | | | | ○ | NO | NO | NO |
| | 2.F.2 | Foam Blowing Agents | Closed Cells | Urethane Foam | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | ○ | NO | NO | NO |
| | | | | | disposal | | | | IE | NO | NO | NO |
| | | | | Extruded Polystyrene Foam | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | ○ | NO | NO | NO |
| | | | | | disposal | | | | IE | NO | NO | NO |
| | | | Open Cells | High Expanded Polyethylene Foam | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | NO | NO | NO | NO |
| | | | | | disposal | | | | NO | NO | NO | NO |
| | 2.F.3 | Fire Protection | | | manufacturing | | | | NO | NO | NO | NO |
| | | | | | stocks | | | | ○ | NO | NO | NO |
| | | | | | disposal | | | | NO | NO | NO | NO |
| | 2.F.4 | Aerosols | Metered Dose Inhalers | | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | ○ | NO | NO | NO |
| | | | | | disposal | | | | IE | NO | NO | NO |
| | | | Aerosols | | manufacturing | | | | ○ | NO | NO | NO |
| | | | | | stocks | | | | ○ | NO | NO | NO |
| | | | | | disposal | | | | IE | NO | NO | NO |
| | 2.F.5 | Solvents | | | manufacturing | | | | NO | NO | NO | NO |
| | | | | | stocks | | | | ○ | ○ | NO | NO |
| | | | | | disposal | | | | IE | IE | NO | NO |
| | 2.F.6 | Other Applications | | | | | | | | | | |
| 2.G Other Product Manufacture and Use | 2.G.1 | Electrical Equipment | | | manufacturing | | | | | | ○ | |
| | | | | | stocks | | | | | | ○ | |
| | | | | | disposal | | | | | | IE | |
| | 2.G.2 | $SF_6$ and PFCs from Other Product Use | Military Applications | | manufacturing | | | | | NE | NE | |
| | | | | | stocks | | | | | NE | ○ | |
| | | | | | disposal | | | | | NE | NE | |
| | | | Accelerators | | manufacturing | | | | | NE | NE | |
| | | | | | stocks | | | | | NO | ○ | |
| | | | | | disposal | | | | | NE | NE | |
| | | | Soundproof Windows | | manufacturing | | | | | NE | NE | |
| | | | | | stocks | | | | | NE | NE | |
| | | | | | disposal | | | | | NE | NE | |
| | | | Adiabatic Properties: Shoes and Tyres | | manufacturing | | | | | NE | NE | |
| | | | | | stocks | | | | | NO | NO | |
| | | | | | disposal | | | | | NE | NE | |
| | | | Other Railway Silicon Rectifiers | | manufacturing | | | | | NA | NA | |
| | | | | | stocks | | | | | NA | NA | |
| | | | | | disposal | | | | | ○ | NA | |
| | 2.G.3 | $N_2O$ from Product Uses | Medical Applications | | | | | ○ | | | | |
| | | | Use During Semiconductor/Liquid Crystal Manufacturing | | | | | ○ | | | | |
| 2.H Other | 2.H.2 | Food and Beverages Industry | | | | ○ | | | | | | |
| | 2.H.3 | Emissions from imported carbonated gas | | | | ○ | | | | | | |

In FY2018, total GHG emissions from this sector amounted to approximately 100,105 kt-$CO_2$ eq., accounting for 8.1% of national total emissions (excluding LULUCF) in Japan. The emissions of $CO_2$, $CH_4$, and $N_2O$ from this sector have decreased by 37.4% compared to FY1990. The emissions of HFCs, PFCs, $SF_6$, and $NF_3$ from this sector have increased by 49.3% compared to 1990.

The main driving factors for the decrease in emissions for this sector since FY1990 are the decrease in emissions of HFC-23 produced as a by-product of HCFC-22 production due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures (chemical industry), the decrease in $CO_2$ emissions from cement production (mineral industry) as the clinker production declined, the decrease in $N_2O$ emissions from adipic acid production (chemical industry) as the $N_2O$ abatement equipment came on stream. However, HFC emissions from the product uses as ODS substitutes have largely increased.

The methodological tiers used in the IPPU sector are as shown in the below Table 4-2.

Table 4-2 Methodological tiers used in the IPPU sector

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES | $CO_2$ | | $CH_4$ | | $N_2O$ | | | |
|---|---|---|---|---|---|---|---|---|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor | | |
| 2.A. Mineral industry | CS,T2 | CS | | | | | | |
| 2.B. Chemical industry | CS,T1,T2,T3 | CS,D | CS,T1 | CS | CS,T1,T2,T3 | CS,PS | | |
| 2.C. Metal industry | NA | NA | CS | CS | | | | |
| 2.D. Non-energy products from fuels and solvent use | D,T1,T2 | CS,D | NA | NA | NA | NA | | |
| 2.E. Electronic industry | | | | | | | | |
| 2.F. Product uses as ODS substitutes | | | | | | | | |
| 2.G. Other product manufacture and use | | | | | CS | OTH | | |
| 2.H. Other | CS | | NA | NA | NA | NA | | |
| **GREENHOUSE GAS SOURCE AND SINK CATEGORIES** | **HFCs** | | **PFCs** | | **$SF_6$** | | **$NF_3$** | |
| | **Method applied** | **Emission factor** | **Method applied** | **Emission factor** | **Method applied** | **Emission factor** | **Method applied** | **Emission factor** |
| 2.A. Mineral industry | | | | | | | | |
| 2.B. Chemical industry | T2,T3 | CS,OTH | T3 | OTH | T3 | OTH | T3 | OTH |
| 2.C. Metal industry | CS | CS | T2 | D,CS | T2 | OTH | | |
| 2.D. Non-energy products from fuels and solvent use | | | | | | | | |
| 2.E. Electronic industry | T2 | D,CS | T2 | D,CS | T2 | D,CS | T2 | D,CS |
| 2.F. Product uses as ODS substitutes | CS | D,CS | CS | CS | | | | |
| 2.G. Other product manufacture and use | | | CS | CS | CS,T1,T2 | CS,D | | |
| 2.H. Other | | | | | | | | |

Note: D: IPCC default, T1-T3: IPCC Tier 1-3, CS: country specific, PS: plant specific, OTH: other

## 4.2. Mineral Industry (2.A.)

This category covers $CO_2$ emissions from the calcination of mineral raw material such as $CaCO_3$, $MgCO_3$, $Na_2CO_3$, etc. This section includes GHG emissions from Cement production (2.A.1.), Lime production (2.A.2.), Glass production (2.A.3.), and Other process uses of carbonates (2.A.4.).

In FY2018, emissions from this category were 33,707 kt-$CO_2$ and represented 2.7% of total GHG emissions (excluding LULUCF). The emissions decreased by 31.5% compared to FY1990.

Table 4-3 $CO_2$ Emissions from 2.A. Mineral Industry

| Gas | | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 2.A.1 | Cement production | | kt-$CO_2$ | 38,701 | 42,142 | 35,086 | 32,280 | 25,308 | 24,321 | 24,983 | 25,625 | 26,805 | 26,557 | 25,936 | 25,969 | 26,429 | 26,183 |
| | 2.A.2 | Lime production | | kt-$CO_2$ | 6,674 | 5,795 | 5,900 | 6,646 | 5,365 | 6,285 | 5,896 | 5,679 | 5,767 | 5,812 | 5,477 | 5,504 | 5,583 | 5,663 |
| | 2.A.3 | Glass production | | kt-$CO_2$ | 313 | 283 | 233 | 252 | 140 | 164 | 168 | 179 | 193 | 194 | 193 | 189 | 196 | 202 |
| | 2.A.4 | Other process uses of carbonates | Ceramics | kt-$CO_2$ | 930 | 1,066 | 981 | 737 | 896 | 891 | 855 | 903 | 930 | 932 | 855 | 766 | 738 | 678 |
| | | | Other uses of soda ash | kt-$CO_2$ | 119 | 118 | 102 | 78 | 65 | 63 | 61 | 52 | 48 | 51 | 49 | 47 | 41 | 45 |
| | | | Other | kt-$CO_2$ | 2,493 | 1,742 | 1,617 | 1,238 | 1,005 | 1,028 | 1,126 | 1,191 | 1,260 | 1,184 | 1,148 | 1,058 | 983 | 937 |
| | Total | | | kt-$CO_2$ | 49,230 | 51,146 | 43,919 | 41,230 | 32,779 | 32,752 | 33,089 | 33,629 | 35,004 | 34,731 | 33,659 | 33,533 | 33,971 | 33,707 |

### 4.2.1. Cement Production (2.A.1.)

#### *a) Category Description*

$CO_2$ is emitted by the calcination of limestone, the main component of which is calcium carbonate, during the production of clinker[1)], an intermediate product of cement and the main component of which is calcium oxide. Although to a lesser extent than calcium carbonate, limestone also contains magnesium carbonate, which by calcination emits $CO_2$.

| $CO_2$ emission mechanism of the cement production process |
|---|
| $CaCO_3 \rightarrow CaO + CO_2$ |
| $MgCO_3 \rightarrow MgO + CO_2$ |

1) Cement clinker, a black nodule like a volcanic rock with a diameter of 1 cm or so is formed, by introducing a mixture of raw materials such as clay, silica stone, or iron materials, in addition to the main material limestone, into a large rotating kiln after pre-heating, and calcining them under high temperatures, and then rapidly cooling by air. This is ground up, and with the addition of gypsum, is transformed into cement. (from Japan Cement Association's website, partially edited)

#### *b) Methodological Issues*

- ***Estimation Method***

Following the Tier 2 method in the *2006 IPCC Guidelines*, the $CO_2$ emissions from this source was estimated by multiplying the amount of clinker produced by a country-specific emission factor.

$$E = EF_{cl} \times M_{cl} \times CF_{ckd}$$

| | |
|---|---|
| $E$ | : $CO_2$ emissions from cement production [t-$CO_2$] |
| $EF_{cl}$ | : Emission factor [t-$CO_2$/t-clinker] |
| $M_{cl}$ | : Clinker production [t] |
| $CF_{ckd}$ | : Cement kiln dust correction coefficient |

- ***Emission Factors***

Since Japan's cement industry takes in large amounts of waste and byproducts from other industries and recycles them as substitute raw materials for cement production, clinker contains CaO and MgO from sources other than carbonates. This CaO and MgO do not go through the limestone calcination stage and therefore does not emit $CO_2$ during the clinker production process. For that reason, emission factors were determined by estimating the CaO and MgO content of clinker from carbonates, by subtracting CaO and MgO originating from waste and other sources from the total CaO and MgO content of clinker. Japan applies 1.00 for the cement kiln dust (CKD) correction coefficient, because normally almost all CKD is recovered and used again in the production process, as confirmed by the Cement Association.

The emission factors for $CO_2$ emitted from cement production were established as follows.

$$EF = EF_{CaO} + EF_{MgO}$$

| | |
|---|---|
| $EF_{CaO}$ | : $CaCO_3$-origin $CO_2$ emission factor (established by the following equation) |
| $EF_{MgO}$ | : $MgCO_3$-origin $CO_2$ emission factor (established by the following equation) |

$$EF_{CaO} = (CaO_{cl} - CaO_{Cl\text{-}Waste}) \times 0.785$$

$$CaO_{Cl\text{-}Waste} = \frac{W_{dry} \times CaO_{Waste}}{M}$$

| | |
|---|---|
| $CaO_{Cl}$ | : CaO content of clinker |
| $CaO_{Cl\text{-}waste}$ | : CaO content of clinker (waste-origin) |
| 0.785 | : Molecular weight ratio of $CO_2$ to CaO |
| $W_{dry}$ | : Weight of inputs of waste and other materials (dry) |
| $CaO_{Waste}$ | : CaO content of waste and other materials |
| $M$ | : Production amount of clinker |

$$EF_{MgO} = (MgO_{Cl} - MgO_{Cl\text{-}Waste}) \times 1.092$$

$$MgO_{Cl\text{-}Waste} = \frac{W_{dry} \times MgO_{Waste}}{M}$$

| | |
|---|---|
| $MgO_{Cl}$ | : MgO content of clinker |
| $MgO_{Cl\text{-}Waste}$ | : MgO content of clinker (waste-origin) |
| 1.092 | : Molecular weight ratio of $CO_2$ to MgO |
| $W_{dry}$ | : Weight of inputs of waste and other materials (dry) |
| $MgO_{Waste}$ | : MgO content of waste and other materials |
| $M$ | : Production amount of clinker |

- ***Dry weight of waste and other materials input in raw material processing***

  The following 13 types of waste and other materials were chosen for this calculation: coal ash (incineration residue), sewage sludge incineration ash, municipal solid waste incineration ash, glass refuse/ceramics refuse, concrete refuse, blast furnace slag (water granulated), blast furnace slag (slow-cooled), steelmaking slag, nonferrous slag, casting sand, particulates/dust, coal ash (fluidized bed furnace ash), and coal ash (from dust collectors) (these waste account for over 90% of the CaO and 80% of the MgO from waste and other materials). Waste amounts (emission-based) and the water content of each waste and other material were determined from studies by the Japan Cement Association (only for 2000 and thereafter).

- ***Content of CaO and MgO from waste and other materials in clinker***

  The dry weights of each type of waste and other materials are multiplied by the respective CaO and MgO content for each type as found by the Japan Cement Association, thereby yielding the respective total CaO and MgO amounts in clinker derived from waste and other materials. This is divided by clinker production amount to find the CaO and MgO content from waste and other materials in clinker.

- ***CaO and MgO content of clinker, excluding the CaO and MgO from waste and other materials***

  CaO and MgO content in waste and other materials is subtracted from the respective average CaO and MgO content of clinker as determined by the Japan Cement Association, which yields the respective proportion of CaO and MgO in clinker that is used to set emission factors.

Table 4-4 Composition of waste-origin material

| Group | Types of waste | Water content | CaO content | MgO content |
|---|---|---|---|---|
| Incineration residue | Coal ash | 7.2 – 15.3% | 5.0 - 5.8% | 1.0 - 1.1% |
| | Sewage sludge incineration ash [1)] | 10.9 - 16.0% | 7.4 - 12.5% | 3.5 - 3.8% |
| | Municipal solid waste incineration ash [1)] | 19.2 - 24.6% | 10.0 - 26.5% | 2.6 - 2.8% |
| Glass refuse, Concrete refuse, and Ceramics refuse | Glass refuse, Ceramics refuse [1)] | 12.1 - 32.7% | 17.5 - 31.1% | 1.0 - 2.5% |
| | Concrete refuse [1)] | 0 - 37.2% | 6.4 - 43.9% | 1.0 - 1.1% |
| Slag | Blast furnace slag (water granulated) | 5.0 - 16.9% | 40.0 - 42.4% | 4.7 - 5.8% |
| | Blast furnace slag (slow-cooled) | 5.5 - 11.2% | 40.8 - 41.5% | 6.1 - 6.5% |
| | Steelmaking slag | 7.7 - 14.1% | 34.8 - 40.5% | 2.0 - 3.0% |
| | Nonferrous slag | 3.8 - 8.4% | 6.4 - 10.0% | 1.1 - 1.5% |
| | Casting sand [1)] | 9.6 – 14.0% | 6.5% | 1.3 - 1.6% |
| Particulates (dust collector dust) | Particulates/dust | 8.9 - 14.3% | 9.0 - 13.4% | 1.2 - 1.5% |
| | Coal ash (fluidized bed furnace ash) [1)] | 0.1 - 3.2% | 14.5 - 20.7% | 0.7 - 0.9% |
| | Coal ash | 1.0 - 3.9% | 4.1 - 5.0% | 1.0 - 1.1% |

1) Newly added from FY2009.

Table 4-5 $CO_2$ emission factors for cement production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average CaO content in clinker | % | 65.9 | 65.9 | 66.0 | 65.9 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 |
| Waste origin CaO content in clinker | % | 2.6 | 2.6 | 2.9 | 2.0 | 1.7 | 1.7 | 2.0 | 1.8 | 1.7 | 1.6 | 1.6 | 1.6 | 1.7 | 1.8 |
| CaO content in clinker excluding waste origin CaO | % | 63.3 | 63.3 | 63.0 | 63.9 | 64.1 | 64.1 | 63.7 | 64.0 | 64.1 | 64.1 | 64.2 | 64.1 | 64.1 | 64.0 |
| $CO_2$/CaO | | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 |
| Emission factor | t-$CO_2$/t | 0.497 | 0.497 | 0.495 | 0.501 | 0.503 | 0.503 | 0.500 | 0.502 | 0.503 | 0.503 | 0.504 | 0.503 | 0.503 | 0.502 |
| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Average MgO content in clinker | % | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| Waste origin MgO content in clinker | % | 0.3 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| MgO content in clinker excluding waste origin MgO | % | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 |
| $CO_2$/MgO | | 1.092 | 1.092 | 1.092 | 1.092 | 1.092 | 1.092 | 1.092 | 1.092 | 1.092 | 1.092 | 1.092 | 1.092 | 1.092 | 1.092 |
| Emission factor | t-$CO_2$/t | 0.010 | 0.010 | 0.010 | 0.011 | 0.011 | 0.011 | 0.011 | 0.011 | 0.012 | 0.012 | 0.012 | 0.012 | 0.012 | 0.011 |
| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Combined emission factor | t-$CO_2$/t | 0.508 | 0.508 | 0.505 | 0.512 | 0.514 | 0.514 | 0.511 | 0.514 | 0.514 | 0.515 | 0.516 | 0.515 | 0.515 | 0.514 |

- ***Activity Data***

Cement Association provides the data on the amount of clinker produced. Because there is no statistics on clinker production from FY1990 to FY1999, an estimation is made for past (FY1990 - FY1999) clinker production using the average values of the FY2000 - FY2003 ratios of clinker production (Cement Association data) to limestone consumption (*Yearbook of Ceramics and Building Materials Statistics* (Ministry of Economy, Trade and Industry)).

Table 4-6 Clinker production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Consumption of limestone (actual) | kt (dry) | 89,366 | 97,311 | 81,376 | - | - | - | - | - | - | - | - | - | - | - |
| Clinker production (actual) | kt | - | - | 69,528 | 63,003 | 49,195 | 47,279 | 48,884 | 49,883 | 52,105 | 51,573 | 50,307 | 50,436 | 51,351 | 50,979 |
| Clinker production (actual) / Consumption of limestone (actual)[1)] | | 0.853 | 0.853 | | | | | | | | | | | | |
| Estimated clinker production after correction[2)] | kt | 76,253 | 83,032 | 69,528 | 63,003 | 49,195 | 47,279 | 48,884 | 49,883 | 52,105 | 51,573 | 50,307 | 50,436 | 51,351 | 50,979 |

1) Clinker Production (actual) / Consumption of Limestone (actual) for FY1990- FY1999 is the average value of FY2000-FY2003.
2) Values for FY1990- FY1999 are corrected using estimation, and values for FY2000 and onward are actual.

### c) Uncertainties and Time-series Consistency

- **Uncertainty**

For the uncertainty of the $CO_2$ emission factor and activity data for cement production, the default value given in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was estimated to be 4%.

- **Time-series Consistency**

$CO_2$ emissions from cement production from FY1990 to FY1999 is estimated using estimated activity data and emission factors based on values provided by the Japan Cement Association. For years from FY2000 and onward, the methodology described in the sections above is consistently applied using the data provided by Japan Cement Association.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) Category-specific Recalculations

There have been no source-specific recalculations.

### f) Category-specific Planned Improvements

No improvements are planned.

## 4.2.2. Lime Production (2.A.2.)

### a) Category Description

$CO_2$ is emitted during the calcination of $CaCO_3$, $MgCO_3$ in limestone used as raw material to produce quicklime.

| $CO_2$ generation mechanism of quicklime production process |
|---|
| $CaCO_3 \rightarrow CaO + CO_2$<br>$MgCO_3 \rightarrow MgO + CO_2$ |

### b) Methodological Issues

- **Estimation Method**

$CO_2$ emissions are calculated by multiplying limestone consumption by the country-specific emission factor.

$$E = EF \times M$$

| | |
|---|---|
| $E$ | : $CO_2$ emissions generated by use of raw materials in quicklime production [t-$CO_2$] |
| $EF$ | : Emission factor [t-$CO_2$/t-raw material] |
| $M$ | : Amount of limestone consumed [t-raw material] |

- ***Emission Factors***

An emission factor per unit raw material (limestone) (0.428 t-$CO_2$/t-raw material) provided by the Japan Lime Association was used.

The Emission factor per unit raw material was calculated by finding the $CO_2$ emissions per unit raw material estimated from the amounts of carbon and other substances in raw material constituents and quicklime products, and then finding the weighted average using production amounts of each district. The emission factor for lime production is the same for all years because annual change is thought to be small. This emission factor is country-specific, as described above.

- ***Activity Data***

Limestone consumption data for quicklime and slaked lime use, categorized under 'Ceramic and quarry products- other ceramics and quarry products' in the *Adjusted Price Transaction Table* is used. It is converted to dry weight using the water content from limestone used for cement.

> The Adjusted Price Transaction Table (RIETI):
>
> The *Adjusted Price Transaction Table* is a table created from the monetary input table in the Input-Output Table and the consumption data provided in industrial statistics, and is an application of similar estimation methods as in the *General Energy Statistics* (the Energy Balance Table).
>
> In the existing transaction table attached to the Input-Output Table, although expressing the domestic supply and demand of products without any omission/duplication, there exists the possibility of over/under evaluation of transaction depending on the sector if the actual price differs, since transaction in each sector is based on the input from the average price across all industries. In contrast, the *Adjusted Price Transaction Table* attempts to eliminate differences between sectors, by taking into consideration the uneven transaction prices based on the differences in product quality/form in each sector, and through using statistical values in industrial statistics, etc to the extent which possible.
>
> By using consumption data in the *Adjusted Price Transaction Table* as activity data, it is considered possible to capture activity data for all industries without omission/duplication, and to achieve a correct categorization of emission/non-emission related use, based on its detailed breakdown of sectors.
>
> In the inventory, limestone/dolomite consumption data by sector in the *Adjusted Price Transaction Table* will be used as activity data for each limestone related source, excluding that for Cement production (2.A.1.).

As for the dolomite consumed in dolomitic lime production, it is accounted for under Other process uses of carbonates (2.A.4.), and therefore will not be included under Lime production (2.A.2.). The re-absorption of $CO_2$ by the production of light calcium carbonate is already deducted in the *Adjusted Price Transaction Table*.

As regards lime production in sugar mills, according to an interview conducted with three domestic producers documented in the *Report on the Development of the Foundation for the Mandatory GHG Accounting and Reporting System (2010)* by the Ministry of the Environment (MOE), as regards cane sugar, slaked lime is acquired from outside to make the lime milk at all domestic producers, and as for beet sugar, in cases when limestone is calcined, the $CO_2$ emitted is reabsorbed into the lime cake. On the basis of this information, $CO_2$ emissions from sugar manufacturing are not estimated.

As regards aluminium production in Japan, it was confirmed that lime has never been produced from FY1990 onward according to information from the Japan Aluminum Association. (Aluminium production ended in 2014.) Therefore, the $CO_2$ emissions are not estimated.

Table 4-7 Limestone consumption

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Limestone consumption (dry) | kt | 15,595 | 13,540 | 13,785 | 15,527 | 12,534 | 14,684 | 13,775 | 13,269 | 13,474 | 13,579 | 12,797 | 12,860 | 13,045 | 13,232 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 2% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 4%.

- ***Time-series consistency***

Limestone consumption data provided in the *Adjusted Price Transaction Table* is used as lime production activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, $CO_2$ emission from lime production has been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

Recalculations have been conducted for FY2017, based on updates made to limestone consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.2.3. Glass production (2.A.3.)

### *a) Category Description*

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases $CO_2$ derived from $CaCO_3$ and $MgCO_3$. Similarly, $CO_2$ is emitted from soda ash, barium carbonate, potassium carbonate, strontium carbonate, and lithium carbonate. There is still no detailed information available regarding the use of bone ash in glass production in Japan.

$CO_2$ generating mechanism of limestone and dolomite use

$CaCO_3 \rightarrow CaO + CO_2$
$MgCO_3 \rightarrow MgO + CO_2$

### *b) Methodological Issues*

- ***Estimation Method***

The amounts of limestone, dolomite, soda ash, barium carbonate, potassium carbonate, strontium carbonate, and lithium carbonate used in glass production are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of $CO_2$ and $CaCO_3$ by the $CaCO_3$ content, calculated from the percentage of CaO that can be extracted from limestone (55.4%, the median value of the "54.8% to 56.0%" given in *The Story of Lime* [Japan Lime Association]), and the value obtained when multiplying the molecular weight ratio of $CO_2$ and $MgCO_3$ by the $MgCO_3$ content, calculated from the percentage of MgO that can be extracted from limestone (0.5%, the median value of the "0.0% to 1.0%" given in *The Story of Lime*). The emission factor is country-specific, as shown below. A review of this EF was conducted in 2009, and it was confirmed that it remains valid.

・Proportion of CaO extractable from limestone : 55.4 %
(Median of 54.8% to 56.0% [b])
・Proportion of MgO extractable from limestone : 0.5 % [b]
(Median of 0.0% to 1.0% [b])
・Molecular weight of $CaCO_3$ (primary constituent of limestone) : 100.0869 [a]
・Molecular weight of $MgCO_3$ : 84.3139 [a]
・Molecular weight of CaO : 56.0774 [a]
・Molecular weight of MgO : 40.3044 [a]
・Molecular weight of $CO_2$ : 44.0095 [a]

・$CaCO_3$ content = proportion of CaO extractable from limestone × molecular weight of $CaCO_3$ / molecular weight of CaO
・$MgCO_3$ content = proportion of MgO extractable from limestone × molecular weight of $MgCO_3$ / molecular weight of MgO

○Emission factor = (molecular weight of $CO_2$ / molecular weight of $CaCO_3$ × $CaCO_3$ content)
+ (molecular weight of $CO_2$ / molecular weight of $MgCO_3$ × $MgCO_3$ content)
= 440 [kg-$CO_2$/t]

Reference:
a) *Atomic Weights of the Elements 1999 [http://www.ciaaw.org/pubs/TSAW-1999.pdf]* (IUPAC)
b) *The Story of Lime* (Japan Lime Association)

➢ ***Dolomite***

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of $CO_2$ and $CaCO_3$ by the $CaCO_3$ content, calculated from the percentage of CaO that can be extracted from dolomite (34.5%, the median value of the 33.1% to 35.85% range given in *The Story of Lime*), and the value obtained when multiplying the molecular weight ratio of $CO_2$ and $MgCO_3$ by the $MgCO_3$ content, calculated from the percentage of MgO that can be extracted from dolomite (18.3%, the median value of the 17.2% to 19.5% range given in *The Story of Lime*). The emission factor is country-specific, as shown below. A review of this EF was conducted in 2009, and it was confirmed that it remains valid.

・Proportion of CaO extractable from dolomite : 34.5%
(Median value of the 33.1% to 35.85% [a])
・Proportion of MgO extractable from dolomite : 18.3%
(Median value of the 17.2% to 19.5% [a])
・Molecular weight of $CaCO_3$ (major constituent of dolomite) : 100.0869
・Molecular weight of $MgCO_3$ (major constituent of dolomite) : 84.3142
・Molecular weight of CaO : 56.0774
・Molecular weight of MgO : 40.3044
・Molecular weight of $CO_2$ : 44.0098

・$CaCO_3$ content = proportion of CaO extractable from dolomite × molecular weight of $CaCO_3$/ molecular weight of CaO
・$MgCO_3$ content = proportion of MgO extractable from dolomite × molecular weight of $MgCO_3$/ molecular weight of MgO

○Emission factor = molecular weight of $CO_2$ / molecular weight of $CaCO_3$ × $CaCO_3$ content + molecular weight of $CO_2$ / molecular weight of $MgCO_3$ × $MgCO_3$ content
= 471 [kg-$CO_2$/t]

Reference:
a) *The Story of Lime* (Japan Lime Association)

➢ ***Soda ash***

See section 2.A.4.b Other uses of soda ash.

➢ ***Other materials***

For barium carbonate ($BaCO_3$), 0.22t-$CO_2$/t, based on molecular weight ratio of $CO_2$ to $BaCO_3$, is used. For potassium carbonate ($K_2CO_3$), 0.32t-$CO_2$/t, based on molecular weight ratio of $CO_2$ to $K_2CO_3$, is used. For strontium carbonate ($SrCO_3$), 0.30t-$CO_2$/t, based on molecular weight ratio of $CO_2$ to $SrCO_3$, is used. For lithium carbonate ($Li_2CO_3$), 0.60t-$CO_2$/t, based on molecular weight ratio of $CO_2$ to $Li_2CO_3$, is used.

● ***Activity Data***

➢ ***Limestone, Dolomite, and Soda ash***

Of the limestone, dolomite, and soda ash consumption data in the *Adjusted Price Transaction Table*, all limestone, dolomite, soda ash consumption categorized under 'emissive use' that are under the Glass products related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-8 Main uses and corresponding sectors in the *Adjusted Price Transaction Table*

| Use | Corresponding sectors (Limestone) | Corresponding sectors (Dolomite) | Corresponding sectors (Soda ash) |
|---|---|---|---|
| Glass products | 251 Ceramic and quarry products - glass/glass products | 251 Ceramic and quarry products - glass/glass products | 251 Ceramic and quarry products -glass/glass products |

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-9 Amounts of limestone, dolomite, and soda ash consumption

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Limestone consumption (dry) | kt | 66 | 42 | 26 | 31 | 12 | 17 | 16 | 20 | 23 | 23 | 23 | 22 | 24 | 26 |
| Dolomite consumption (dry) | kt | 264 | 250 | 203 | 230 | 126 | 151 | 154 | 164 | 176 | 176 | 174 | 169 | 176 | 180 |
| Soda ash consumption (dry) | kt | 358 | 320 | 257 | 288 | 173 | 197 | 201 | 217 | 235 | 236 | 237 | 232 | 240 | 247 |

➢ ***Other materials***

For barium carbonate, shipment amounts for cathode-ray tube optical glass given in the *Mineral Resources Material Flow* (Japan Oil, Gas and Metals National Corporation) converted to pure substance mass (69%) are used for years FY2000 to FY2010. For other years, extrapolation using production amounts of glass bulbs for lights and electron tubes (including tubes and rods) given in the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials* (METI) are applied.

For potassium carbonate, domestic demand obtained by subtracting export quantities from import quantities given in the *Trade Statistics of Japan* (the Ministry of Finance) converted to pure substance mass (57%) are used for years FY1991 and onward.

For strontium carbonate, demand amounts of tube glass (including flat panel glass and other glass) converted to pure substance mass (59%) are used for years FY2000 to FY2006, FY2008, and FY2010.For FY2007 and 2009, interpolation was applied. For years FY1990 to FY1999, extrapolation using production amounts of glass bulbs for lights and electron tubes (including tubes and rods) given in the *Yearbook of Ceramics and Building Materials Statistics* (METI) was applied, and for years from FY2011 and onward extrapolation using demand amounts of $SrCO_3$ given in the *Mineral Resources Material Flow* are applied.

For lithium carbonate, demand amounts of ceramic additives (19%) given in the *Mineral Resources Material Flow* are used for years FY2002 and onward. For years FY1998 to FY2001, extrapolation using demand amounts for glass additives given in the *Mineral Resources Material Flow* are applied. For years FY1990 to FY1997, production amounts of plate glass given in the *Yearbook of Ceramics and Building Materials Statistics* (METI) for years FY1990 to FY1997 are applied.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 5% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 6%.

- ***Time-series consistency***

For activity data, the same source-data are used as much as possible throughout the time series. The emission factors are constant for all years from FY1990. Therefore, $CO_2$ emission has been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

Recalculations have been conducted based on the revision of consumption data of limestone (FY2017), dolomite (FY2017) and soda ash (FY2016 to 2017) in the *Adjusted Price Transaction Table*. The revision of demand amounts of strontium carbonate (FY2017) and lithium carbonate (FY2015 to FY2017) in the *Mineral Resources Material Flow* also contributed to this. See Chapter 10 for impact on trend.

#### *f) Category-specific Planned Improvements*

No improvements are planned.

### 4.2.4. Other process uses of carbonates (2.A.4.)

### 4.2.4.1. Ceramics (2.A.4.a)

#### *a) Category Description*

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases $CO_2$ derived from $CaCO_3$ and $MgCO_3$.

#### *b) Methodological Issues*

- ***Estimation Method***

The amounts of limestone and dolomite used in ceramics production are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***

See section 4.2.3. b).

➢ ***Dolomite***

See section 4.2.3. b).

- ***Activity Data***

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use' that are under the Ceramics products related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-10 Corresponding sectors in the *Adjusted Price Transaction Table*

| Uses | Corresponding sectors in the *Adjusted Price Transaction Table* (Limestone) | Corresponding sectors in the *Adjusted Price Transaction Table* (Dolomite) |
|---|---|---|
| Ceramics products | | 063 Mining industry – non-metallic minerals |
| | 2531-01 Ceramic and quarry products- ceramics | 2531-01 Ceramic and quarry products- ceramics |
| | 2591-01 Ceramic and quarry products - clay refractories | 2591-01 Ceramic and quarry products - clay refractories,<br>2599-01 Ceramic and quarry products carbon graphite products |
| | | 2599-09 Ceramic and quarry products - other ceramic and quarry products |
| | | 2811-01 Metal Products - metal products for construction use<br>to 2899-09 Metal Products - other metal products |
| | | 6741-09 Private services - other amusement |

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-11 Amounts of limestone and dolomite consumption

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Limestone consumption For Ceramic Products (dry) | kt | 442 | 1,110 | 1,138 | 467 | 417 | 400 | 423 | 426 | 629 | 761 | 799 | 670 | 617 | 632 |
| Dolomite consumption For Ceramic Products (dry) | kt | 1,561 | 1,227 | 1,020 | 1,128 | 1,514 | 1,519 | 1,421 | 1,519 | 1,387 | 1,269 | 1,069 | 1,000 | 991 | 848 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

Same as 4.2.3 Glass Production. See section 4.2.3.c).

- ***Time-series consistency***

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, $CO_2$ emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

Recalculations have been conducted for FY2011 to FY2017, based on updates made to limestone and dolomite consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.2.4.2. Other uses of soda ash (2.A.4.b)

### *a) Category Description*

$CO_2$ is released during the use of soda ash ($Na_2CO_3$).

### *b) Methodological Issues*

- ***Estimation Method***

$CO_2$ emissions from soda ash use are calculated by multiplying soda ash consumption by the country-specific emission factor.

- ***Emission Factors***

Soda ash consumption data categorized under 'for emission purpose' in the *Adjusted Price Transaction Table* does not differentiate between domestic products and imported products, and therefore the emission factor is established by taking a weighted average of the below emission factors for domestic soda ash and imports, by total domestic shipment and total import amounts.

For domestic soda ash, the emission factor is set as follows using data on the purity of soda ash. (The inter-annual fluctuation in the purity of soda ash is small, and therefore the emission factor will be set constant over the time-series.)

$$EF = P \times MW_{CO_2} / MW_{Na_2CO_3}$$
$$= 0.995 \times 44.01 / 105.99$$
$$= 0.413 [\text{t-}CO_2/\text{t}]$$

*EF* : Emission factor for domestic soda ash
*P* : Purity of soda ash (arithmetic mean between the 2 domestic companies)
$MW_{CO_2}$ : Molecular weight of $CO_2$
$MW_{Na_2CO_3}$ : Molecular weight of $Na_2CO_3$

For soda ash imported, and other disodium carbonate imported, there is not enough information to set representative emission factors. Therefore, the default value (0.415 [t-$CO_2$/t-$Na_2CO_3$]) specified in the *2006 IPCC Guidelines* (vol. 3 p. 2.7) is used.

- ***Activity Data***

Soda ash consumption data categorized under 'for emission purpose' in the *Adjusted Price Transaction Table* is used. (excluding consumption for glass production)

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 5% in the *2006 IPCC Guidelines* was used for both limestone and dolomite. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used for both limestone and dolomite. As a result, the uncertainty for emissions was estimated as 6% for both limestone and dolomite.

- ***Time-series consistency***

Soda ash consumption data provided in the *Adjusted Price Transaction Table* is used as soda ash use activity data for all years from FY1990. The emission factor is constant for all years from FY1990. Therefore, $CO_2$ emission from soda ash use has been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

Recalculations have been conducted for FY2011 to FY2017, based on updates made to soda ash consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.2.4.3. Non-metallurgical magnesium production (2.A.4.c)

Emissions are included under 2.A.4.d. Other, and are therefore reported as IE.

### 4.2.4.4. Other (2.A.4.d)

#### *a) Category Description*

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases $CO_2$ derived from $CaCO_3$ and $MgCO_3$.

$CO_2$ generating mechanism of limestone and dolomite use

$CaCO_3 \rightarrow CaO + CO_2$
$MgCO_3 \rightarrow MgO + CO_2$

#### *b) Methodological Issues*

- ***Estimation Method***

The amounts of limestone and dolomite used in desulfurization of exhaust gas and production of chemical products are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***

See section 4.2.3. b).

➢ ***Dolomite***

See section 4.2.3. b).

- ***Activity Data***

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use,' that are under the desulfurization of exhaust gas and production of chemical products related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-12 Uses and corresponding sectors in the *Adjusted Price Transaction Table*

| Uses | Corresponding sectors in the *Adjusted Price Transaction Table* (Limestone) | Corresponding sectors in the *Adjusted Price Transaction Table* (Dolomite) |
|---|---|---|
| Desulfurization of exhaust gas | 063 Mining industry – non-metallic minerals | |
| Chemical products | 2011-01 Chemical Products - chemical fertilizers | 2011-01 Chemical Products - chemical fertilizers |
| | 2029-09 Chemical Products - other inorganic chemical industry products | 2029-09 Chemical Products - other inorganic chemical industry products |
| | | 2081-011 Chemical Products - processed oil and fat products |
| | 2049-09 Chemical Products - other organic chemical industry products | 2049-09 Chemical Products - other organic chemical industry products |
| | | 2071-01 Chemical Products - medicaments |
| | | 2089-09 Chemical Products - catalytic and other chemical end products |

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-13 Amounts of limestone and dolomite consumption

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Limestone consumption | | | | | | | | | | | | | | | |
| For Flue Gas Desulfurization (dry) | kt | 1,841 | 2,139 | 1,813 | 2,075 | 1,699 | 1,795 | 2,008 | 2,149 | 2,067 | 1,741 | 1,627 | 1,605 | 1,501 | 1,388 |
| For Chemical Products (dry) | kt | 3,668 | 1,717 | 1,772 | 683 | 531 | 491 | 507 | 510 | 753 | 910 | 949 | 771 | 705 | 717 |
| Dolomite consumption | | | | | | | | | | | | | | | |
| For Chemical Products (dry) | kt | 147 | 96 | 84 | 54 | 52 | 47 | 41 | 44 | 41 | 38 | 32 | 27 | 27 | 22 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

See section 4.2.3. c).

- ***Time-series consistency***

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, $CO_2$ emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

Recalculations have been conducted for FY2011 to FY2017, based on updates made to limestone and dolomite consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3. Chemical Industry (2.B.)

This category covers $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, and $NF_3$ emissions from the processes of chemical productions.

This section includes GHG emissions from the following sources: Ammonia production (2.B.1.), Nitric acid production (2.B.2.), Adipic acid production (2.B.3.), Caprolactam, glyoxal and glyoxylic acid production (2.B.4), Carbide production (2.B.5.), Titanium dioxide production (2.B.6), Petrochemical and carbon black production (2.B.8), and Fluorochemical production (2.B.9.).

In FY2018, emissions from this category were 5,040 kt-$CO_2$ eq. and represented 0.4% of Japan's total GHG emissions (excluding LULUCF). The total emissions of $CO_2$, $CH_4$, and $N_2O$ from this category had decreased by 71.6% compared to FY1990. The total of HFCs, PFCs, $SF_6$, and $NF_3$ had decreased by 98.5% compared to 1990.

Table 4-14 Emissions from 2.B. Chemical Industry

| Gas | | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 2.B.1 | Ammonia production | | kt-$CO_2$ | 3,418 | 3,457 | 3,184 | 2,167 | 1,923 | 2,123 | 2,008 | 1,855 | 1,932 | 1,890 | 1,947 | 1,658 | 1,726 | 1,458 |
| | 2.B.5 | Carbide production | Silicon carbide | kt-$CO_2$ | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| | | | Calcium carbide | kt-$CO_2$ | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| | 2.B.6 | Titanium dioxide production | | kt-$CO_2$ | 102 | 39 | 53 | 59 | 43 | 62 | 65 | 51 | 60 | 62 | 53 | 58 | 58 | 59 |
| | 2.B.8 | Petrochemical and carbon black production | Methanol | kt-$CO_2$ | 56 | 51 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | | | Ethylene | kt-$CO_2$ | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| | | | Ethylene dichloride and vinyl chloride monomer | kt-$CO_2$ | 150 | 171 | 193 | 200 | 191 | 184 | 146 | 130 | 148 | 150 | 169 | 170 | 175 | 172 |
| | | | Ethylene oxide | kt-$CO_2$ | 171 | 191 | 231 | 240 | 190 | 202 | 202 | 204 | 220 | 214 | 221 | 212 | 227 | 214 |
| | | | Acrylonitrile | kt-$CO_2$ | 440 | 476 | 536 | 509 | 461 | 524 | 486 | 404 | 364 | 342 | 315 | 319 | 323 | 341 |
| | | | Carbon black | kt-$CO_2$ | 1,633 | 1,563 | 1,590 | 1,659 | 1,308 | 1,505 | 1,380 | 1,261 | 1,294 | 1,253 | 1,161 | 1,168 | 1,230 | 1,259 |
| | | | Phthalic anhydride | kt-$CO_2$ | 117 | 124 | 118 | 81 | 51 | 60 | 55 | 60 | 59 | 58 | 60 | 58 | 61 | 58 |
| | | | Maleic anhydride | kt-$CO_2$ | 123 | 138 | 163 | 114 | 94 | 102 | 91 | 78 | 89 | 88 | 90 | 91 | 94 | 92 |
| | | | Hydrogen | kt-$CO_2$ | 6 | 21 | 39 | 34 | 31 | 34 | 32 | 31 | 28 | 24 | 27 | 29 | 29 | 29 |
| | Total | | | kt-$CO_2$ | 7,041 | 7,014 | 6,810 | 5,795 | 4,872 | 5,427 | 5,103 | 4,652 | 4,787 | 4,683 | 4,591 | 4,300 | 4,485 | 4,220 |
| $CH_4$ | 2.B.5 | Carbide production | Silicon carbide | kt-$CH_4$ | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| | 2.B.8 | Petrochemical and carbon black production | Methanol | kt-$CH_4$ | 0.19 | 0.17 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | | | Ethylene | kt-$CH_4$ | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| | | | Ethylene dichloride and vinyl chloride monomer | kt-$CH_4$ | 0.01 | 0.02 | 0.02 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | | | Ethylene oxide | kt-$CH_4$ | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| | | | Carbon black | kt-$CH_4$ | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| | | | Styrene | kt-$CH_4$ | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| | Total | | | kt-$CH_4$ | 1.50 | 1.48 | 1.37 | 1.35 | 1.43 | 1.45 | 1.43 | 1.13 | 1.13 | 1.01 | 1.27 | 1.07 | 1.01 | 0.91 |
| | Total | | | kt-$CO_2$ eq. | 37.49 | 37.09 | 34.15 | 33.69 | 35.83 | 36.23 | 35.71 | 28.14 | 28.20 | 25.22 | 31.79 | 26.76 | 25.26 | 22.71 |
| $N_2O$ | 2.B.2 | Nitric acid production | | kt-$N_2O$ | 2.47 | 2.46 | 2.57 | 2.52 | 1.54 | 1.81 | 1.49 | 1.53 | 1.54 | 1.55 | 1.40 | 1.28 | 1.16 | 1.07 |
| | 2.B.3 | Adipic acid production | | kt-$N_2O$ | 24.20 | 24.03 | 12.56 | 1.68 | 3.49 | 1.66 | 1.05 | 0.51 | 0.77 | 0.48 | 0.38 | 0.49 | 0.30 | 0.20 |
| | 2.B.4 | Caprolactam, glyoxal and glyoxylic acid production | Caprolactam | kt-$N_2O$ | 4.66 | 4.93 | 5.20 | 3.36 | 2.52 | 2.56 | 2.48 | 2.30 | 1.92 | 1.26 | 0.90 | 0.50 | 0.55 | 0.43 |
| | | | Glyoxal | kt-$N_2O$ | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| | | | Glyoxylic acid | kt-$N_2O$ | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| | Total | | | kt-$N_2O$ | 32.28 | 32.43 | 21.30 | 8.58 | 7.92 | 6.08 | 5.06 | 4.34 | 4.22 | 3.28 | 2.68 | 2.27 | 2.01 | 1.70 |
| | Total | | | kt-$CO_2$ eq. | 9,620 | 9,665 | 6,348 | 2,558 | 2,360 | 1,813 | 1,507 | 1,293 | 1,259 | 979 | 798 | 676 | 599 | 506 |
| Total of $CO_2$, $CH_4$, and $N_2O$ | | | | kt-$CO_2$ eq. | 16,698 | 16,716 | 13,193 | 8,387 | 7,267 | 7,276 | 6,646 | 5,973 | 6,074 | 5,687 | 5,420 | 5,003 | 5,109 | 4,749 |
| Gas | | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| HFCs | 2.B.9 | Fluorochemical production | By-product emissions: Production of HCFC-22 | kt-$CO_2$ eq. | 15,929 | 21,460 | 15,688 | 586 | 50 | 53 | 16 | 18 | 16 | 24 | 30 | 24 | 38 | 12 |
| | | | Fugitive emissions | kt-$CO_2$ eq. | 2 | 559 | 296 | 449 | 234 | 128 | 151 | 120 | 131 | 101 | 83 | 149 | 95 | 88 |
| | Total | | | kt-$CO_2$ eq. | 15,930 | 22,019 | 15,984 | 1,035 | 284 | 181 | 168 | 138 | 147 | 124 | 113 | 172 | 133 | 100 |
| PFCs | 2.B.9 | Fluorochemical production | Fugitive emissions | kt-$CO_2$ eq. | 331 | 914 | 1,661 | 1,041 | 459 | 248 | 206 | 148 | 111 | 107 | 115 | 97 | 78 | 87 |
| $SF_6$ | | | Fugitive emissions | t | 152 | 197 | 36 | 41 | 10 | 8 | 6 | 5 | 4 | 3 | 2 | 2 | 2 | 2 |
| | | | | kt-$CO_2$ eq. | 3,471 | 4,492 | 821 | 930 | 233 | 189 | 132 | 123 | 93 | 62 | 52 | 50 | 41 | 46 |
| $NF_3$ | | | Fugitive emissions | t | 0.2 | 1.0 | 7.0 | 72.1 | 66.8 | 76.9 | 93.1 | 76.4 | 86.4 | 56.1 | 23.5 | 25.1 | 13.6 | 3.4 |
| | | | | kt-$CO_2$ eq. | 3 | 17 | 120 | 1,240 | 1,149 | 1,323 | 1,601 | 1,314 | 1,486 | 965 | 404 | 432 | 234 | 58 |
| Total of F-gases | | | | kt-$CO_2$ eq. | 19,735 | 27,442 | 18,587 | 4,246 | 2,124 | 1,942 | 2,108 | 1,723 | 1,837 | 1,258 | 684 | 752 | 486 | 291 |

## 4.3.1. Ammonia Production (2.B.1.)

### *a) Category Description*

### *1) $CO_2$*

In ammonia production, $CO_2$ is emitted when hydrocarbon feedstock is broken down to make $H_2$.

$CO_2$ generating mechanism of ammonia production

$0.88CH_4 + 1.26air + 1.24H_2O \rightarrow 0.88CO_2 + N_2 + 3H_2$

Ammonia synthesis

$N_2 + 3H_2 \rightarrow 2NH_3$

### *2) $CH_4$*

Emission of $CH_4$ from the ammonia production has been confirmed by actual measurements. As there are not enough examples to enable the establishment of an emission factor, it is currently not possible to calculate emissions. The *2006 IPCC Guidelines* also do not give a default emission factor. Therefore, $CH_4$ was reported as "NE".

### *3) $N_2O$*

Emission of $N_2O$ from ammonia production is theoretically impossible, and given that even in actual measurements the emission factor for $N_2O$ is below the limits of measurement, $N_2O$ was reported as "NA".

### *b) Methodological Issues*

- ***Estimation Method***

$CO_2$ emissions are calculated by multiplying the amount of fuels consumed as ammonia feedstock by country-specific emission factors. Since carbonated gas, mainly provided from Ammonia production plants, was injected and geologically stored in years 1990 to 1993, 1997 to 1999, 2003, and 2004, this amount is deducted from emissions. (See section 3.4.4 (1.C.) for details)

- ***Emission Factors***

The same emission factors that are used to calculate $CO_2$ emissions from the fuel combustion sector (Chapter 3) are used for each feedstock listed in Table 4-15. It should be noted that the implied emission factor changes every year, since the composition of the feedstocks consumed for ammonia production varies annually. The inter-annual changes in the $CO_2$ IEF for 2004/2005 (-9%), 2011/2012 (+8%), and 2015/2016 (-11%) are primarily caused by a decrease, an increase and a decrease in emissions from oil coke consumption, respectively.

Table 4-15 Emission factors and calorific values of feedstocks used when producing ammonia

| Item | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Naphtha | GCV | MJ/l | 33.63 | 33.63 | 33.57 | 33.55 | 33.53 | 33.53 | 33.53 | 33.53 | 33.31 | 33.31 | 33.31 | 33.31 | 33.31 | 33.31 |
| | CEF | tC/TJ | 18.17 | 18.17 | 18.17 | 18.17 | 18.17 | 18.17 | 18.17 | 18.17 | 18.63 | 18.63 | 18.63 | 18.63 | 18.63 | 18.63 |
| LPG | GCV | MJ/kg | 50.53 | 50.63 | 50.70 | 50.75 | 50.72 | 50.77 | 50.76 | 50.78 | 50.07 | 50.09 | 50.10 | 50.10 | 50.11 | 50.10 |
| | CEF | tC/TJ | 16.54 | 16.51 | 16.49 | 16.48 | 16.48 | 16.47 | 16.47 | 16.47 | 16.38 | 16.37 | 16.36 | 16.36 | 16.35 | 16.36 |
| Off gas | GCV | $MJ/m^3$ | 39.35 | 39.35 | 44.90 | 44.90 | 44.90 | 44.90 | 44.90 | 44.90 | 46.12 | 46.12 | 46.12 | 46.12 | 46.12 | 46.12 |
| | CEF | tC/TJ | 14.15 | 14.15 | 14.15 | 14.15 | 14.15 | 14.15 | 14.15 | 14.15 | 14.44 | 14.44 | 14.44 | 14.44 | 14.44 | 14.44 |
| Natural gas | GCV | $MJ/m^3$ | 42.09 | 42.39 | 42.55 | 42.87 | 44.84 | 44.67 | 44.74 | 44.75 | 39.62 | 39.62 | 39.62 | 39.62 | 39.62 | 38.38 |
| | CEF | tC/TJ | 13.90 | 13.90 | 13.90 | 13.90 | 13.90 | 13.90 | 13.90 | 13.90 | 13.97 | 13.97 | 13.97 | 13.97 | 13.97 | 13.91 |
| Coal | GCV | MJ/kg | 25.95 | 25.95 | 26.60 | 25.70 | 25.70 | 25.70 | 25.70 | 25.70 | 25.97 | 25.97 | 25.97 | 25.97 | 25.97 | 26.08 |
| | CEF | tC/TJ | 24.71 | 24.71 | 24.71 | 24.71 | 24.71 | 24.71 | 24.71 | 24.71 | 24.42 | 24.42 | 24.42 | 24.42 | 24.42 | 24.29 |
| Oil coke | GCV | MJ/kg | 35.58 | 35.58 | 35.60 | 29.90 | 29.90 | 29.90 | 29.90 | 29.90 | 33.29 | 33.29 | 33.29 | 33.29 | 33.29 | 33.29 |
| | CEF | tC/TJ | 25.35 | 25.35 | 25.35 | 25.35 | 25.35 | 25.35 | 25.35 | 25.35 | 24.50 | 24.50 | 24.50 | 24.50 | 24.50 | 24.50 |
| LNG | GCV | MJ/kg | 54.54 | 54.53 | 54.52 | 54.51 | 54.49 | 54.49 | 54.48 | 54.47 | 54.46 | 54.46 | 54.46 | 54.46 | 54.46 | 54.70 |
| | CEF | tC/TJ | 13.94 | 13.95 | 13.94 | 13.94 | 13.95 | 13.95 | 13.95 | 13.96 | 13.96 | 13.95 | 13.96 | 13.96 | 13.96 | 13.87 |
| COG | GCV | $MJ/m^3$ | 21.51 | 21.57 | 21.27 | 21.42 | 21.15 | 21.32 | 21.12 | 20.75 | 18.87 | 18.87 | 18.87 | 18.87 | 18.87 | 18.38 |
| | CEF | tC/TJ | 10.99 | 10.99 | 10.99 | 10.99 | 10.99 | 10.99 | 10.99 | 10.99 | 10.93 | 10.93 | 10.93 | 10.93 | 10.93 | 10.88 |

Reference: *General Energy Statistics* (Agency for Natural Resources and Energy)

- ***Activity Data***

The fixed units (including weight and volume) for the fuel types in Table 4-16 below, which are from the Ministry of Economy, Trade and Industry's *Yearbook of the Current Survey of Energy Consumption*, were converted using the calorific values in the Agency for Natural Resources and Energy's *General Energy Statistics*, and results were used as activity data. Consumption data on some fuel types are confidential.

Table 4-16 Amount of feedstocks used for ammonia production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Naphtha | kl | 189,714 | 477,539 | 406,958 | 92,453 | 72,045 | 70,067 | 67,646 | 67,869 | 71,494 | 66,079 | 73,612 | 18,421 | NO | NO |
| LPG | t | 226,593 | 45,932 | 5,991 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Off gas | $10^3m^3$ | C | 230,972 | 240,200 | 147,502 | 140,783 | 143,634 | 126,809 | NO | NO | NO | NO | NO | NO | NO |
| Natural gas | $10^3m^3$ | C | 100,468 | 86,873 | 77,299 | 21,773 | 41,640 | 41,169 | 45,808 | 47,956 | 51,858 | 17,498 | 637 | 979 | 1,011 |
| Coal | t | C | 209,839 | 726 | 1,239 | 522 | 629 | 879 | 390 | 919 | 787 | 362 | 891 | 483 | 928 |
| Oil coke | t | C | 273,125 | 420,862 | 353,983 | 351,594 | 394,116 | 365,340 | 405,557 | 401,721 | 426,743 | 468,684 | 416,722 | 462,107 | 371,819 |
| LNG | t | C | 46,501 | 23,395 | 165,606 | 145,699 | 157,918 | 161,588 | 169,109 | 168,155 | 127,824 | 122,453 | 131,446 | 122,081 | 122,818 |
| COG | $10^3m^3$ | C | 35,860 | 55,333 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

Note: C: Confidential

- ***Point to Note***

Fuel consumption in this category has been deducted from energy sector activity data (see Chapter 3).

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

The uncertainty of each fuel was estimated. For the uncertainty of emission factors, the upper limit and lower limit values of the 95% confidence interval for the carbon emission factors were applied. For the uncertainty of the activity data, the same values were applied as in fuel combustion. As a result, the uncertainty of emissions are the following: naphtha -3 - +1%; LPG -3 - +1%; hydrocarbon gas -4 - +3%; natural gas -1 - +1%; coal (steam coal, imported coal) -4 - +3%; oil coke -3 - +1%; LNG -1 - +1%; and COG -4 - +3%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series, from the *Current Survey of Energy Consumption*. The emission factor is constantly based on the *General Energy Statistics* throughout the time series. Therefore, $CO_2$ emission from ammonia production has been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

$CO_2$ emissions was recalculated for FY2017, based on updates made to the activity data of Naphtha. The revision of the gross calorific values of natural gas (FY2013 to FY2017) also contributed to this. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3.2. Nitric Acid Production (2.B.2.)

### *a) Category Description*

$N_2O$ is emitted when nitric acid ($HNO_3$) is produced from ammonia.

$N_2O$ generating mechanism in nitric acid production

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$
$$2NO + H_2O \rightarrow 2NO_2$$
$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO \quad (\rightarrow N_2O)$$

In Japan, the main processes used in nitric acid production are the New Fauser Process (medium pressure) and Chemico Process (high pressure), both based on the Ostwald chemical process. With regard to $N_2O$ decomposition, there are catalytic decomposition units in operation.

### *b) Methodological Issues*

- ***Estimation Method***

$N_2O$ emissions were estimated by multiplying the nitric acid production amount by an emission factor, based on the Tier 2 method given in the *2006 IPCC Guidelines*. Emission data for individual factories are confidential, and therefore the nitric acid production amount and the emission factor were set for all of Japan. The amount of $N_2O$ destroyed is currently unavailable but is reflected in the emission factor.

$$E = EF \times NAP$$

*E* : $N_2O$ emissions from nitric acid production [kg-$N_2O$]
*EF* : Emission factor [kg-$N_2O$/t]
*NAP* : Nitric acid production amount [t]

- ***Emission Factors***

Data for individual factories are confidential, and therefore the emission factor was set by using each factory's nitric acid production amount to find the weighted average of Japan's 10 nitric acid producing factories' emission factors (measurement data). These emission factors take $N_2O$ recovery and destruction into account.

Table 4-17 $N_2O$ emission factors for nitric acid production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EFs for nitric acid production | kg-$N_2O$/t | 3.50 | 3.51 | 3.92 | 4.18 | 3.34 | 3.58 | 3.49 | 3.38 | 3.55 | 3.54 | 3.60 | 3.59 | 3.27 | 3.26 |

- ***Activity Data***

Production amounts of nitric acid are directly provided by the Ministry of Economy, Trade and Industry.

Table 4-18 Amount of nitric acid production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitric acid production | kt | 706 | 701 | 656 | 602 | 461 | 506 | 426 | 453 | 434 | 437 | 388 | 356 | 355 | 328 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

As for the uncertainty of the emission factor, the standard deviation was calculated from the emission factors and production amounts of each plant, and was assessed to be 73%. For the uncertainty of activity data, the default value of 2% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated as 73%.

- ***Time-series Consistency***

Emissions throughout the time series are consistently estimated using the activity data and emission factors provided by the Ministry of Economy, Trade and Industry.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3.3. Adipic Acid Production (2.B.3.)

### *a) Category Description*

$N_2O$ is emitted in the adipic acid ($C_6H_{10}O_4$) production process through the reaction of cyclohexanone, cyclohexanol, and nitric acid.

### *b) Methodological Issues*

- ***Estimation Method***

Emissions were estimated using the $N_2O$ generation rates, $N_2O$ decomposition amount, and adipic acid production amount of the relevant operating sites.

- ***Emission Factors***

Country-specific emission factors were established using the following parameters. Relevant emission factor/parameter data are confidential.

➢ ***Nitrous oxide generation rate***

Actual measurement data provided from the sole producer of adipic acid as an end product in Japan.

➢ ***Nitrous oxide decomposition rate***

The figure used is the result of measurement of the rate of decomposition of nitrous oxide in the operating site.

➢ ***Decomposition unit operation rate***

A full-scale survey on the number of operation hours is conducted annually for $N_2O$ decomposition units and adipic acid production plants. The operating rate is based on this survey.

- ***Activity Data***

The activity data for nitrous oxide emissions associated with the manufacturing of adipic acid is the amount of adipic acid produced provided to the Ministry of Economy, Trade and Industry by the manufacturer. Relevant data used in estimation is confidential.

- ***Point to Note***

From 1990 to 1997, $N_2O$ emissions from adipic acid production increased gradually. However, $N_2O$ decomposition units were installed in adipic acid production plants in March 1999, and emissions since then have decreased dramatically. There was a temporary growth in the emissions in 2000 due to the low operating rate of $N_2O$ decomposition units caused by mechanical failure of the decomposition units.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

The uncertainty of the emission factor for adipic acid was estimated by combining the uncertainty of the $N_2O$ generation rate, $N_2O$ decomposition rate, and the operating rate of the decomposition unit. As

a result, the uncertainty of the emission factor was estimated as 9%. A 2% uncertainty given by the *2006 IPCC Guidelines* was applied for activity data. As a result, the uncertainty for adipic acid was estimated as 9%.

- ***Time-series Consistency***

Activity data and emission factors consistently provided by the producer of adipic acid are used to estimate emissions throughout the time series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.3.4. Caprolactam, glyoxal and glyoxylic acid production (2.B.4.)

#### 4.3.4.1. Caprolactam Production (2.B.4.a)

***a) Category Description***

Caprolactam is a monomer for nylon-6 which transforms into Nylon 6 by ring-opening polymerization. Nylon 6 is used as fibers for carpets etc, or resin material. $N_2O$ is emitted from ammonia oxidation during the manufacturing process.

***b) Methodological Issues***

- ***Estimation Method***

Emissions are calculated by multiplying the amount of caprolactam produced by a weighted average emission factor, based on plant-specific emission factors established in accordance with Tier 1 - 3 methods in the *2006 IPCC Guidelines*.

- ***Emission Factors***

A country-specific emission factor per production amount was established by dividing total emissions by total production amounts. This was based on data provided from Japan Chemical Industry Association, including production amounts, emission factors, and emissions for all five plants producing caprolactam in Japan. Each plant's emission factor fluctuates by year.

- ***Activity Data***

Caprolactam production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* compiled by the Ministry of Economy were used as activity data.

Table 4-19 Caprolactam production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Caprolactam production | kt | 516 | 546 | 575 | 455 | 401 | 411 | 392 | 366 | 342 | 266 | 241 | 220 | 223 | 210 |

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

As for the uncertainty of the emission factor, the standard deviation was calculated from the emission factors and production amounts of each plant and was assessed to be 99%. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 99%.

- ***Time-series Consistency***

For the activity data, data from the *Yearbook of Current Production Statistics – Chemical Industry* are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.3.4.2. Glyoxal Production (2.B.4.b)

***a) Category Description***

Glyoxal is mainly used as a crosslinking agent for acrylic resins, disinfectant, gelatin hardening agent, and textile finishing agent etc. It's produced from oxidation of acetaldehyde with concentrated nitric acid, or from the catalytic oxidation of ethylene glycol, and $N_2O$ is emitted in the process of oxidation of acetaldehyde. (See below)

$$2C_2H_4O + 2HNO_3 \rightarrow 2C_2H_2O_2 + N_2O + H_2O$$

***b) Methodological Issues***

- ***Estimation Method***

Emissions are calculated in accordance with the Tier 3 method in the *2006 IPCC Guidelines*, by multiplying the amount of glyoxal produced by an emission factor. There is no production from FY2010 onward, but emissions for FY1990 to FY2011 are reported as “C” due to confidentiality reasons of Glyoxylic acid for FY2010 and FY2011.

- ***Emission Factors***

A country-specific emission factor per production amount based on information provided by the manufacturer was used. This was established based on the amounts of gas emitted in the manufacturing process of each product, and measurements of $N_2O$ concentrations, and will be applied to all years.

- ***Activity Data***

No statistics are available on glyoxal production amounts, and therefore the production amounts at one manufacturer that had been producing until recent were used as activity data. There is no production

from FY2010 onward.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 10% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 10%.

- ***Time-series Consistency***

For the activity data, data from the one manufacturer that had been producing until recent are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.3.4.3. Glyoxylic acid Production (2.B.4.c)

***a) Category Description***

Glyoxylic acid is used for the production of synthetic aromas, agrochemicals, and pharmaceutical intermediates. It is produced by nitric acid oxidation of glyoxal, and $N_2O$ is emitted in the process of reduction of nitric acid.

***b) Methodological Issues***

- ***Estimation Method***

Emissions are calculated in accordance with the Tier 3 method in the *2006 IPCC Guidelines*, by multiplying the amount of glyoxylic acid produced by an emission factor. There is no production from FY2012 onward.

- ***Emission Factors***

A country-specific emission factor per production amount based on information provided by the manufacturer was used. This was established based on the amounts of gas emitted in the manufacturing process of each product, and measurements of $N_2O$ concentrations, and will be applied to all years.

- ***Activity Data***

No statistics are available on glyoxylic acid production amounts, and therefore the production amounts at one manufacturer that had been producing until recent were used as activity data. There is no production from FY2012 onward.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 10% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 10%.

- ***Time-series Consistency***

For the activity data, data from the one manufacturer that had been producing until recent are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3.5. Carbide Production (2.B.5.)

## 4.3.5.1. Silicon Carbide Production (2.B.5.a)

### *a) Category Description*

#### *1) $CO_2$*

$CO_2$ is emitted by the reaction of petroleum coke with silica as raw materials in the production of silicon carbide.

| $CO_2$ generating mechanism in the silicon carbide production process |
|---|
| $SiO_2 + 3C \rightarrow SiC + 2CO \quad (\rightarrow CO_2)$ |

#### *2) $CH_4$*

In Japan, silicon carbide is produced in electric arc furnaces, and it is believed that $CH_4$ is generated from the oxidation of coke, which is used as a reducing agent in silicon carbide production.

### *b) Methodological Issues*

#### *1) $CO_2$*

- ***Estimation Method***

Emissions are calculated by multiplying the amount of petroleum coke used as silicon carbide feedstock by an emission factor.

- ***Emission Factors***

Because Japan does not have measurement data or emission factor data, the default value 2.3 [t-$CO_2$/t]

for silicon carbide production in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for $CO_2$ emissions from silicon carbide production is the amount of petroleum coke consumed, provided by Japan's only silicon carbide production facility. The data is confidential.

***2) $CH_4$***

- ***Estimation Method***

Emissions were calculated by multiplying an emission factor based on actual figures obtained in Japan by the energy consumption of electric arc furnaces. This is the same method used for calculating $CH_4$ emissions in the Fuel Combustion Sector (1.A. Solid Fuels).

- ***Emission Factors***

The emission factor of energy consumption in electric arc furnaces (12.8 kg-$CH_4$/TJ) was determined from $CH_4$ concentrations in the flue gas, measured dry flue gas amounts per hour, and measured quantity of heat generated per hour. See Chapter 3, 3.2.5 $CH_4$ and $N_2O$ Emissions from Energy Industry (1.A.1.:$CH_4$, $N_2O$)

- ***Activity Data***

The activity data for $CH_4$ emissions from silicon carbide production is the amount of energy consumed, provided by Japan's only silicon carbide production facility. The data is confidential.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

***1) $CO_2$***

For the uncertainty of the emission factor, the default value of 10% was applied as provided by the *2006 IPCC Guidelines*. For the uncertainty of activity data, the default value of 5% given by *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 11%.

***2) $CH_4$***

The uncertainty of the emission factor, the default value of 10% was applied as provided by the *IPCC 2006 Guidelines*. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 11%.

- ***Time-series Consistency***

For both $CO_2$ and $CH_4$ activity data, the same sources are consistently used throughout the time series-from the manufacturing facility. The emission factors for both gases are constant throughout the time series. Therefore, $CO_2$ and $CH_4$ emissions from silicon carbide have been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3.5.2. Calcium Carbide Production and Use (2.B.5.b)

### *a) Category Description*

#### *1) $CO_2$*

$CO_2$ is generated in the process of making the quicklime and is also emitted by the combustion of CO occurring from calcium carbide production. However, the former is included in emissions from Other process uses of carbonates (2.A.4.), and therefore only reducing agent-origin emissions are accounted for here. Further, $CO_2$ is generated by the combustion of acetylene, which is generated by reacting calcium carbide with water, and these emissions are reported here.

$CO_2$ generator mechanism in the calcium carbide production process

(Production)

$CaCO_3 \rightarrow CaO + CO_2$

$CaO + 3C \rightarrow CaC_2 + CO\ (\rightarrow CO_2)$

(Use)

$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2\ (\rightarrow CO_2)$

#### *2) $CH_4$*

Byproduct gases (mainly CO) generated in carbide production include a small amount of $CH_4$, all of which is recovered and burned as fuel, with none being emitted outside the system. Therefore, emissions from this source are reported as “NA”.

### *b) Methodological Issues*

- ***Estimation Method***

$CO_2$ emissions are calculated by multiplying calcium carbide production by the following emission factor, based on the Tier 2 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

For years FY1990 to FY2007, because Japan does not have measurement data or emission factor data, the below default values in the *2006 IPCC Guidelines* is used.

Table 4-20 $CO_2$ Emission factors for calcium carbide production and consumption (FY1990- FY2007)

| Units | From reducing agent in production | From use |
|---|---|---|
| t-$CO_2$/t | 1.09 | 1.10 |

For years after FY2008, country-specific emission factors from reducing agents during production (changes annually) are used, which are based on measurement data from the two calcium carbide producing companies in Japan. These emission factors are confidential.

The default emission factor (1.10 t-$CO_2$/t) for calcium carbide use is also used for FY2008 and onwards.

The calcium carbide production amount used for calculating the $CO_2$ EF includes not only $CaC_2$ but also unreactive CaO used as raw material. This is the reason for the EF being lower than the stoichiometric value derived from a reaction only involving $CaC_2$. In Japan, $CaC_2$ is produced under

conditions with excessive CaO. With $CaC_2$, the higher the purity, the higher is the melting point. Therefore, to avoid the rise in viscosity and hardening in the cooler parts of the plant which impairs production, the melting point is suppressed through intentionally maintaining a lower purity. Purity is also kept low to reduce reactivity from the viewpoint of safety.

- ***Activity Data***

Calcium carbide production data provided by the Carbide Industry Association are used as the calcium carbide production amount. It includes not only $CaC_2$ but also unreactive CaO used as raw material. The data are confidential.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainty of the $CO_2$ emission factor, the 10% default value was applied as provided by the *2006 IPCC Guidelines* for both reducing agent origin and from use. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* for both reducing agent origin and from use. As a result, the uncertainty for emissions for both reducing agent origin and from use was estimated as 11%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant from FY1990 to FY2007, and for years from FY2008 and onward, country-specific emission factors are used. This is because there is no data available on the scale of production or improvements in manufacturing technology to establish country-specific emission factors for earlier years, and therefore default emission factors are used for FY1990 to FY2007.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.3.6. Titanium dioxide Production (2.B.6)

***a) Category Description***

Titanium dioxide ($TiO_2$) is a kind of white pigment, generally used in paper, plastics, rubber, ceramics, fabrics, floor covering, printing ink, and paint etc. The two forms of $TiO_2$, anatase $TiO_2$ and rutile $TiO_2$ (both tetragonal), differ in terms of the crystalline structure, and the anatase $TiO_2$ is produced by hydrolyzing titanium sulfate and calcination (the sulfate process), or from titanium slag. Rutile $TiO_2$ is produced through the carbothermal chlorination of synthetic rutile to produce titanium tetrachloride ($TiCl_4$) and oxidation of the $TiCl_4$ vapours to $TiO_2$. (the chloride route)

$CO_2$ is emitted from the oxidization of carbon electrodes in the production of titanium slag in electric furnaces, from the oxidization of black coal during the production of synthetic rutile, and from the

oxidization of oil coke in the chloride route. The following reactions occur to in the chloride route.

$$2TiO_2 + 4Cl_2 + 3C \rightarrow 2TiCl_4 + 2CO + CO_2$$
$$TiCl_4 + O_2 \rightarrow TiO_2 + 2Cl_2$$

### *b) Methodological Issues*

- ***Estimation Method***

For rutile titanium dioxide (the chloride route), emissions are calculated by multiplying titanium dioxide production amounts (rutile $TiO_2$) produced through the chloride route which entails $CO_2$ emissions, by an emission factor provided by the manufacturer, based on the Tier 1 method in the *2006 IPCC Guidelines*.

For rutile titanium dioxide (from synthetic rutile), emissions are calculated by multiplying synthetic rutile production amounts by the default emission factor, based on the Tier 1 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

For rutile $TiO_2$ (the chloride route), an emission factor calculated as follows, based on coke input etc into the process at the manufacturer, is used.

$$E = (CI - CO) \times CC \times \frac{44}{12}$$
$$EF = E / AD$$

*E* : $CO_2$ emissions
*CI* : Coke input amount
*CO* : Carry-over amount (Raw material left over without reacting)
*CC* : Carbon content of coke
*EF* : $CO_2$ emission factor
*AD* : Titanium dioxide production amounts

Emission factors that can be drawn from the above equation, are only for FY2011 to FY2013, and therefore for years FY1990 – FY2010, the average for FY2011- FY2013 are used. (For years from FY2011 and onward, country-specific emission factors provided by the Japan Titanium Dioxide Industry Association are used)

$CO_2$ EF for rutile $TiO_2$ is lower than the IPCC default because in the case of Japanese manufacturers, reactions take place under high temperatures such as 1,000 degrees Celsius, and therefore a second reaction ($TiO_2 + 2Cl_2 + 2CO \rightarrow TiCl_4 + 2CO_2$) is simultaneously taking place, in addition to the above-mentioned reactions described in the *2006 IPCC Guidelines* (yielding 3 mol of $CO_2$ from 2 mol of $TiO_2$), and uses CO. Because of this, and assuming that this CO is used completely in the first-mentioned reaction, 1 mol of $TiO_2$ only yields 1 mol of $CO_2$. (There does not exist any excess carbon. $CO_2$ occurs only from input coke.)

For rutile titanium dioxide (from synthetic rutile), the default value of 1.43 t-$CO_2$/t from the *2006 IPCC Guidelines* is used.

- ***Activity Data***

For rutile titanium dioxide production amounts (the chloride route), the titanium dioxide amounts produced in the chloride route process (provided by the Japan Titanium Dioxide Industry Association) which entails $CO_2$ emissions is used.

For rutile titanium dioxide production amounts (from synthetic rutile), synthetic rutile production amounts (provided by METI) is used.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainty of emission factors for rutile titanium dioxide and synthetic rutile, the default values from the *IPCC 2006 Guidelines* of 15% and 10%, were respectively used. For the uncertainty of activity data, the default value of 5% from the *2006 IPCC Guidelines* was used for both rutile titanium dioxide and synthetic rutile. As a result, the uncertainty of emissions was estimated as 16% and 11%, respectively.

- ***Time-series Consistency***

For the activity data, data from the Japan Titanium Dioxide Industry Association and METI are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.3.7. Soda Ash Production (2.B.7.)

In Japan, the ammonium chloride soda process is used to produce soda ash ($Na_2CO_3$). The soda ash production process involves calcinating limestone and coke in a lime kiln, which emits $CO_2$. Almost all lime-derived $CO_2$ is stored in the product.

In the soda ash production process, purchased $CO_2$ is sometimes input through a pipeline, but because these $CO_2$ emissions are from the ammonia industry, they are already included in Ammonia production (2.B.1.). Also, the coke consumed is listed as that for heating in the *Yearbook of the Current Survey of Energy Consumption*, and thus $CO_2$ emissions from coke are already counted under Fuel combustion (1.A.). Therefore, all emissions from this source are already included in other categories and are reported as “IE”. Coke is input as a heat-source and $CO_2$ source. The thinking on where to account for $CO_2$ emissions from coke is the same as that for Iron and steel production.

The *2006 IPCC Guidelines* offer a method to calculate $CO_2$ emissions from calcinating trona ($Na_2CO_3$-$NaHCO_3$-$2H_2O$), but these emissions are not estimated because in Japan soda ash has never been manufactured by trona calcination.

## 4.3.8. Petrochemical and Carbon Black Production (2.B.8.)

### 4.3.8.1. Methanol Production (2.B.8.a)

#### *a) Category Description*

$CO_2$ and $CH_4$ are emitted during the production of methanol.

#### *b) Methodological Issues*

- ***Estimation Method***

$CO_2$ and $CH_4$ emissions from methanol production are calculated using the Tier 1 method given in the *2006 IPCC Guidelines*.

According to industry organizations, the production (synthesis) of methanol stopped in Japan in 1995 due to the price difference with overseas methanol. Since then all methanol has been imported, and methanol production plants disappeared from Japan in about 1995.

Accordingly, from FY1990 to FY1995, emissions are reported using the production amounts from industry organization statistics. For FY1996 and thereafter, emissions are reported as "NO" because it is assumed that methanol has not been produced (synthesized) since 1995.

- ***Emission Factors***

The default value for $CO_2$ from methanol given in the *2006 IPCC Guidelines* which corresponds to Japan's country-specific production method was used. The emission factor is 0.67 [t-$CO_2$/t] (Refer to the *2006 IPCC Guidelines* vol. 3 p 3.73, Table 3.12).

The default value for $CH_4$ from methanol given in the *2006 IPCC Guidelines* was used. The emission factor is 2.3 [kg-$CH_4$/t] (Refer to the *2006 IPCC Guidelines* vol. 3 p 3.74).

- ***Activity Data***

Production amounts of methanol (on calendar year basis) given by the Methanol and Formalin Association were used as activity data for $CO_2$ and $CH_4$ emissions from methanol production.

Table 4-21 Methanol production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Methanol production | kt | 84 | 75 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

#### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the emission factor, the default values from the *IPCC 2006 Guidelines* of -30 - +30% ($CO_2$) and -80 - +30% ($CH_4$) were used. For the uncertainty of activity data, the default values of similar chemical products from the *IPCC 2006 Guidelines* of -5 - +5% were used. As a result, the uncertainty of $CO_2$ and $CH_4$ emissions were estimated as -30 - +30% and -80 - +30%, respectively.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, $CO_2$ and $CH_4$ emissions from methanol production have been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3.8.2. Ethylene Production (2.B.8.b)

### *a) Category Description*

#### *1) $CO_2$, $CH_4$*

$CO_2$ is emitted in the ethylene production process. $CH_4$ is emitted by naphtha cracking through steam cracking in the ethylene production process.

Carbon losses in the ethylene production process are accounted for under petrochemicals in the energy conversion sector of the *General Energy Statistics* (Energy Balance Table). The petrochemicals sector represents the process of production of by-products such as refinery gas, fuels, and other oil products, from the factories that produce basic chemical feedstock from naphtha and reformed material oil, by regarding it as energy conversion.

#### *2) $N_2O$*

There is almost no nitrogen contained in naphtha, the raw material of ethylene, and the ethylene production process takes place under conditions that are almost completely devoid of oxygen. In accordance with expert judgment, there is theoretically no $N_2O$ emissions.

### *b) Methodological Issues*

- ***Estimation Method***

$CH_4$ and $CO_2$ emissions from ethylene production were calculated by multiplying ethylene production by Japan's country-specific emission factor, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*. $CO_2$ emissions from the energy use of industrial process off gases obtained from the feedstocks in Japan's ethylene production (steam cracking process) are considered to be included in emissions from Refinery Gas under Petrochemical - Energy Use in the *General Energy Statistics*. These emissions are already accounted for in '1.A.2.c. Chemicals'.

- ***Emission Factors***

➢ ***$CO_2$***

The emission factor was set, based on a survey conducted by the Japan Petrochemical Industry Association in 2009 on the $CO_2$ emission factor from ethylene production.

This country-specific $CO_2$ EF was established based on $CO_2$ emissions from decoking, etc and ethylene production data. $CO_2$ emissions from the energy use of industrial process off gases obtained from the feedstocks are accounted for under '1.A. Fuel combustion,' and therefore there is a difference between the CSEF and the IPCC default value.

This emission factor is confidential.

➢ ***$CH_4$***

Estimates of amount of exhaust gas from flare stacks at a normal operation and an unsteady operation at operating sites in Japan (assuming that 98% of the amount that enters is combusted[1]), and measured amount of exhaust gas from naphtha cracking furnaces and furnaces heated by re-cycled gas, were divided by the production amount to calculate emission factors for each company. The weighted average based on production from each company was then applied to establish the emission factor. (Surveyed by the Japan Petrochemical Industry Association) This emission factor is confidential.

- ***Activity Data***

Ethylene production amounts from the *Yearbook of Current Production Statistics – Chemical Industry* (METI) were used as activity data for emissions of $CH_4$ and $CO_2$ from ethylene production.

Table 4-22 Ethylene production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ethylene production | kt | 5,966 | 6,951 | 7,566 | 7,549 | 7,219 | 6,999 | 6,474 | 6,261 | 6,764 | 6,687 | 6,780 | 6,286 | 6,459 | 6,186 |

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

The uncertainty for both $CO_2$ and $CH_4$ emission factors for ethylene were calculated by finding the 95% confidence interval of emission factors. The estimated uncertainty for both $CO_2$ and $CH_4$ was 77%. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for both $CO_2$ and $CH_4$ was estimated as 77%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, $CO_2$ and $CH_4$ emissions from ethylene production have been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.3.8.3. 1,2-Dichloroethane and Chloroethylene (2.B.8.c)

***a) Category Description***

***1) $CO_2$***

1,2-dichloroethane (Ethylene Dichloride) is a precursor of polyvinyl chloride and is mainly used for

[1] The assumption was set based on a flaring efficiency of 98% shown in the IPCC GPG (Table 2.16 note e).

chloroethylene (VCM) production. It is also used for cleaning agents, solvents, pesticides, and fumigants etc. It is manufactured by the direct chlorination process or the oxychlorination process, or by a process combining the two. The direct chlorination process involves gas-phase reaction of ethylene with chlorine to produce ethylene dichloride, and the oxychlorination process involves gas-phase reaction of ethylene with hydrochloric acid and oxygen to produce ethylene dichloride. The oxychlorination process produces $CO_2$ from the oxidation of the ethylene. (See the below)

$$C_2H_4 + 0.5O_2 + 2HCl \rightarrow C_2H_4Cl_2 + H_2O$$
$$[C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O]$$

The ethylene dichloride is cracked to produce chloroethylene monomer, a precursor of polyvinyl chloride, and hydrochloric acid. The ethylene dichloride is cracked to produce chloroethylene monomer, a precursor of polyvinyl chloride, and hydrochloric acid. Since the hydrochloric acid can be utilized in the oxychlorination process, the combined process of the two spread widely. $CO_2$ is emitted through the same chemical reactions as the above in the combined process.

***2) $CH_4$***

1,2-dichloroethane passes through washing, refining, and thermolysis processes to become chloroethylene ($C_2H_3Cl$). A very small amount of $CH_4$ is contained in the exhaust gases of the reaction, and of the washing and refining processes.

***b) Methodological Issues***

- ***Estimation Method***

$CO_2$ emissions are calculated by multiplying the production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*.

For years FY1990 to FY2000, $CH_4$ emissions are calculated by multiplying the production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*. According to Vinyl Environmental Council, equipment installation for exhaust gas combustion was completed for all plants, and the $CH_4$ contained in the tail gas is below detectable levels. Therefore, emissions are reported as NO for years FY2001 and onward. (The amount combusted is reported as recovered)

- ***Emission Factors***

  - ***$CO_2$***

A $CO_2$ emission factor (0.0647 t-$CO_2$/tVCM) per chloroethylene production provided by the Vinyl Environmental Council was applied for all years.

This emission factor was established by dividing the total measured $CO_2$ emissions across all five plants producing 1,2-dichloroethane and chloroethylene in 2012, by the total chloroethylene production amounts in 2012.

The default value 0.294t$CO_2$/ tVCM also accounts for $CO_2$ emitted from combustion of auxiliary fuel, but for the above country-specific emission factor, this is removed in order to avoid double-counting with the energy sector, resulting in a lower value than the default.

  - ***$CH_4$***

The concentration of $CH_4$ in waste gas from three member companies of the Vinyl Environmental

Council (representing approximately 70% of total 1,2-dichloroethane production in Japan) was measured, and a weighted average was calculated to establish the emission factor. (Years FY1990 to FY2000) The emission factor is 0.0050 [kg-$CH_4$/t]. Based on the information on the production processes in each Dichloroethane producing company, the representativeness of the EF has been confirmed. (Surveyed by the Vinyl Environmental Council) The installation of equipment for exhaust gas combustion has progressed, and due to this, the fraction of $CH_4$ in the tail gas is lower than the default value and is now below detectable levels. No emission factors are set for years FY2001 and onward.

- ***Activity Data***

VCM (Chloroethylene) production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* (METI) were used as activity data for $CO_2$ emissions

1,2-Dichloroethane production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* were used as activity data for $CH_4$ emissions.

Table 4-23 VCM (Chloroethylene) production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VCM production amount | kt | 2,316 | 2,648 | 2,976 | 3,098 | 2,958 | 2,850 | 2,253 | 2,009 | 2,286 | 2,315 | 2,616 | 2,621 | 2,706 | 2,664 |

Table 4-24 1,2-Dichloroethane production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,2-Dichloroethane production | kt | 2,683 | 3,014 | 3,346 | 3,639 | 3,213 | 3,155 | 2,841 | 2,558 | 2,733 | 2,730 | 3,003 | 3,012 | 3,158 | 3,113 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the $CO_2$ and $CH_4$ emission factors for 1,2-dichloroethane production, the default values of -50 - +20% and -10 - +10% in the *2006 IPCC Guidelines* were respectively applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of 1,2-dichloroethane production was estimated as -50 - +21% and -11 - +11%, respectively.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, $CH_4$ emissions from 1,2-Dichloroethane production have been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

### 4.3.8.4. Ethylene oxide Production (2.B.8.d)

#### *a) Category Description*

#### *1) $CO_2$, $CH_4$*

Ethylene oxide is produced by reacting ethylene with oxygen over a catalyst, with $CO_2$ released as a by-product. (See below) There are two methods in providing oxygen; one through providing air, and the other through providing pure oxygen separated from air.

$$C_2H_4 + 0.5O_2 \rightarrow C_2H_4O$$
$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

The $CO_2$ emitted is partially vented into the atmosphere, and is partially recovered by a carbonate solution to be used in food and beverage production etc.

Generally, ethylene oxide production is a process where gases are recycled, and therefore it is necessary to partially purge the gases out of the system so to suppress the rise in pressure due to the accumulation of non- reactive fine impurities (such as argon or nitrogen) contained in the raw material gas, which results in gas emissions. This contains gases such as ethylene, methane, oxygen, or argon, and are generally flared as they are, but $CH_4$ may be emitted through leakage or venting.

#### *b) Methodological Issues*

- ***Estimation Method***

➢ ***$CO_2$***

Following the Tier 3 method of the *2006 IPCC Guidelines*, emissions are estimated by multiplying the total domestic production amount by a country-specific emission factor established based on factory-specific data. The difference between emissions estimated using an EF which does not reflect recovery, and emissions estimated using an EF which reflects recovery (the actual EF used for this sub-category) is reported under $CO_2$ from carbonated gas and dry ice production (2.H.2). (See below)

$$E_{CO_2} = EO \times EF_1$$

| | |
|---|---|
| $E_{CO_2}$ | : $CO_2$ emissions from ethylene oxide production |
| $EO$ | : Ethylene oxide production amount per year |
| $EF_1$ | : $CO_2$ emissions per ethylene oxide production amount (reflecting recovery) |

$$R_{CO_2} = EO \times EF_2 - E_{CO_2}$$

| | |
|---|---|
| $R_{CO_2}$ | : $CO_2$ recovery amount from ethylene oxide production processes |
| $EO$ | : Ethylene oxide production amount per year |
| $EF_2$ | : $CO_2$ emissions per ethylene oxide production amount (without reflecting recovery) |

➢ ***$CH_4$***

Following the Tier 1 method of the *2006 IPCC Guidelines*, emissions are estimated by multiplying the total domestic production amount by a country-specific emission factor established based on factory-specific data.

- ***Emission Factors***

  - ***$CO_2$***

EFs per production amount (recovery reflected: 0.24 t-$CO_2$/t, recovery not reflected: 0.33 t-$CO_2$/t) are used. (provided by the Japan Petrochemical Industry Association) The EFs are a simple average of factory-specific EFs for all factories in Japan, and are based on the carbon balance, etc of the amounts of raw or secondary material input, and amounts of product or by-product output. The production amounts per factory are confidential, and therefore a weighted average cannot be taken. Additionally, since all ethylene oxide is produced by the same process (the Oxygen method), it is considered that a simple average would not divert far from the actual conditions. In the Oxygen method applied in Japan, the selectivity of the catalyst is higher than that of the default, and therefore the EF not reflecting recovery is lower than the default value of 0.663 t-$CO_2$/t.

  - ***$CH_4$***

An EF based on measured data and specific to the manufacturer is used. The $CH_4$ emission data used to establish the EF is estimated by the manufacturer based on an estimation of $CH_4$ emissions into the atmosphere, which is further based on the $CH_4$ amount in the gas introduced from outside when gases are purged from the process. Data are only available from FY2004, and therefore for the preceding years, a three-year average of data from FY2004 to FY2006 will be taken and applied. The data is confidential.

- ***Activity Data***

  - ***$CO_2$***

The ethylene oxide production amounts in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) are used. (Table 4-25)

Table 4-25 Ethylene oxide production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ethylene oxide pruduction | kt | 714 | 795 | 961 | 1,001 | 792 | 843 | 842 | 849 | 915 | 894 | 923 | 882 | 945 | 893 |

  - ***$CH_4$***

The ethylene oxide production amount at the one manufacturer is used. The data is confidential.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainty for the $CO_2$ emission factor, the default value of 10% in the *2006 IPCC Guidelines* was applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 11%.

For the uncertainty for the $CH_4$ emission factor, the default value of 60% in the *2006 IPCC Guidelines* was applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 60%.

- ***Time-series Consistency***

For activity data, the same source – the *Yearbook of Current Production Statistics - Chemical Industry* and data from one manufacturer are used throughout the time series. The emission factor is set based on data from the same sources. Therefore, $CO_2$ and $CH_4$ emissions from ethylene oxide production have been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.3.8.5. Acrylonitrile Production (2.B.8.e)

***a) Category Description***

***1) $CO_2$***

Acrylonitrile ($C_3H_3N$) is used as raw material for acrylic fiber or synthetic resin and is mainly manufactured by way of direct ammoxidation of propylene with ammonia and oxygen over a metal catalyst. (SOHIO process) On the order of 85 percent of the propylene feedstock is converted to either the primary product acrylonitrile or secondary products acetonitrile or hydrogen cyanide. (See below chemical equations 1 to 3) The remainder of the propylene feedstock is either converted to other hydrocarbons through side reactions in the ammoxidation process or converted directly to $CO_2$ by direct oxidation of the feedstock in the ammoxidation process (See below chemical equation 4)

Equation 1: Acrylonitrile reaction

$$CH_2 = CHCH_3 + 1.5O_2 + NH_3 \rightarrow CH_2 = CHCN + 3H_2O$$

Equation 2: Hydrogen cyanide reaction

$$CH_2 = CHCH_3 + 3O_2 + 3NH_3 \rightarrow 3HCN + 6H_2O$$

Equation 3: Acetonitrile reaction

$$CH_2 = CHCH_3 + 1.5O_2 + 1.5NH_3 \rightarrow 1.5CH_3CN + 3H_2O$$

Equation 4: Feedstock oxidation

$$CH_2 = CHCH_3 + 4.5O_2 \rightarrow 3CO_2 + 3H_2O$$

***2) $CH_4$***

The $CH_4$ off-gases are analyzed in the plants manufacturing acrylonitrile, but since no emissions are detected, they are reported as NA.

***b) Methodological Issues***

- ***Estimation Method***

Emissions are calculated by multiplying the acrylonitrile production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 3 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

A $CO_2$ emission factor per production (0.73 t-$CO_2$/t, provided by the Japan Petrochemical Industry Association) is applied for all years. This emission factor is an arithmetic mean of plant-specific $CO_2$ emission factors for all plants, based on the carbon balance of raw material and secondary material input

and product and by-product output for each plant. This is done due to the fact that production data for each plant are confidential and this does not allow for taking a weighted average, and that acrylonitrile is manufactured by the same process throughout Japan (SOHIO process), which means that taking an arithmetic mean will not deviate far from actual conditions.

In the acrylonitrile manufacturing processes in Japan, acetonitrile and hydrogen cyanide are collected as products, and therefore the emission factor is close to the default value in the *2006 IPCC Guidelines* (0.79 t-$CO_2$/t). The reason for it being slightly lower is due to efforts made to improve the efficiency of production.

- ***Activity Data***

Acrylonitrile production amounts given in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) were used for activity data.

Table 4-26 Acrylonitrile production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acrylonitrile production amount | kt | 602 | 652 | 734 | 697 | 631 | 718 | 665 | 553 | 499 | 468 | 431 | 437 | 443 | 467 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 60% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 5% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 60%.

- ***Time-series Consistency***

For activity data, the same source, the *Yearbook of Current Production Statistics - Chemical Industry,* are used throughout the time series. The emission factor is constant throughout the time series. Therefore, $CO_2$ emissions from acrylonitrile production have been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3.8.6. Carbon Black Production (2.B.8.f)

### *a) Category Description*

#### *1) $CO_2$, $CH_4$*

Carbon black is mainly produced from the partial combustion of byproduct oil and gas from the petroleum refining and metallurgical refining processes in a high temperature atmosphere. (furnace black process) The $CO_2$ and $CH_4$ in the tail gas (off gas) emitted from the carbon black production

process is released into the atmosphere.

### *b) Methodological Issues*

- ***Estimation Method***

  - ***$CO_2$***

$CO_2$ emissions from carbon black production are calculated by multiplying the carbon black production amount by Japan's country-specific emission factor, in accordance with the Tier 1 method in the *2006 IPCC Guidelines.*

  - ***$CH_4$***

$CH_4$ emissions from carbon black production are calculated by multiplying the carbon black production amount by Japan's country-specific emission factor, established based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

  - ***$CO_2$***

Since it is considered that the $CO_2$ from natural gas that is used to heat the furnace (secondary feedstock origin) is already accounted for under fuel combustion (1.A.), only $CO_2$ from the oil and gas used directly as raw material (primary feedstock origin) is accounted for here. A $CO_2$ emission factor per production (2.06 t-$CO_2$/t) provided by the Carbon Black Association is used. This is established by taking a weighted average of total $CO_2$ measurements (subtracting out the carbon left over in the product from the carbon in the raw material, then dividing it by the weight of the product) for all five member companies' plants, with the production amounts of each company. Since these five companies cover over 95% of domestic production and sales, the emission factor is considered representative for Japan. All companies use the oil furnace process, and therefore emission factors do not differ much nor vary much annually.

  - ***$CH_4$***

In carbon black manufacturing plants in Japan, $CH_4$ is only emitted into the atmosphere during non-steady operation, when venting is done at shutdowns and startups. According to the *Carbon Black Handbook* (Carbon Black Association), the concentrations of $CH_4$, and the concentrations of CO, $CO_2$, and $CH_4$ combined in the average tail gas is 0.6wt% and 21.5wt% respectively, and this is the same for during shutdowns and startups. Therefore, the $CH_4$ emission factor can be calculated from the $CO_2$ emission factor (2.06 t-$CO_2$/t) as the below. The data is confidential.

$$EF_{CH_4} = 2.06[\text{t-}CO_2/\text{t}] \times R \times \frac{0.6[\text{wt\%}]}{21.5[\text{wt\%}]} \times \frac{16}{44}$$

$EF_{CH_4}$ : EF for carbon black production

$R$ : The ratio of venting time at shutdowns and startups to the total operation time

No gas leakage occurs from the system, since inside the process the air pressure is negative, and therefore only emissions associated with venting is estimated.

- ***Activity Data***

Carbon black production amounts given in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) were used for activity data for both $CO_2$ and $CH_4$ emissions associated with the manufacturing of carbon black.

Table 4-27 Carbon black production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Carbon black production | kt | 793 | 759 | 772 | 805 | 635 | 730 | 670 | 612 | 628 | 608 | 563 | 567 | 597 | 611 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

The uncertainty for the emission factor for carbon black was calculated by finding the 95% confidence interval of emission factors. The estimated uncertainty was 55% for both $CO_2$ and $CH_4$. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used for both $CO_2$ and $CH_4$. As a result, the uncertainty of carbon black production emissions was estimated at 55% for both $CO_2$ and $CH_4$.

- ***Time-series Consistency***

For activity data, the same source, the *Yearbook of Current Production Statistics - Chemical Industry*, are used throughout the time series. The emission factor is constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3.8.7. Styrene Production (2.B.8.g.-)

### *a) Category Description*

$CH_4$ is emitted in the styrene production process.

### *b) Methodological Issues*

- ***Estimation Method***

$CH_4$ emissions from styrene production were calculated by multiplying styrene production amount by Japan's country-specific emission factor, based on the method given in the *2006 IPCC Guidelines*.

- ***Emission Factors***

Estimates of amount of exhaust gas from flare stacks at a normal operation and an unsteady operation at operating sites in Japan (assuming that 98% of the amount that enters is combusted[2]), and measured amount of waste gas from heating furnaces, were divided by the production amount to calculate emission factors for each company. The weighted average by production from each company was then applied to establish the emission factor. (Surveyed by the Japan Petrochemical Industry Association) This emission factor is confidential.

[2] See footnote 1.

- ***Activity Data***

Styrene monomer production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* (METI) were used as activity data for $CH_4$ emissions from styrene production.

Table 4-28 Styrene monomer production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Styrene production | kt | 2,227 | 2,952 | 3,020 | 3,375 | 3,043 | 3,019 | 2,594 | 2,426 | 2,539 | 2,518 | 2,260 | 1,952 | 2,100 | 1,994 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

The uncertainty for the $CH_4$ emission factor for styrene production was estimated by finding the 95% confidence interval of emission factors. The estimated uncertainty was 113%. For the uncertainty of activity data, the standard value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated as 113%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, $CH_4$ emissions from styrene production have been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3.8.8. Phthalic anhydride Production (2.B.8.g.-)

### *a) Category Description*

Phthalic anhydride is used as raw material for plasticizers, synthetic resins, paints, dyes etc. CO and $CO_2$ are emitted during the oxidation of naphthalene and o-xylene in the production process of Phthalic anhydride. CO is also combusted and ultimately emitted as $CO_2$.

### *b) Methodological Issues*

- ***Estimation Method***

The production amount of phthalic anhydride is multiplied by an emission factor per production amount to calculate emissions.

- ***Emission Factors***

The $CO_2$ generation rate (mol %) was calculated by assuming that carbon that did not become products or other by-products ultimately become $CO_2$, and by using the yield of products or other by-products (mol %) per production process of phthalic anhydride (*Petrochemical Processes* (The Japan Petroleum Institute)) The EFs in each production process are calculated from the $CO_2$ emissions per production

amount, based on the generation rate of $CO_2$ and products and the molecular weight of each substance. The yield is shown with an upper limit and lower limit in *Petrochemical Processes*, and therefore EFs are set using the median value.

Table 4-29 Generation rate of each substance by production process of phthalic anhydride

| Production process | Product yield [mol %] | Maleic Anhydride [mol %] | Other [mol %] | $CO_2$ * [mol %] | EF * [t-$CO_2$/t] |
|---|---|---|---|---|---|
| Oxidation of naphthalene | 87-91 | 3-5 | 1 | 2-8 | 0.19 |
| Oxidation of o-xylene | 80-83 | 4-6 | 1-2 | 10-16 | 0.54 |

Reference: *Petrochemical Processes* (The Japan Petroleum Institute) (excluding*)

Following this, a weighted average is taken for each year to set the EF for all of Japan. This is based on the productive capacity by year and by production process in the *Chemicals Handbook* (The Heavy and Chemical Industries News Agency)

Table 4-30 The weighted average EF based on productive capacity of phthalic anhydride

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weighted average EF | t-$CO_2$/t | 0.39 | 0.39 | 0.41 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 |

Note: No information is available on the productive capacity per production process prior to FY1996, and therefore the FY1996 value is used for the preceding years.

- ***Activity Data***

The production amounts of phthalic anhydride in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) are used.

Table 4-31 Phthalic anhydride production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phthalic anhydride production | kt | 300 | 319 | 288 | 216 | 137 | 160 | 148 | 162 | 158 | 156 | 159 | 156 | 163 | 155 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the emission factor, a 32% value, derived from the upper/lower limits of the theoretical value of the yield which was used to establish the emissions factor, was used. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 32%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is based on a consistent methodology throughout the time series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

### 4.3.8.9. Maleic anhydride Production (2.B.8.g.-)

#### *a) Category Description*

Maleic anhydride is used as raw material for unsaturated polyester resins, or for resin improving agents, food additives, pharmaceutical ingredients, or synthetic raw material for organic acids such as malic acid and succinic acid. CO and $CO_2$ are emitted during the oxidation of benzene and n-butane in the production process of maleic anhydride. CO is also combusted and ultimately emitted as $CO_2$.

#### *b) Methodological Issues*

- ***Estimation Method***

The production amount of maleic anhydride is multiplied by an emission factor per production amount to calculate emissions.

- ***Emission Factors***

The $CO_2$ generation rate (mol %) was calculated by assuming that carbon that did not become products or other by-products ultimately become $CO_2$, and by using the yield of products or other by-products (mol %) per production process of maleic anhydride (*Petrochemical Processes* (The Japan Petroleum Institute)) The EFs in each production process are calculated from the $CO_2$ emissions per production amount, based on the generation rate of $CO_2$ and products and the molecular weight of each substance. The yield is shown with an upper limit and lower limit in *Petrochemical Processes*, and therefore EFs are set using the median value.

Table 4-32 Generation rate of each substance by production process of maleic anhydride

| Production process | Product yield [mol %] | $CO_2$ * [mol %] | EF * [t-$CO_2$/t] |
|---|---|---|---|
| Oxidation of benzene | 70-80 | 20-30 | 0.74 |
| Oxidation of n-butane | 55-60 | 40-45 | 1.65 |

Reference: *Petrochemical Processes* (The Japan Petroleum Institute) (excluding *)

Following this, a weighted average is taken for each year to set the EF for all of Japan. This is based on the productive capacity by year and by production process in the *Chemicals Handbook* (The Heavy and Chemical Industries News Agency)

Table 4-33 The weighted average EF based on productive capacity of maleic anhydride

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weighted average EF | t-$CO_2$/t | 1.20 | 1.20 | 1.23 | 1.11 | 1.11 | 1.11 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 |

Note: No information is available on the productive capacity per production process prior to FY1996, and therefore the FY1996 value is used for the preceding years.

- ***Activity Data***

The production amounts of maleic anhydride in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) are used.

Table 4-34 Maleic anhydride production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maleic anhydride production | kt | 103 | 116 | 132 | 103 | 85 | 93 | 88 | 75 | 86 | 85 | 87 | 88 | 90 | 89 |

#### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the emission factor, a 16% value, derived from the upper/lower limits of the

theoretical value of the yield which was used to establish the emissions factor, was used. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 17%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is based on a consistent methodology throughout the time series.

#### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

#### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

#### *f) Category-specific Planned Improvements*

No improvements are planned.

### 4.3.8.10. Hydrogen Production (2.B.8.g.-)

#### *a) Category Description*

$CO_2$ is emitted from the steam reforming process of fossil fuels such as natural gas, petroleum, etc during hydrogen production. Hydrogen is produced as a by-product during petroleum refining, ethylene production, etc, and is recovered and used, however relevant emissions are already captured under other categories. Therefore, $CO_2$ generated from hydrogen production from raw materials, where the sole purpose is to obtain hydrogen, is addressed here.

#### *b) Methodological Issues*

- ***Estimation Method***

The production amount of hydrogen is multiplied by an emission factor per production amount to calculate emissions.

- ***Emission Factors***

The aggregated $CO_2$ emissions from industrial gas producers was divided by the aggregated production amounts of hydrogen to establish a $CO_2$ EF per production. Both aggregated values are based on values reported by member companies of the Japan Industrial and Medical Gases Association.

Table 4-35 Emission factors for hydrogen production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emission factor | t-$CO_2$ / $10^3Nm^3$ | 0.82 | 0.83 | 0.83 | 0.88 | 0.87 | 0.87 | 0.87 | 0.88 | 0.86 | 0.85 | 0.85 | 0.84 | 0.86 | 0.86 |

- ***Activity Data***

The production amounts of hydrogen are for those processes that entail $CO_2$ emissions, and are based on values reported by member companies of the Japan Industrial and Medical Gases Association.

Table 4-36 Hydrogen production amount

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydrogen production | $10^3Nm^3$ | 7,431 | 25,116 | 46,562 | 37,911 | 36,277 | 38,889 | 37,437 | 34,846 | 32,170 | 28,394 | 32,257 | 34,235 | 34,095 | 33,574 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

The uncertainty value of 77% for ethylene production was used for the EF uncertainty. Similarly, for the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for $CO_2$ emissions from hydrogen production was estimated as 77%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is based on a consistent methodology throughout the time series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

The emission factors were revised for FY2013 to FY2017 resulting in recalculations. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3.9. Fluorochemical Production (2.B.9.)

### 4.3.9.1. By-product Emissions: Production of HCFC-22 (2.B.9.-)

### *a) Category Description*

HFC-23 is generated as a by-product of HCFC-22 production.

### *b) Methodological Issues*

- ***Estimation Method***

Emissions are estimated by subtracting the recovery and destruction amount of by-product HFC-23 (measured data) from the amount of by-product HFC-23 generated at HCFC-22 production plants in Japan. The amount of by-product HFC-23 was estimated by multiplying the production of HCFC-22 by the generation rate of HFC-23 (obtained from the results of composition analysis of the interior of a reactor). Emission factors are country-specific.

The recovery/destruction units are constantly running when the plants are in operation. If any trouble arises in the units, management practices are to stop the plant operation, and for any portion of emissions without recovery/destruction, this is reflected in the data.

$$E = P_{HCFC\text{-}22} \times EF - R$$

| | |
|---|---|
| $E$ | : Emissions of by-product HFC-23 associated with the production of HCFC-22 |
| $P_{HCFC\text{-}22}$ | : Production of HCFC-22 [t] |
| $EF$ | : Rate of generation of HFC-23 [%] |
| $R$ | : Amount of recovery and destruction [t] |

Table 4-37 Indices related to By-product Emissions of HFC-23: Production of HCFC-22

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production of HCFC-22 | t | 60,122 | 81,000 | 95,271 | 65,715 | 26,682 | 46,149 | 45,314 | 54,388 | 47,546 | 51,753 | 49,121 | 48,833 | 52,646 | 56,933 |
| Rate of generation of HFC-23 | % | 2.13% | 2.13% | 1.70% | 1.90% | 2.34% | 2.01% | 1.53% | 1.60% | 1.41% | 1.46% | 1.46% | 1.38% | 1.47% | 1.80% |
| Emission rate to production of HCFC-22 | % | 1.79% | 1.79% | 1.11% | 0.06% | 0.01% | 0.01% | 0.002% | 0.002% | 0.002% | 0.003% | 0.004% | 0.003% | 0.005% | 0.001% |
| Emissions | t | 1,076 | 1,450 | 1,060 | 40 | 3 | 4 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 1 |
| | kt-$CO_2$ eq. | 15,929 | 21,460 | 15,688 | 586 | 50 | 53 | 16 | 18 | 16 | 24 | 30 | 24 | 38 | 12 |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council, Ministry of Economy, Trade and Industry* (hereafter, *Documents of Fluorocarbons etc Measures Working Group*), *Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods* (hereafter, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*)

Note: Emissions decreased because all manufacturing facilities were equipped with recovery/destruction units in 2004. The low emission rate to production is due to efforts made in preventing the fall of the operating rates through the improvement in techniques of operation management of destruction facilities and maintenance. Emission reduction has further advanced since, with continuous efforts made in improvement of operation management techniques etc.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using the combined HCFC-22 production amounts for the purpose of material for fluorocarbon polymers (estimated from the production amounts of fluorocarbon polymers and the ratio of HCFC-22 production amounts for the purpose of material for fluorocarbon polymers to the production amounts of fluorocarbon polymers (an average of 1995-2006 where data were available)) and HCFC-22 production amounts for the purpose of refrigerants (estimated from total HCFC-22 shipment amounts[3], and HCFC-22 shipment amounts for the purpose of refrigerants from 1995) as data for total HCFC-22 production amounts, and by using data on the emission rate to the production of HCFC-22 from 1995, and extrapolating for these years.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the emissions, a 2% value from the *2006 IPCC Guidelines* was applied.

- ***Time-series Consistency***

For years after 1995, the Manufacturing Industries Sub-Group, Ministry of Economy, Trade and Industry annually collects and estimates F-gas emissions. For the years 1990 to 1994, estimates have been done by extrapolation, etc of relevant data from 1995 onward, and therefore time-series consistency is taken into account to the extent possible.

### *d) Category-specific QA/QC and Verification*

The data collected and estimated by the Manufacturing Industries Sub-Group, Ministry of Economy, Trade and Industry, is checked by the Committee for Greenhouse Gas Estimation Methods and is used in the inventory. Emissions are surveyed for all production plants in Japan. Composition analysis is carried out frequently, as in the case where one plant takes measurements every day. Concentration measurements are implemented at the vent of the plant.

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

[3] MITI, Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council, 1997.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.3.9.2. Fugitive Emissions (2.B.9.-)

### *a) Category Description*

HFCs, PFCs, $SF_6$, and $NF_3$ are emitted as fugitive emissions during manufacturing. Regarding returned gas cylinders, when residual gas is decomposed and the containment shell is cleansed, or when there is release into the atmosphere, these emissions are reported under this subcategory.

### *b) Methodological Issues*

- ***Estimation Method***

Emissions were reported based on measurement data at each of HFCs, PFCs, $SF_6$, and $NF_3$ manufacturing plant in Japan. Recovery, etc is hereby taken into account. The recovery/destruction units are constantly running when the plants are in operation. If any trouble arises in the units, management practices are to stop the plant operation.

The associated indices are given in the table below.

Table 4-38 Fugitive emissions from HFC production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emissions | kt-$CO_2$ eq. | 2 | 559 | 296 | 449 | 234 | 128 | 151 | 120 | 131 | 101 | 83 | 149 | 95 | 88 |

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Fluorocarbon Manufactures Association), and data provided by the Ministry of Economy, Trade and Industry, *Documents of the first meeting of the Breakout Group on F-gases and FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods*

Note: With emission reduction measures such as installation of destruction units subsidized by the government, and re-evaluation of the production processes, emission reduction has advanced.

Table 4-39 Fugitive emissions from PFC production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emissions | kt-$CO_2$ eq. | 331 | 914 | 1,661 | 1,041 | 459 | 248 | 206 | 148 | 111 | 107 | 115 | 97 | 78 | 87 |

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Chemical Industry Association), *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: With emission reduction measures such as installation of destruction units subsidized by the government, and re-evaluation of the production processes, emission reduction has advanced. The installation of destruction units in 2011 for lean gas emitted further contributed to the achievement of emission reduction.

Table 4-40 Indices related to fugitive emissions from $SF_6$ production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production of $SF_6$ | t | 1,848 | 2,392 | 1,556 | 2,313 | 2,562 | 2,201 | 1,993 | 2,230 | 2,128 | 1,997 | 2,027 | 2,003 | 1,680 | 1,658 |
| Emissions | t | 152 | 197 | 36 | 41 | 10 | 8 | 6 | 5 | 4 | 3 | 2 | 2 | 2 | 2 |
| | kt-$CO_2$ eq. | 3,471 | 4,492 | 821 | 930 | 233 | 189 | 132 | 123 | 93 | 62 | 52 | 50 | 41 | 46 |

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Chemical Industry Association), *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: Emissions decreased because all manufacturing facilities were equipped with recovery/destruction units in 2009. Re-evaluation of the production processes and handling at shipment has also advanced emission reduction.

Table 4-41 Indices related to fugitive emissions from $NF_3$ production

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production of $NF_3$ | t | 6 | 37 | 208 | 1,663 | 2,887 | 3,642 | 3,612 | 3,501 | 4,148 | 4,660 | 4,963 | 4,366 | 4,649 | 4,719 |
| Emissions | t | 0.2 | 1.0 | 7.0 | 72.1 | 66.8 | 76.9 | 93.1 | 76.4 | 86.4 | 56.1 | 23.5 | 25.1 | 13.6 | 3.4 |
| | kt-$CO_2$ eq. | 3 | 17 | 120 | 1,240 | 1,149 | 1,323 | 1,601 | 1,314 | 1,486 | 965 | 404 | 432 | 234 | 58 |

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Chemical Industry Association)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using HFC, PFC, and $SF_6$ shipment amounts[4] which is thought to be proportional to HFC, PFC, and $SF_6$ production amounts, and the ratio of emissions to the HFC, PFC, $SF_6$, and $NF_3$ production amounts from 1995, and weighted average GWPs for HFCs and PFCs from 1995, and extrapolating for these years.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainties of the emissions for all HFCs, PFCs, $SF_6$, and $NF_3$, a 2% value from the *2006 IPCC Guidelines* was applied.

- ***Time-series Consistency***

See section 4.3.9.1. c).

### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.4. Metal Industry (2.C.)

This category covers $CO_2$, $CH_4$, HFC, PFC and $SF_6$ emissions from the manufacturing processes of metal products.

This section includes GHG emissions from the following sources: Iron and steel production (2.C.1.), Ferroalloys production (2.C.2.), Aluminum production (2.C.3.), Magnesium production (2.C.4.), Lead production (2.C.5.), and Zinc production (2.C.6.).

In FY2018, emissions from Metal production were 6,006 kt-$CO_2$ eq. and represented 0.5% of Japan's total GHG emissions (excluding LULUCF). The total emissions of $CO_2$ and $CH_4$ from this category had decreased by 21.2% compared to FY1990. The total of HFCs, PFCs and $SF_6$ had decreased by 21.4% compared to 1990.

[4] *Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council, 1997* (MITI). All further reference to 'shipment amounts' used for emission estimates for years 1990 to 1994 are from the same source.

Table 4-42 Emissions from 2.C. Metal Industry

| Gas | | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 2.C.1 | Iron and steel production | Use of electric arc furnaces in steel production | kt-$CO_2$ | 356 | 357 | 201 | 242 | 112 | 160 | 162 | 174 | 145 | 161 | 132 | 143 | 170 | 175 |
| | | | Limestone and dolomite use in iron and steel production | kt-$CO_2$ | 6,888 | 6,492 | 6,538 | 6,255 | 5,356 | 5,941 | 5,803 | 5,889 | 6,044 | 5,961 | 5,808 | 5,693 | 5,576 | 5,538 |
| $CH_4$ | 2.C.1 | Iron and steel production | Use of electric arc furnaces in steel production | kt-$CH_4$ | 0.74 | 0.72 | 0.67 | 0.68 | 0.51 | 0.59 | 0.60 | 0.59 | 0.60 | 0.59 | 0.55 | 0.55 | 0.59 | 0.60 |
| | 2.C.2 | Ferroalloys production | | kt-$CH_4$ | 0.19 | 0.14 | 0.13 | 0.13 | 0.11 | 0.12 | 0.11 | 0.13 | 0.13 | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 |
| | Total | | | kt-$CH_4$ | 0.92 | 0.85 | 0.80 | 0.80 | 0.62 | 0.71 | 0.72 | 0.72 | 0.73 | 0.71 | 0.67 | 0.66 | 0.70 | 0.71 |
| | Total | | | kt-$CO_2$ eq. | 23.05 | 21.34 | 20.04 | 20.10 | 15.43 | 17.70 | 17.96 | 17.99 | 18.16 | 17.68 | 16.69 | 16.50 | 17.43 | 17.79 |
| Total of $CO_2$ and $CH_4$ | | | | kt-$CO_2$ eq. | 7,267 | 6,871 | 6,760 | 6,517 | 5,484 | 6,118 | 5,983 | 6,081 | 6,208 | 6,139 | 5,956 | 5,852 | 5,764 | 5,730 |
| Gas | | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| HFCs | 2.C.4 | Magnesium production | | kt-$CO_2$ eq. | NO | NO | NO | NO | NO | NO | 1.00 | 1.29 | 1.29 | 1.29 | 0.86 | 1.14 | 1.43 | 1.72 |
| PFCs | 2.C.3 | Aluminium production | | kt-$CO_2$ eq. | 203.66 | 103.55 | 26.41 | 21.76 | 16.22 | 15.28 | 15.24 | 13.27 | 9.59 | 1.91 | 0.00 | 0.00 | 0.00 | 0.00 |
| $SF_6$ | 2.C.4 | Magnesium production | | t | 6.43 | 5.00 | 43.00 | 48.42 | 10.00 | 12.88 | 8.00 | 8.00 | 7.00 | 8.00 | 10.00 | 13.80 | 10.80 | 12.00 |
| | | | | kt-$CO_2$ eq. | 146.54 | 114.00 | 980.40 | 1,104.05 | 228.00 | 293.73 | 182.40 | 182.40 | 159.60 | 182.40 | 228.00 | 314.64 | 246.24 | 273.60 |
| Total of F-gases | | | | kt-$CO_2$ eq. | 350 | 218 | 1,007 | 1,126 | 244 | 309 | 199 | 197 | 170 | 186 | 229 | 316 | 248 | 275 |

### 4.4.1. Iron and Steel Production (2.C.1.)

The General Energy Statistics (Energy Balance Table) is a statistic that provides a comprehensive overview of domestic energy supply and demand. As mentioned in section 4.2.1 of the *2006 IPCC Guidelines*, carbon serves a dual purpose in the iron making process, primarily as a reducing agent to convert iron oxides to iron, but also as an energy source to provide heat when carbon and oxygen react exothermically. Coke etc used as a reducing agent are included in the fuel consumption amounts in the *General Energy Statistics* and related emissions are comprehensively captured in 1.A.2.a (Energy sector - iron and steel) in Japan. Therefore, allocating emissions from the consumption of reducing agents to the energy sector does not make a difference in total emissions, but is rather more accurate, because it ensures completeness. The sum of 1.A.2.a (energy sector - iron and steel) and 2.C.1 (IPPU sector - iron and steel production) are comparable to the emissions that are calculated in line with the *2006 IPCC Guidelines* (See the table below).

Table 4-43 $CO_2$ emissions from iron and steel production (for energy and reducing agent use)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.A.2.a (Energy sector - iron and steel) | kt-$CO_2$ | 150,689 | 143,096 | 152,113 | 154,175 | 135,644 | 153,172 | 148,896 | 151,309 | 157,569 | 155,124 | 148,897 | 142,785 | 139,784 | 136,047 |
| 2.C.1 (IPPU sector - iron and steel production) | kt-$CO_2$ | 7,244 | 6,850 | 6,740 | 6,497 | 5,468 | 6,101 | 5,965 | 6,063 | 6,189 | 6,122 | 5,939 | 5,836 | 5,746 | 5,712 |
| Total of $CO_2$ | kt-$CO_2$ | 157,933 | 149,946 | 158,853 | 160,671 | 141,112 | 159,273 | 154,861 | 157,372 | 163,759 | 161,245 | 154,836 | 148,621 | 145,530 | 141,759 |

Regarding reducing agents for iron and steel production, see Table 3-10 and Table 3-62. Regarding the IEF of 2.C.1, see section 'Use of Electric Arc Furnaces in Steel Production' (2.C.1.a).

#### 4.4.1.1. Steel Production (2.C.1.a)

##### *1) $CO_2$*

Coke oxidizes when it is used as a reduction agent in steel production, and $CO_2$ is generated. The amount of coke used has been included under consumption of fuel in the Fuel Combustion Sector (1.A.), and the $CO_2$ generated through the oxidization of coke used as a reducing agent has already been calculated under Fuel Combustion Sector (1.A.).

### 4.4.1.2. Use of Electric Arc Furnaces in Steel Production (2.C.1.a)

#### *a) Category Description*

$CO_2$ is emitted from carbon electrodes when using electric arc furnaces to make steel. $CH_4$ is also emitted from electric arc furnaces during iron and steel production.

#### *b) Methodological Issues*

#### *1) $CO_2$*

- ***Estimation Method***

$CO_2$ emissions from arc furnaces for steel production are estimated by amount of carbon calculated by weight of production and import of carbon electrodes minus weight of export of carbon electrodes. This difference of the carbon is assumed to be diffused to the atmosphere as $CO_2$. The carbon included in electric furnaces gas given in the *General Energy Statistics* are subtracted from the $CO_2$ emission in this source since these emissions are included in category 1.A fuel combustion.

The $CO_2$ equivalent of the AD is emissions, and therefore the implied emission factors are the molecular weight ratio of $CO_2$ to C, 44/12.

- ***Activity Data***

Production of carbon electrodes given in *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials* (METI) and import and export of carbon electrodes given in *Trade Statistics of Japan*, Ministry of Finance are used.

Table 4-44 $CO_2$ emissions from carbon electrodes of furnaces

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #A Import | t | 12,341 | 18,463 | 11,363 | 15,075 | 11,218 | 17,321 | 20,437 | 20,027 | 19,960 | 19,226 | 18,209 | 19,773 | 16,653 | 15,720 |
| #B Domestic production | t | 211,933 | 186,143 | 184,728 | 216,061 | 169,545 | 205,081 | 217,847 | 197,278 | 180,322 | 180,555 | 151,979 | 141,193 | 161,919 | 160,049 |
| #C Export | t | 87,108 | 92,812 | 107,998 | 138,409 | 116,489 | 139,757 | 154,204 | 135,863 | 128,435 | 121,079 | 103,834 | 90,664 | 104,032 | 100,268 |
| #D Electric furnaces gas | t | 39,983 | 14,300 | 33,201 | 26,700 | 33,709 | 39,017 | 39,949 | 33,898 | 32,146 | 34,760 | 30,444 | 31,273 | 28,049 | 27,806 |
| Domestic consumptions (#A + #B - #C - #D) | t | 97,184 | 97,493 | 54,892 | 66,028 | 30,564 | 43,629 | 44,132 | 47,544 | 39,700 | 43,941 | 35,910 | 39,029 | 46,491 | 47,695 |
| $CO_2$ emissions | kt-$CO_2$ eq. | 356 | 357 | 201 | 242 | 112 | 160 | 162 | 174 | 145 | 161 | 132 | 143 | 170 | 175 |

#### *2) $CH_4$*

- ***Estimation Method***

Emissions were calculated by multiplying an emission factor based on actual measurements obtained in Japan by the energy consumption of electric arc furnaces. This is the same method used for calculating $CH_4$ emissions in the Fuel Combustion Sector (1.A. Stationary sources).

- ***Emission Factors***

The emission factor of energy consumption of electric arc furnaces (12.8 kg-$CH_4$/TJ) was determined by using the data from actual measurement surveys. (See Chapter 3, 3.2.5. and Chapter 4, 4.3.5.1)

- ***Activity Data***

Energy consumption amounts included in the "electric furnace" category for the iron and steel industries of the *General Energy Statistics* were used.

Table 4-45 Energy consumption in electric arc furnaces

| Electricity consumption | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electric furnaces | TJ | 57,564 | 55,986 | 52,457 | 52,747 | 39,753 | 45,793 | 47,185 | 46,195 | 46,786 | 46,156 | 42,919 | 43,045 | 46,109 | 46,697 |

***c) Uncertainties and Time-series Consistency***

***1) $CO_2$***

- ***Uncertainty***

Because all $CO_2$ from electric arc furnaces are assumed to escape into the atmosphere, no emission factor has been set. Therefore, by assessing the uncertainty for activity data the uncertainty for emissions is assessed. As a result of combining the uncertainties of the parameters for activity data, the uncertainty was estimated as 5%.

- ***Time-series Consistency***

For activity data (emissions), the same sources are used throughout the time series. Therefore, $CO_2$ emissions from electric arc furnaces have been estimated in a consistent manner throughout the time-series.

***2) $CH_4$***

- ***Uncertainty***

The uncertainty for the emission factor has been estimated as 163% and the uncertainty for activity data has been estimated as 5% (see chapter 3). As a result, the uncertainty for $CH_4$ emissions has been estimated as 163%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, $CH_4$ emissions from electric arc furnaces in steel production have been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

Recalculations of $CO_2$ emissions have been conducted for FY 2013 to FY2017, based on updates made to energy consumption in electric arc furnaces given in the *General Energy Statistics.* Recalculations of $CH_4$ emissions have been conducted for FY2017, based on updates made to the energy consumption of electric arc furnaces. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.4.1.3. Pig Iron Production (2.C.1.b)

***1) $CO_2$***

$CO_2$ generated from pig iron production is emitted when coke etc, are used as a reduction agent. The amount of coke etc used has been included under consumption of fuel in the Fuel Combustion Sector (1.A.), and the $CO_2$ generated through the oxidization of coke, etc used as a reducing agent has already been calculated under Fuel Combustion Sector (1.A.).

#### *2) $CH_4$*

It is theoretically impossible for $CH_4$ generation in association with pig iron production, and it has been confirmed that $CH_4$ is not emitted from actual measurements. Therefore, emissions have been reported as "NA".

### 4.4.1.4. Limestone and dolomite use in Iron and Steel Production (2.C.1.b)

#### *a) Category Description*

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases $CO_2$ derived from $CaCO_3$ and $MgCO_3$.

#### *b) Methodological Issues*

- ***Estimation Method***

The amounts of limestone and dolomite used in iron and steel production are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***

See section 4.2.3. b).

➢ ***Dolomite***

See section 4.2.3. b).

- ***Activity Data***

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use' that are under the Iron and steel/Refining related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-46 Corresponding sectors in the *Adjusted Price Transaction Table*

| Uses | Corresponding sectors in the *Adjusted Price Transaction Table* (Limestone) | Corresponding sectors in the *Adjusted Price Transaction Table* (Dolomite) |
|---|---|---|
| Iron and steel/Refining | 2611-01 Steel - pig iron to 2611-04 Steel - crude ore (electric furnace) | 2611-01 Steel - pig iron to 2631-03 Steel - cast and forged materials (iron) |
| | 2631-02 Steel - cast pipe, -03 - cast and forged materials (iron) | |
| | 2711-01 Non-ferrous metal - copper, -02 Non-ferrous metal lead and zinc | 2711-02 Non-ferrous metal - lead and zinc |
| | 2729-03 Non-ferrous metal - non-ferrous metal cast and forged products | |

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-47 Amounts of limestone and dolomite consumption

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Limestone consumption For Steel and Refinement (dry) | kt | 14,430 | 13,590 | 13,619 | 12,577 | 11,000 | 11,815 | 11,542 | 11,669 | 11,895 | 11,732 | 11,504 | 11,263 | 11,053 | 10,987 |
| Dolomite consumption For Steel and Refinement (dry) | kt | 1,144 | 1,089 | 1,160 | 1,530 | 1,096 | 1,576 | 1,539 | 1,603 | 1,720 | 1,695 | 1,584 | 1,565 | 1,512 | 1,493 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of emission factors, a 3% default value in the *2006 IPCC Guidelines* was used for both limestone and dolomite. For the uncertainty for activity data, a 3% default value in the *2006 IPCC Guidelines* was used for both limestone and dolomite. As a result, the uncertainty for emissions was estimated as 4% for both limestone and dolomite.

- ***Time-series consistency***

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, $CO_2$ emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

Recalculations of $CO_2$ emissions have been conducted for FY2011 to FY2017, based on updates made to limestone and dolomite consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.4.1.5. Direct reduced iron production (2.C.1.c)

### *1) $CO_2$*

$CO_2$ is generated during the production of direct reduced iron, through the oxidation of natural gas or coal used as reductants. However, there has not been any production of direct reduced iron in Japan, and therefore, it has been reported as “NO”.

### *2) $CH_4$*

$CH_4$ is generated from the combustion of natural gas or coal when making direct reduced iron. However, there has not been any production of direct reduced iron in Japan, and therefore, it has been reported as “NO”.

## 4.4.1.6. Sinter Production (2.C.1.d)

### *1) $CO_2$*

$CO_2$ generated when making sinter is generated by the combustion of coke fines; these emissions come under the Fuel combustion sector (1.A.). As they are already calculated in this 1.A. sector, they are reported as “IE”.

$CO_2$ emissions from limestone and dolomite used when making sinter are counted under “4.4.1.4. Limestone and dolomite use in Iron and Steel Production”.

***2) $CH_4$***

$CH_4$ generated when making sinter is all generated by the combustion of coke fines; these emissions come under the Fuel Combustion Sector (1.A.). As they are already calculated in this sector, they are reported as "IE".

### 4.4.1.7. Pellet Production (2.C.1.e)

***1) $CO_2$***

$CO_2$ generated when making pellets is generated by the combustion of fine ore; these emissions come under the Fuel combustion sector (1.A.). As they are already calculated in this 1.A. sector, they are reported as "IE".

$CO_2$ emissions from limestone and dolomite used when making pellets are counted under "4.4.1.4. Limestone and dolomite use in Iron and Steel Production".

***2) $CH_4$***

$CH_4$ generated when making pellets is generated by the combustion of fine ore; these emissions come under the Fuel Combustion Sector (1.A.). As they are already calculated in this sector, they are reported as "IE".

$CO_2$ emissions from limestone and dolomite used when making pellets are counted under "4.4.1.4. Limestone and dolomite use in Iron and Steel Production".

## 4.4.2. Ferroalloys Production (2.C.2.)

***a) Category Description***

***1) $CO_2$***

Ferroalloys are produced in Japan, and the $CO_2$ that is generated in association with the ferroalloys production is emitted as a result of the oxidization of coke used as a reducing agent. Consumption of coke is included in consumption of fuel under the Fuel Combustion Sector (1.A.), and $CO_2$ generated as a consequence of the oxidization of coke used as a reduction agent has already been calculated under the Fuel Combustion Sector (1.A.).The thinking on where to account for $CO_2$ emissions from coke is the same as that for Iron and steel production. Regarding reducing agents for ferroalloys production, see Table 3-10. Residual carbon in the ferroalloys is oxidized when the ferroalloys are used in the production of iron and steel, and are released into the atmosphere as $CO_2$.

$CO_2$ emissions from limestone and dolomite that are used as slag forming materials have already been accounted for under iron and steel production (2.C.1.) as $CO_2$ emissions occurring from limestone and dolomite used during production.

Therefore, $CO_2$ emissions have been reported as "IE".

Regarding carbon in the ore, it is thought that the primary raw materials for ferroalloys in Japan (currently, imported manganese ores, nickel ores, and chromium ores) are rarely imported as carbonate

ores[5]. Their contribution to $CO_2$ emissions is small, and therefore these are not estimated.

### 2) $CH_4$

Ferroalloys are manufactured in Japan in electric arc furnaces, small-scale blast furnaces, and Thermit furnaces. $CH_4$ generated in association with ferroalloy production is thought to be generated when the oxidization of coke, a reduction agent, takes place.

### b) Methodological Issues

- ***Estimation Method***

$CH_4$ emissions from ferroalloy production were calculated by multiplying an emission factor based on actual measurements obtained in Japan by the energy consumption of electric arc furnaces**.**

- ***Emission Factors***

The value for the emission factor of electric arc furnaces (12.8 kg-$CH_4$/TJ) was used because these furnaces produce ferroalloys.

The EF is established using measured $CH_4$ concentration, measured dry gas emissions per hour, calories per hour (electricity), and therefore needs to be per electricity (in TJ). Additionally, if the operation of the furnace or type of ferroalloy is similar, the electricity consumption could be considered proportional to coke consumption or ferroalloy production. This EF reflects the average operation of furnaces/type of ferroalloy at the time of measurement in Japan. The equation below shows the process of deriving the emission factor.

$$EF = C_{CH_4} \times G \times MW / V_m / H$$

| | |
|---|---|
| $EF$ | : Emission factor [kg-$CH_4$/TJ] |
| $C_{CH_4}$ | : Measured $CH_4$ concentration in the emitted gas [ppm] |
| $G$ | : Measured dry gas emissions per hour [$m^3_N$/h] |
| $MW$ | : Molecular weight of $CH_4$ = 16 [g/mol] |
| $V_m$ | : Volume of 1 mole of ideal gas at standard pressure = 22.4 [$10^{-3}m^3$/mol] |
| $H$ | : Calories per hour [MJ/h] |

Some of the parameters were established using measurements which were conducted generally in line with the guidance in the *2006 IPCC Guidelines*, for instance with making efforts to cover a representative sample.

- ***Activity Data***

Energy consumption amounts included in the "ferroalloy" category for the iron and steel industries of the *General Energy Statistics* were used.

Table 4-48 Energy consumption for ferroalloy production

| Electricity consumption | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electric furnaces (for Ferroalloys) | TJ | 14,456 | 10,699 | 10,181 | 10,072 | 8,458 | 9,510 | 8,938 | 10,038 | 9,956 | 9,102 | 9,228 | 8,507 | 8,362 | 8,894 |

### c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty for the emission factor has been estimated as 163% and the uncertainty for activity data

[5] Most of the manganese ores distributed in Japan are high grade manganese oxide ores ($MnO_2$) and it is thought that low grade manganese carbonates ores are rarely distributed.

has been estimated as 5% (see chapter 3). As a result, the uncertainty for $CH_4$ emissions has been estimated as 163%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, $CH_4$ emissions from furnaces for ferroalloy have been estimated in a consistent manner throughout the time-series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.4.3. Aluminum Production (2.C.3.)

#### 4.4.3.1. By-product emissions (2.C.3.-)

***a) Category Description***

***1) $CO_2$***

$CO_2$ generated in association with aluminum smelting is emitted in conjunction with the oxidization of the anode paste used as a reducing agent. Consumption of coke, the main ingredient in the anode paste has been included in fuel consumption under the Fuel combustion sector (1.A.), and the $CO_2$ that is generated by the oxidization of coke used as a reducing agent has already been calculated under the Fuel combustion sector (1.A.). Therefore, it has been reported as “IE”.

In addition to coke, binder pitch is also used in anodes paste for aluminum refining. All of this pitch is produced from by-product coal tar from coke ovens in Japan, where the coal tar consumption is treated as energy use under the Industry sector of the *General Energy Statistics*. None of it is imported. Therefore, emissions are accounted for under stationary combustion in the energy sector.

***2) PFCs***

PFCs are emitted during aluminum refining, due to the use of a fluoride melt consisting mainly of cryolite during electrolysis.

***b) Methodological Issues***

- ***Estimation Method***

Emissions were estimated by multiplying the production amount of primary aluminum refining by Japan’s country-specific emission factors calculated using the equation prescribed in the *2006 IPCC Guidelines*.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by extrapolation etc of relevant data for these years.

- ***Emission Factors***

The equation prescribed in the Tier 2 method of the *2006 IPCC Guidelines*, and its associated slope coefficients set by technology, together with the weight fraction of gases was used to determine emission factors, as shown in the table below.

For the years 1990 to 1994, the emission factor for 1995 is used.

Table 4-49 PFC emission factors and aluminum production amounts

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PFC-14 ($CF_4$) EF | kg-PFC-14/t | 0.709 | 0.709 | 0.482 | 0.398 | 0.390 | 0.388 | 0.387 | 0.386 | 0.386 | 0.386 | 0 | 0 | 0 | 0 |
| PFC-116 ($C_2F_6$) EF | kg-PFC-116/t | 0.060 | 0.060 | 0.041 | 0.034 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0 | 0 | 0 | 0 |
| Production of aluminium | t | 34,100 | 17,338 | 6,500 | 6,490 | 4,930 | 4,670 | 4,670 | 4,075 | 2,950 | 588 | 0 | 0 | 0 | 0 |

Reference: *Yearbook of Minerals and Non-Ferrous Metals Statistics* (METI), *Documents of Fluorocarbons etc Measures Working Group*

- ***Activity Data***

As the activity data for PFC emissions from aluminum refining, the aluminum production amounts given in the *Yearbook of Minerals and Non-Ferrous Metals Statistics* compiled by the Ministry of Economy, Trade and Industry (1995 to 1997), and the *Documents of Fluorocarbons etc Measures Working Group* (previously the Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy, Trade and Industry) (1998 and beyond), were used. (Production ended in 2014.)

For the years 1990 to 1994, aluminum production amounts given in the *Yearbook of Minerals and Non-Ferrous Metals Statistics* compiled by the Ministry of Economy, Trade and Industry were used.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the emission factor and uncertainty of the activity data, the respective default values of 44% and 2% in the *2006 IPCC Guidelines* were applied. As a result, the uncertainty of the emissions was determined to be 44%.

- ***Time-series Consistency***

See section 4.3.9.1. c)

### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d)

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.4.3.2. F-gases used in foundries (2.C.3.-)

Emission from this source was reported as “NO” as it has been confirmed that Japan had no record of the use of $SF_6$ in aluminum forging processes.

### 4.4.4. Magnesium Production (2.C.4.)

#### *a) Category Description*

HFCs and $SF_6$ are emitted in magnesium foundries, due to its use as cover gas to prevent oxidation of molten magnesium.

#### *b) Methodological Issues*

Emissions are an aggregation of all HFCs and $SF_6$ used by magnesium foundries. The data that has been reported is given in documentation prepared by the Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group of the Ministry of Economy, Trade and Industry's Industrial Structure Council, for emissions of HFCs and $SF_6$ used in magnesium foundries. The associated indices are given in the table below.

Table 4-50 Indices related to HFCs and $SF_6$ emitted from magnesium foundries

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Consumption of HFC-134a | t | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.9 | 0.9 | 0.9 | 0.6 | 0.8 | 1.0 | 1.2 |
| Consumption of $SF_6$ | t | 6.4 | 5.0 | 43.0 | 48.4 | 10.0 | 12.9 | 8.0 | 8.0 | 7.0 | 8.0 | 10.0 | 13.8 | 10.8 | 12.0 |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using other die cast production amounts (excluding aluminium and zinc) which is thought to be proportional to molten magnesium amounts, and the consumption amount of $SF_6$ from 1995, and extrapolating for these years.

#### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

The uncertainty of emissions was set at the 5% value of the upper limit for the Tier 2 method in the *2006 IPCC Guidelines*.

- ***Time-series Consistency***

See section 4.3.9.1. c).

#### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

#### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

#### *f) Category-specific Planned Improvements*

No improvements are planned.

### 4.4.5. Lead production (2.C.5.)

$CO_2$ generated from lead production are emitted by the oxidization of coke used as reductants. The amount of coke consumed as reductant used in lead production is included under "Direct heating purposes" (a fuel category under non-ferrous bare metal industry) in the *Yearbook of the Current Survey of Energy Consumption*. Since emissions are already accounted for under 1.A.2. Manufacturing

industries and construction in the Energy sector, emissions are reported as IE. The thinking on where to account for $CO_2$ emissions from coke is the same as that for Iron and steel production.

### 4.4.6. Zinc production (2.C.6.)

Similar to lead, $CO_2$ generated from zinc production are emitted by the oxidization of coke used as reductants. The amount of coke consumed as reductants used in zinc production is included under "Direct heating purposes" (a fuel category under non-ferrous bare metal industry) in the *Yearbook of the Current Survey of Energy Consumption*. Since emissions are already accounted for under 1.A.2. Manufacturing industries and construction in the Energy sector, emissions are reported as IE. The thinking on where to account for $CO_2$ emissions from coke is the same as that for Iron and steel production.

When Smithsonite ($ZnCO_3$) which includes carbon in the ore are used as raw material, there is the possibility of $CO_2$ arising from the ore in the reduction process. However, there are currently no cases of Smithsonite use in Japan.

## 4.5. Non-energy products from fuels and solvent use (2.D.)

This category covers $CO_2$ emissions from the use of non-energy products from fuels and solvents. This section includes GHG emissions from the following sources: Lubricant use (2.D.1.), Paraffin wax use (2.D.2.), and Urea used as a catalyst (2.D.3.).

In FY2018, emissions from this category were 2,644 kt-$CO_2$ eq. and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 29.6% compared to FY1990.

Table 4-51 Emissions from 2.D. Non-energy Products from Fuels and Solvent Use

| Gas | | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 2.D.1 | Lubricant use | | kt-$CO_2$ | 343 | 353 | 350 | 324 | 302 | 303 | 284 | 259 | 269 | 263 | 243 | 230 | 233 | 253 |
| | 2.D.2 | Paraffin wax use | | kt-$CO_2$ | 50 | 37 | 36 | 36 | 30 | 35 | 30 | 27 | 28 | 26 | 25 | 24 | 24 | 26 |
| | 2.D.3 | Other | Urea-based catalysts | kt-$CO_2$ | 0.00 | 0.00 | 0.00 | 0.12 | 0.64 | 0.98 | 1.57 | 2.46 | 3.51 | 4.60 | 5.54 | 5.66 | 6.74 | 7.91 |
| | | | NMVOC incineration | kt-$CO_2$ | 1,648 | 1,986 | 2,273 | 2,504 | 2,532 | 2,410 | 2,385 | 2,261 | 2,385 | 2,234 | 2,213 | 2,323 | 2,418 | 2,358 |
| | Total | | | kt-$CO_2$ | 2,040 | 2,377 | 2,659 | 2,865 | 2,864 | 2,748 | 2,701 | 2,551 | 2,685 | 2,527 | 2,486 | 2,583 | 2,682 | 2,644 |

### 4.5.1. Lubricant use (2.D.1.)

#### *a) Category Description*

$CO_2$ is emitted from the oxidation of lubricants and grease during use. Emissions from the total loss type of engine oil are reported in the energy sector (See 1.A.3.), and emissions from other types than the above-mentioned type of engine oil are reported under this sector.

#### *b) Methodological Issues*

- ***Estimation Method***

Emissions were calculated by multiplying lubricant and grease consumption amounts per oil type, by the carbon content and oxidation during use (ODU) factor per oil type, based on the Tier 2 method given in the *2006 IPCC Guidelines*. (See below)

$$E = \sum_i \left( LC_i \times CC_i \times ODU_i \times \frac{44}{12} \right)$$

$E$ : Emissions from the oxidation of lubricants and grease during use [kt-$CO_2$]
$LC_i$ : Lubricant and grease consumption amounts [TJ]
$CC_i$ : Carbon content of fuel [kt-C/TJ]
$ODU_i$ : ODU factor for oil
$i$ : Type of lubricant and grease

- ***Emission Factors***

For carbon content, the carbon emission factors of lubricants and heavy oil products in the *General Energy Statistics* (Agency for Natural Resources and Energy) are used. For the ODU factor, the default values in the *2006 IPCC Guidelines* are used. (lubricants: 0.2, grease: 0.05)

- ***Activity Data***

For lubricants, the consumption amounts for types other than total loss types of engine oil are calculated by subtracting the consumption amounts of the total loss type from the total of consumption amounts of engine oil. (See section 3.2.8. Activity data)

For grease, the consumption amounts are calculated by multiplying the domestic sales amounts in the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, by the calorific values of heavy oil products in the *General Energy Statistics*. However, for years FY1992 to FY1999, the domestic sales data are not available from these statistics. Therefore, the domestic sales for these years are estimated by subtracting the total of exports and stocks at the end of the year, from the total of stocks at the start of the year and production and imports, which are respectively shown in these statistics.

Table 4-52 Consumption of engine oil (for types other than total loss types) and grease

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Consumption of engine oil (for types other than total loss types) | TJ | 23,449 | 24,385 | 24,144 | 22,298 | 20,804 | 20,768 | 19,476 | 17,756 | 17,788 | 17,384 | 15,998 | 15,168 | 15,389 | 16,786 |
| Consumption of grease | TJ | 3,152 | 2,503 | 2,435 | 2,658 | 2,299 | 2,622 | 2,573 | 2,397 | 2,478 | 2,486 | 2,464 | 2,337 | 2,164 | 2,146 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of emission factors, a 50% default value in the *2006 IPCC Guidelines* was applied for both lubricants and grease. For the uncertainty of the activity data, a 5% default value in the *2006 IPCC Guidelines* was applied for both lubricants and grease. As a result, the uncertainty of emissions was assessed to be 50% for both lubricants and grease.

- ***Time-series Consistency***

For activity data, the same source the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* etc are used throughout the time series. The emission factors are constant throughout the time series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

Recalculations have been conducted for FY2017, based on updates made to the consumption of

lubricants. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.5.2. Paraffin wax use (2.D.2.)

### *a) Category Description*

$CO_2$ is emitted from the oxidation of paraffin wax during use.

### *b) Methodological Issues*

- ***Estimation Method***

Emissions were calculated based on the Tier 1 method given in the *2006 IPCC Guidelines*. (See below)

$$E_{CO_2} = PW \times CC_{Wax} \times ODU_{Wax} \times \frac{44}{12}$$

$E_{CO_2}$ : Emissions from paraffin wax during use [t-$CO_2$]
$PW$ : Paraffin wax consumption amounts [TJ]
$CC_{Wax}$ : Carbon content of paraffin wax [kg-C/GJ]
$ODU_{Wax}$ : ODU factor for paraffin wax

- ***Emission Factors***

For carbon content, the carbon emission factor of heavy oil products in the *General Energy Statistics* (Agency for Natural Resources and Energy) is used. For the ODU factor, the default value in the *2006 IPCC Guidelines* is used. (0.2)

- ***Activity Data***

The consumption amounts are calculated by multiplying the domestic sales amounts in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and *Yearbook of Mineral Resources and Petroleum Products Statistics*, by the calorific values of heavy oil products in the *General Energy Statistics*.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of emission factors, a 100% default value in the *2006 IPCC Guidelines* was applied. For the uncertainty of the activity data, a 5% default value in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was assessed to be 100%.

- ***Time-series Consistency***

For activity data, the same source-the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* etc are used throughout the time series. The emission factors are constant throughout the time series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

Recalculations have been conducted for FY2017, based on update made to the gross calorific value of paraffin wax. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.5.3. Other (2.D.3.)

### 4.5.3.1. Urea used as a catalyst (2.D.3.-)

### *a) Category Description*

The urea SCR system for cars is a technology to reduce NOx emissions, by the reduction of NOx in exhaust gas using ammonia and decomposing it into $N_2$ and $H_2O$. By spraying urea aqueous into high temperature exhaust gas, this is hydrolyzed to yield ammonia gas, and $CO_2$ is emitted as follows.

$$CO(NH_2)_2 + H_2O \rightarrow 2NH_3 + CO_2$$

### *b) Methodological Issues*

- ***Estimation Method***

Emissions were calculated based on the *2006 IPCC Guidelines*. (See below)

$$E_{CO_2} = AD \times \frac{12}{60} \times P \times \frac{44}{12}$$

*AD* : Consumption amount of urea-based additives in urea SCR systems [kt]
*P* : Ratio of urea in urea-based additives [%] (Default value: 32.5%)

- ***Emission Factors***

For the Ratio of urea in urea-based additives (P), the default value of 32.5% in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The cumulative number of cars with urea SCR systems (data provided by the Japan Automobile Manufacturers Association) is first multiplied by the consumption amount of diesel oil per car, and then further multiplied by ratio of consumption amount of urea-based additives to diesel, to yield the consumption amount of urea-based additives. This is then multiplied by the ratio of imports to the domestic total consumption to finally yield the consumption amount of urea-based additives for imports only[6].

$$AD = N \times L \times R \times D \times I$$

*AD* : Consumption amount of urea -based additives in urea SCR systems [kt]
*N* : Cumulative number of cars with urea SCR systems [thousand cars]
*L* : Consumption amount of diesel oil per car [kL/car]
*R* : Ratio of consumption amount of urea-based additives to diesel [%]
*D* : Density of diesel oil [t/kL]

[6] Domestically produced urea is from $CO_2$ recovered from ammonia production processes, and therefore the $CO_2$ associated with it is already included in 2.B.1. Ammonia production emissions.

*I* : Ratio of imports [%]

Table 4-53 Parameters used to calculate the consumption amount of urea -based additives, and their sources and methods of establishment

| Item | Sources and methods of establishment |
|---|---|
| Cumulative number of cars with urea SCR systems [thousand cars] | Data provided by the Japan Automobile Manufacturers Association |
| Consumption amount of diesel oil per car [kL/car] | Calculated by dividing the total consumption amount of diesel based on the *Statistical Yearbook of Motor Vehicle Transport* and *Statistical Yearbook of Motor Vehicle Fuel Consumption* (Ministry of Land, Infrastructure, Transport and Tourism) by the total number of registered cars |
| Ratio of consumption amount of urea-based additives to diesel [%] | 2%, as a median value of 1 to 3 % in the *2006 IPCC Guidelines* |
| Density of diesel oil [t/kL] | 0.8831 t/kL, based on the *Handbook on the General Energy Statistics* (RIETI) |
| Ratio of imports [%] | Ratio of urea imports to (domestic shipment amounts + imports) for each year, based on the *Yearbook of Fertilizer Statistics (Pocket Edition)* (Ministry of Agriculture, Forestry and Fisheries) |

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainty of emission factor, a 5% default value in the *2006 IPCC Guidelines* (cars - combustion origin) was applied. For the uncertainty of the activity data, a 5% default value in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was assessed to be 7%.

- ***Time-series Consistency***

For activity data, the same source-data provided by the Japan Automobile Manufacturers Association etc are used throughout the time series. The emission factors are constant throughout the time series.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

Recalculations have been conducted for FY2015 to FY2017, based on updates made to urea domestic shipment amounts of the *Yearbook of Fertilizer Statistics (Pocket Edition)*, since such data is one of parameters for establishment of activity data. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.5.3.2. NMVOC Incineration (2.D.3.-)

***a) Category Description***

$CO_2$ is emitted in the process of NMVOC incineration from facilities etc that use solvents.

### *b) Methodological Issues*

- ***Estimation Method***

$CO_2$ emissions from NMVOC incineration were calculated, for five use types - Paint, Cleansing agents, Printing, Chemical products, and Other, by estimating the domestic supply of solvents, the emissions into the atmosphere, the material recycle amounts, and then subtracting emissions into the atmosphere and the material recycle amounts from the domestic supply of solvents, to yield the amounts incinerated. $CO_2$ emissions from the incineration of some used solvents are already accounted for in the energy sector (alternative fuel use) and waste sector (waste incineration without energy recovery), and therefore are subtracted out from emissions in this category.

$$E_{CO_2} = \sum_i \left( I_i \times C_i \times \frac{44}{12} \right)$$

$E_{CO_2}$ : $CO_2$ emissions from NMVOC incineration [t]
$I_i$ : NMVOC incineration amounts for use type i [t]
$C_i$ : Average carbon content of NMVOCs for use type i

$$I_i = S_i - E_i - R_i$$

$I_i$ : NMVOC incineration amounts for use type i [t]
$Si$ : Domestic supply of solvents for use type i [t]
$Ei$ : NMVOC emissions into the atmosphere for use type i [t]
$Ri$ : Material recycle amounts for use type i [t]

- ***Emission Factors***

The average carbon content is calculated by weighting it by the composition rate of each NMVOC substance emitted from each source. (Same values are used as those for conversion to indirect $CO_2$) The carbon contents of each substance is obtained from molecular formulae, and the type of substance and composition rate of NMVOCs are estimated based on the national emission inventory for volatile organic compounds (VOC) by the Ministry of Environment and other information. From FY2015, an average carbon content for this category (0.64) is used.

- ***Activity Data***

Parameters are set as follows:

➢ ***Domestic supply of solvents for use type i***

For paint, the data for total amount of solvents in paint from the *Compilation of Estimation Results of VOC Emissions from Paint* (Japan Paint Manufacturers Association), and shipment amounts of thinners for paint given in the *Survey on the Actual Conditions of the Paint Manufacturing Industry* (Japan Paint Manufacturers Association) etc, were used. For cleansing agents, printing, chemical products, and other, the data for national sales amounts of solvents by use from the *VOC Emission Inventory Report* (Ministry of the Environment, March 2007), and demand for 'other' use of acetone from the *Petrochemical Industry of Japan* (The Heavy and Chemical Industries News Agency) etc, were used. (For years lacking data, interpolation or extrapolation using product sales amounts etc was applied to estimate)

➢ ***NMVOC emissions into the atmosphere for use type i***

For NMVOC emissions into the atmosphere Ei, NMVOC emissions by source was used. (For details of estimation methods, see Annex 3)

➢ ***Material recycle amounts for use type i***

The material recycle amounts of solvents for use type i in the year FY2011 was first estimated by multiplying the supply of solvents for use type i in the year FY2011, by the ratio of external recycle amounts for use type i in the year FY2011 (*Survey on Organic Solvents Use and Emission Treatment*, Japan Solvent Recycling Industry Association, May, 2012) to the solvent supply amounts for use type i in the year FY2011. This was then multiplied by the growth rate (based on the *Survey on Solvent Recycle Amounts*, Japan Solvent Recycling Industry Association) of solvent collection amounts from FY2011.

Table 4-54 NMVOC incineration amounts by use type

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paints | kt | 266 | 289 | 331 | 339 | 298 | 296 | 262 | 264 | 263 | 260 | 285 | 303 | 329 | 309 |
| Cleaning agents | kt | 85 | 100 | 90 | 108 | 67 | 65 | 67 | 44 | 45 | 48 | 46 | 53 | 51 | 49 |
| Printing solvents | kt | 172 | 195 | 237 | 234 | 221 | 231 | 235 | 235 | 232 | 220 | 219 | 210 | 210 | 204 |
| Chemical products | kt | 51 | 79 | 131 | 150 | 172 | 182 | 183 | 179 | 190 | 183 | 193 | 201 | 205 | 209 |
| Other | kt | 155 | 208 | 209 | 302 | 343 | 336 | 336 | 331 | 366 | 346 | 367 | 381 | 394 | 397 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of emission factor, a 2%, uncertainty of the specially controlled industrial waste (waste oil) was applied. For the uncertainty of activity data, a 60%, uncertainty of the specially controlled industrial waste (waste oil) was applied. As a result, the uncertainty of emissions was assessed to be 60%.

- ***Time-series Consistency***

Consistent activity data and emission factors are used throughout the time series as much as possible.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

Because of the updates made to the methods of establishment of amounts of domestic supply of solvents for paint, recalculations have been conducted for all years. The revision of the Indices of Industrial Production used for estimating of supply of solvents, and the revision of NMVOC emissions into the atmosphere from other use (addition of sources) also contributed to the recalculation for all years. For FY2015 to FY2017, the revision of *Yearbook of Current Production Statistics - Chemical Industry* used for estimating amounts of domestic supply of solvents also contributed to the recalculation. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.5.3.3. Road Paving with Asphalt (2.D.3.-)

Roads in Japan are paved with asphalt, but almost no $CO_2$ are thought to be emitted in the process. It is not possible, however, to be completely definitive about the absence of emissions. Emissions have also never been actually measured, and as no default emission factor is available, it is not currently possible to calculate emissions.

#### 4.5.3.4. Asphalt Roofing (2.D.3.-)

Asphalt roofing is manufactured in Japan, but information on the manufacturing process and activity data is inadequate, and it is not possible to definitively conclude that $CO_2$ is not emitted from the manufacturing of asphalt roofing. Emissions have also never been actually measured, and as no default emission factor is available, it is not currently possible to calculate emissions.

## 4.6. Electronics industry (2.E.)

This category covers HFC, PFC, $SF_6$, and $NF_3$ emissions from the manufacturing of the electronic devices. This section includes GHG emissions from the following sources: Semiconductor (2.E.1.), Liquid Crystals (2.E.2.), Photovoltaics (2.E.3.), and Heat transfer fluid (2.E.4.).

In 2018, emissions from Electronics industry were 2,542 kt-$CO_2$ eq., and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 33.5% compared to 1990.

Table 4-55 Emissions from 2.E. Electronics Industry

| Gas | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HFCs | 2.E.1 | Semiconductor | kt-$CO_2$ eq. | 1 | 271 | 283 | 224 | 150 | 165 | 142 | 122 | 109 | 113 | 113 | 117 | 123 | 113 |
| | 2.E.2 | Liquid crystals | kt-$CO_2$ eq. | 0.001 | 0.3 | 1.8 | 3.0 | 2.3 | 3.0 | 3.3 | 2.4 | 2.4 | 2.3 | 1.9 | 1.9 | 1.9 | 0.4 |
| | Total | | kt-$CO_2$ eq. | 1 | 271 | 285 | 227 | 152 | 168 | 145 | 124 | 112 | 115 | 115 | 119 | 125 | 113 |
| PFCs | 2.E.1 | Semiconductor | kt-$CO_2$ eq. | 1,423 | 3,933 | 6,771 | 4,594 | 2,109 | 2,214 | 1,863 | 1,624 | 1,556 | 1,617 | 1,582 | 1,721 | 1,847 | 1,776 |
| | 2.E.2 | Liquid crystals | kt-$CO_2$ eq. | 31 | 87 | 214 | 152 | 39 | 46 | 59 | 68 | 76 | 90 | 86 | 71 | 84 | 79 |
| | Total | | kt-$CO_2$ eq. | 1,455 | 4,020 | 6,986 | 4,746 | 2,148 | 2,261 | 1,922 | 1,692 | 1,631 | 1,707 | 1,669 | 1,792 | 1,931 | 1,855 |
| $SF_6$ | 2.E.1 | Semiconductor | t | 13.6 | 17.5 | 27.6 | 23.7 | 9.3 | 9.9 | 8.6 | 8.1 | 8.0 | 7.7 | 8.1 | 8.4 | 8.8 | 8.0 |
| | 2.E.2 | Liquid crystals | t | 4.8 | 6.2 | 38.5 | 31.2 | 8.7 | 11.8 | 8.7 | 7.5 | 7.4 | 8.4 | 8.4 | 6.9 | 7.1 | 7.3 |
| | Total | | t | 18.4 | 23.8 | 66.1 | 54.9 | 18.0 | 21.7 | 17.3 | 15.6 | 15.4 | 16.0 | 16.5 | 15.3 | 15.9 | 15.3 |
| | Total | | kt-$CO_2$ eq. | 419 | 542 | 1506 | 1252 | 410 | 494 | 394 | 356 | 351 | 366 | 375 | 349 | 363 | 349 |
| $NF_3$ | 2.E.1 | Semiconductor | t | 1.6 | 9.8 | 5.8 | 9.4 | 10.6 | 11.1 | 10.2 | 10.3 | 6.4 | 7.7 | 8.4 | 10.6 | 11.3 | 11.8 |
| | 2.E.2 | Liquid crystals | t | 0.1 | 0.9 | 3.8 | 4.1 | 1.3 | 1.5 | 1.4 | 1.2 | 1.2 | 1.5 | 1.3 | 1.1 | 1.3 | 1.2 |
| | Total | | t | 1.7 | 10.7 | 9.6 | 13.5 | 11.9 | 12.6 | 11.6 | 11.5 | 7.6 | 9.2 | 9.7 | 11.8 | 12.5 | 13.1 |
| | Total | | kt-$CO_2$ eq. | 30 | 184 | 165 | 232 | 205 | 217 | 199 | 198 | 131 | 158 | 167 | 203 | 216 | 225 |
| Total of All Gases | | | kt-$CO_2$ eq. | 1,904 | 5,016 | 8,941 | 6,457 | 2,916 | 3,140 | 2,661 | 2,370 | 2,225 | 2,346 | 2,326 | 2,463 | 2,634 | 2,542 |

### 4.6.1. Semiconductor (2.E.1.)

#### *a) Category Description*

HFCs, PFCs, $SF_6$, and $NF_3$ are emitted from the manufacturing of semiconductors.

#### *b) Methodological Issues*

- ***Estimation Method***

The Tier 2a method of the *2006 IPCC Guidelines* is used to estimate emissions from semiconductors. These emissions are estimated with purchased amount of F-gases, process supply rates, use rates of F-gases, fractions of gas destroyed, by-product generation rates and fractions of gas destroyed for by-products. Default values are applied for the use rate of F-gases and the by-product generation rates.

Regarding the treatment of the 10% residue after process supply, these emissions are reported under this category when there is a 90% recharging and subsequent shipment. In cases of decomposing the residual 10% and cleansing the containment shell, or release into the atmosphere, these emissions are reported under "2.B.9. Fluorochemical production – fugitive emissions".

Japan Electronics and Information Technology Industries Association data are used for F-gases purchased.

Methods below are applied for each gas.

$$E = FC \times P \times (1-U) \times (1 - a \times d)$$

*E* : HFC-23, PFCs (PFC-14, PFC-116, PFC-218, PFC-c318), $SF_6$, and $NF_3$ emissions
*FC* : Purchased amount of gas
*P* : Process supply rate
*U* : Use rate of gas
*a* : Fraction of gas controlled
*d* : Fraction of gas destroyed

$$BPE = FC \times B \times P \times (1 - a \times d)$$

*BPE* : By-produced PFC-14 etc emissions
*FC* : Purchased amount of gas
*B* : By-production rate
*P* : Process supply rate
*a* : Fraction of gas controlled
*d* : Fraction of gas destroyed

Relevant indices are shown in Table below. The fraction of gas controlled is not reported here due to confidentiality reasons.

Table 4-56 Indices related to emissions of F-gases from manufacturing of semiconductors

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HFC-23 purchased | t | 0.1 | 47.8 | 49.4 | 42.1 | 53.8 | 67.1 | 68.4 | 66.7 | 66.7 | 77.2 | 86.2 | 83.2 | 84.3 | 85.2 |
| PFC-14 purchased | t | 113.3 | 313.0 | 299.9 | 231.5 | 208.9 | 265.3 | 248.3 | 222.4 | 218.1 | 253.6 | 285.5 | 317.1 | 365.1 | 376.3 |
| PFC-116 purchased | t | 75.8 | 209.5 | 561.2 | 393.2 | 171.5 | 194.3 | 159.9 | 139.4 | 117.8 | 105.5 | 96.4 | 102.3 | 126.1 | 92.6 |
| PFC-218 purchased | t | 0.01 | 0.03 | 9.91 | 181.80 | 129.47 | 166.96 | 137.00 | 115.48 | 106.08 | 117.19 | 110.90 | 107.55 | 130.08 | 126.95 |
| PFC-c318 purchased | t | 0.2 | 0.6 | 38.6 | 24.8 | 33.3 | 35.8 | 36.8 | 39.7 | 42.2 | 52.6 | 63.3 | 70.4 | 106.6 | 166.8 |
| $SF_6$ purchased | t | 70.1 | 90.8 | 131.9 | 96.8 | 60.2 | 76.7 | 65.2 | 63.7 | 57.6 | 64.9 | 68.0 | 73.4 | 86.5 | 87.2 |
| $NF_3$ purchased | t | 8.8 | 54.4 | 106.3 | 406.7 | 724.8 | 860.7 | 834.5 | 880.5 | 905.4 | 1,055.3 | 1,232.1 | 1,310.1 | 1,597.4 | 1,876.3 |
| Process supply rate | % | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% |
| Use rate of PFC etc | % | 10 - 98 % | | | | | | | | | | | | | |
| Fraction of PFCs, and $SF_6$ destroyed | % | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% |
| Fraction of $NF_3$ destroyed | % | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% |
| $CF_4$ etc by-production rate | % | 2 - 20 % | | | | | | | | | | | | | |
| By-product $CF_4$ etc removal rate | % | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% |
| HFC emissions | kt-$CO_2$ eq. | 0.73 | 270.62 | 282.71 | 223.98 | 149.81 | 164.93 | 142.19 | 121.63 | 109.24 | 112.89 | 113.08 | 117.33 | 123.13 | 112.74 |
| PFC emissions | kt-$CO_2$ eq. | 1,423.43 | 3,933.17 | 6,771.47 | 4,594.11 | 2,109.08 | 2,214.33 | 1,863.33 | 1,624.17 | 1,555.73 | 1,616.86 | 1,582.22 | 1,721.27 | 1,846.95 | 1,776.32 |
| $SF_6$ emissions | kt-$CO_2$ eq. | 309.09 | 399.99 | 628.71 | 540.21 | 210.92 | 224.79 | 196.50 | 183.55 | 181.46 | 174.76 | 183.97 | 192.15 | 199.95 | 182.11 |
| $NF_3$ emissions | kt-$CO_2$ eq. | 27.29 | 168.28 | 99.55 | 161.04 | 182.13 | 190.69 | 174.82 | 177.03 | 109.78 | 132.01 | 144.65 | 183.10 | 193.74 | 203.40 |

Reference: the *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the Ministry of Economy, Trade and Industry, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-57 Use rate of gases during semiconductor manufacturing

| Gas | Use rate |
|---|---|
| HFC-23 | 60% |
| PFC-14 | 10% |
| PFC-116 | 40% |
| PFC-218 | 60% |
| PFC-c318 | 90% |
| $SF_6$ | 80% |
| $NF_3$ | 80% |
| $NF_3$ remote | 98% |

Reference: Default values from the *2006 IPCC Guidelines* (Table 6.3 Tier 2a)

Table 4-58 $CF_4$ and $C_2F_6$ by-production rate during semiconductor manufacturing

| Gas | $CF_4$ by-production rate | $C_2F_6$ by-production rate |
|---|---|---|
| HFC-23 | 7% | NA |
| PFC-116 | 20% | NA |
| PFC-218 | 10% | NA |
| PFC-c318 | 10% | 10% |
| $NF_3$ | 9% | NA |
| $NF_3$ remote | 2% | NA |

Reference: Default values from the *2006 IPCC Guidelines* (Table 6.3 Tier 2a)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using available domestic HFC, PFC, and $SF_6$ shipment amount, and $NF_3$ production amount data which is thought to be proportional to HFC, PFC, $SF_6$, and $NF_3$ emissions, and extrapolating for these years.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainties of the emission factors, *2006 IPCC Guidelines* default values of 100%, 80%, 300%, and 70% were respectively applied for HFCs, PFCs, $SF_6$, and $NF_3$. For the uncertainties of the activity data, 10% was applied for all HFCs, PFCs, $SF_6$, and $NF_3$, using the upper limit value in the *2006 IPCC Guidelines*. As a result, the uncertainties of the emissions for HFCs, PFCs, $SF_6$, and $NF_3$, were determined to be 100%, 81%, 300%, and 71%, respectively.

- ***Time-series Consistency***

See section 4.3.9.1. c).

***d) Category-specific QA/QC and Verification***

See section 4.3.9.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.6.2. Liquid Crystals (2.E.2.)

***a) Category Description***

HFCs, PFCs, $SF_6$, and $NF_3$ are emitted from the manufacturing of liquid crystals.

***b) Methodological Issues***

- ***Estimation Method***

Methods applied to semiconductors are also applied to emissions from manufacturing of liquid crystals. In principle, default values are applied for the use rate of F-gases and the by-product generation rates. World LCD Industry Cooperation Committee has established a voluntary action plan to reduce PFC emissions and has engaged in reducing PFC emissions. In these activities, IPCC methods should be applied.

Relevant indices are shown in Table below. The fraction of gas controlled is not reported here due to confidentiality reasons.

Table 4-59 Indices related to emissions of F-gases from manufacturing of liquid crystals

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HFC-23 purchased | t | 0.0003 | 0.1 | 0.7 | 1.6 | 1.1 | 1.1 | 1.2 | 1.0 | 1.3 | 1.5 | 1.1 | 1.1 | 1.1 | 1.3 |
| PFC-14 purchased | t | 7.5 | 20.7 | 47.3 | 77.8 | 51.9 | 93.7 | 124.3 | 121.1 | 154.5 | 191.7 | 177.1 | 151.8 | 185.0 | 176.4 |
| PFC-116 purchased | t | 0.1 | 0.4 | 2.7 | 9.9 | 2.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PFC-c318 purchased | t | 0.0 | 0.0 | 0.0 | 0.8 | 1.7 | 1.6 | 1.9 | 1.7 | 1.4 | 1.8 | 1.1 | 1.1 | 1.1 | 0.6 |
| $SF_6$ purchased | t | 8.9 | 11.5 | 85.3 | 101.4 | 127.1 | 176.9 | 129.0 | 104.1 | 107.4 | 126.2 | 126.6 | 109.6 | 116.4 | 117.0 |
| $NF_3$ purchased | t | 1.3 | 8.1 | 106.9 | 232.2 | 532.2 | 764.1 | 718.0 | 668.0 | 783.8 | 918.9 | 808.0 | 691.9 | 813.2 | 767.0 |
| Process supply rate | % | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% |
| Use rate of PFCs etc | % | 40 - 97 % | | | | | | | | | | | | | |
| Fraction of PFCs, and $SF_6$ destroyed | % | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% |
| Fraction of $NF_3$ destroyed | % | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% |
| $CF_4$ etc by-production rate | % | 0.9 - 7 % | | | | | | | | | | | | | |
| By-product $CF_4$ etc removal rate | % | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% |
| HFC emissions | kt-$CO_2$ eq. | 0.0007 | 0.27 | 1.84 | 2.98 | 2.30 | 3.02 | 3.28 | 2.39 | 2.37 | 2.26 | 1.93 | 1.93 | 1.91 | 0.41 |
| PFC emissions | kt-$CO_2$ eq. | 31.35 | 86.62 | 214.10 | 152.03 | 39.32 | 46.50 | 59.12 | 68.22 | 75.63 | 89.74 | 86.46 | 71.21 | 84.16 | 78.70 |
| $SF_6$ emissions | kt-$CO_2$ eq. | 109.62 | 141.86 | 877.24 | 711.76 | 199.39 | 268.88 | 197.92 | 172.05 | 169.84 | 191.07 | 191.25 | 156.60 | 162.66 | 166.91 |
| $NF_3$ emissions | kt-$CO_2$ eq. | 2.53 | 15.61 | 65.82 | 70.59 | 23.06 | 26.37 | 24.24 | 20.74 | 21.38 | 26.19 | 22.18 | 19.61 | 21.94 | 21.13 |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-60 Use rate of gases during liquid crystal manufacturing

| Gas | Use rate |
|---|---|
| HFC-23 | 80% |
| PFC-14 | 40% |
| PFC-116 | 0% |
| PFC-c318 | 90% |
| $SF_6$ | 40% |
| $NF_3$ | 70% |
| $NF_3$ remote | 97% |

Reference: Default values from the *2006 IPCC Guidelines* (Table 6.4 Tier 2a). Since there is no default for PFC-116, 0% was used so as not to underestimate emissions.

Table 4-61 $CHF_3$, $CF_4$, and $C_2F_6$, by-production rate during liquid crystal manufacturing

| Gas | $CHF_3$ by-production rate | $CF_4$ by-production rate | $C_2F_6$ by-production rate |
|---|---|---|---|
| HFC-23 | NA | 7% | 5% |
| PFC-c318 | 2% | 0.9% | NA |

Reference: Default values from the *2006 IPCC Guidelines* (Table 6.4 Tier 2a)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using available domestic HFC, PFC, $SF_6$ shipment, and $NF_3$ production amount data which is thought to be proportional to HFC, PFC, $SF_6$, and $NF_3$ emissions, and extrapolating for these years.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

See section 4.6.1. c).

- ***Time-series Consistency***

See section 4.3.9.1. c).

### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

#### *f) Category-specific Planned Improvements*

No improvements are planned.

### 4.6.3. Photovoltaics (2.E.3.)

Photovoltaics manufacturing using PFCs is only done by one company inside Japan. Therefore emissions are confidential and included in PFC emissions from semiconductor manufacturing and reported as "IE".

### 4.6.4. Heat transfer fluid (2.E.4.)

In the process of electronics manufacturing, fluorinated compounds are used for temperature control. These fluorinated compounds are released through evaporative losses during the cooling of process equipment etc. Emissions were reported as "IE" since PFCs in this category are included in the total reported in 4.7.5. Solvents (2.F.5.), where liquid PFCs etc are collectively captured.

## 4.7. Product uses as substitutes for ODS (2.F.)

This category covers HFC and PFC emissions from the use of the products that are substitutes for ozone depleting substances (ODS). This section includes GHG emissions from the following sources: Refrigeration and air conditioning (2.F.1.), Foam blowing agents (2.F.2.), Fire protection (2.F.3.), Aerosols (2.F.4.), and Solvents (2.F.5.).

In 2018, emissions from this category were 48,278 kt-$CO_2$ eq., and represented 3.9% of Japan's total GHG emissions (excluding LULUCF). The emissions are 10.6 times of 1990.

Table 4-62 Emissions from 2.F. Product uses as substitutes for ODS

| Gas | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HFCs | 2.F.1 | Refrigeration and air conditioning | kt-$CO_2$ eq. | NO | 925 | 2,977 | 8,876 | 17,998 | 20,482 | 23,139 | 26,353 | 29,007 | 32,535 | 35,875 | 38,905 | 41,104 | 43,179 |
| | 2.F.2 | Foam blowing agents | kt-$CO_2$ eq. | 1 | 497 | 484 | 937 | 1,608 | 1,749 | 1,923 | 2,081 | 2,229 | 2,373 | 2,484 | 2,651 | 2,801 | 2,922 |
| | 2.F.3 | Fire protection | kt-$CO_2$ eq. | NO | NO | 5 | 7 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 10 | 10 | 10 |
| | 2.F.4 | Aerosols | kt-$CO_2$ eq. | NO | 1,502 | 3,117 | 1,695 | 845 | 666 | 634 | 561 | 489 | 503 | 540 | 587 | 600 | 544 |
| | 2.F.5 | Solvents | kt-$CO_2$ eq. | NO | NO | NO | 6 | 39 | 60 | 86 | 94 | 109 | 122 | 126 | 130 | 116 | 117 |
| | Total | | kt-$CO_2$ eq. | 1 | 2,923 | 6,583 | 11,522 | 20,498 | 22,966 | 25,791 | 29,097 | 31,844 | 35,543 | 39,034 | 42,282 | 44,631 | 46,772 |
| PFCs | 2.F.5 | Solvents | kt-$CO_2$ eq. | 4,550 | 12,572 | 3,200 | 2,815 | 1,420 | 1,721 | 1,605 | 1,583 | 1,518 | 1,537 | 1,517 | 1,465 | 1,484 | 1,505 |
| Total of All Gases | | | kt-$CO_2$ eq. | 4,551 | 15,496 | 9,783 | 14,336 | 21,918 | 24,686 | 27,396 | 30,680 | 33,361 | 37,079 | 40,551 | 43,747 | 46,115 | 48,278 |

### 4.7.1. Refrigeration and Air Conditioning Equipment (2.F.1.)

#### 4.7.1.1. Domestic Refrigeration Production, Use and Disposal (2.F.1.-)

#### *a) Category Description*

#### *1) HFCs*

HFCs are emitted from the production, use (including failure of devices), and disposal of domestic refrigeration.

#### *2) PFCs*

Emission from this source in the "production" category was reported as "NO" as Japan had no record

of their use in the production of the products. The emission was also reported as "NO" in the "use" and "disposal" categories, because it was unlikely that PFCs were used in imported products, or refrigerants were refilled.

### *b) Methodological Issues*

- ***Estimation Method***

1) Fugitive refrigerants during manufacturing, 2) fugitive refrigerants during use (including failure of devices), and 3) refrigerants contained at the time of disposal minus the amount of HFCs collected under law were estimated separately and then were summed up.

Emissions from use and disposal were estimated by summing up the values calculated for each year of the production of devices. Emission factors are country-specific.

$$E_{total} = M_{manufacturing} \times k + \Sigma\,(N_{operated} \times m_{operation} \times x_{operation}) + \Sigma\,(N_{disposed} \times m_{disposal}) - R$$

| | |
|---|---|
| $E_{total}$ | : HFC emissions from domestic refrigeration |
| $M_{manufacturing}$ | : Total refrigerant contained at production |
| $k$ | : Fugitive refrigerant ratio at production |
| $N_{operated}$ | : Number of operated devices containing HFCs |
| $m_{operation}$ | : Refrigerant contained per operated device |
| $x_{operation}$ | : Fugitive refrigerant ratio from use |
| $N_{disposed}$ | : Number of disposed devices containing HFCs |
| $m_{disposal}$ | : Refrigerant contained per disposed device |
| $R$ | : Collected amount of HFCs |

The associated indices are given in the table below.

Table 4-63 Indices related to emissions of HFCs from domestic refrigeration

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total HFCs charged in the year of production | t | NO | 520 | 590 | 0.3 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Fugitive refrigerant ratio at production | % | 1% | 1% | 1% | 0% | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Number of operated HFC devices | 1,000 devices | NO | 7,829 | 33,213 | 41,796 | 31,471 | 28,085 | 24,509 | 20,984 | 17,637 | 14,520 | 11,691 | 9,182 | 7,045 | 5,280 |
| Refrigerant charged per device at production | g | 150 | 150 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Operational fugitive ratio (including failure) | % | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% |
| Number of HFC devices disposed | 1,000 devices | NO | NO | 177 | 1,839 | 3,445 | 3,588 | 3,600 | 3,456 | 3,204 | 2,850 | 2,451 | 2,027 | 1,620 | 1,249 |
| Amount of HFCs collected under law | t/year | − | − | − | 52 | 111 | 111 | 160 | 169 | 189 | 166 | 144 | 138 | 132 | 136 |
| Emissions from manufacturing | kt-$CO_2$ eq. | NO | 7.436 | 8.437 | 0.001 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Emissions from stocks | kt-$CO_2$ eq. | NO | 5.038 | 17.811 | 22.413 | 16.876 | 15.061 | 13.143 | 11.253 | 9.458 | 7.786 | 6.269 | 4.924 | 3.778 | 2.831 |
| Emissions from disposal | kt-$CO_2$ eq. | NO | NO | 31.060 | 246.196 | 436.464 | 460.170 | 391.114 | 352.286 | 279.422 | 250.686 | 213.029 | 148.607 | 87.154 | 17.769 |
| Emissions | kt-$CO_2$ eq. | NO | 12.474 | 57.308 | 268.609 | 453.340 | 475.231 | 404.257 | 363.539 | 288.880 | 258.472 | 219.298 | 153.531 | 90.932 | 20.600 |

Reference: the *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: Emissions from disposal were estimated by summing up the values calculated for each year of the production of devices, and therefore the refrigerant contained per disposed device cannot be easily provided. However, based on the premise that refrigerators are sealed tight, the refrigerant contained per disposed device in the estimation model is considered equal to refrigerant charged per device.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic refrigeration shipment amounts, the ratio of devices with HFCs, and HFCs charged per shipment amount (derived from shipment amounts from 1995, the ratio of devices with HFCs from 1995, and total HFCs charged during production from 1995), fugitive refrigerant ratio at production from 1995, refrigerant charged per device at production from 1995, operational fugitive ratio from 1995, number of HFC devices disposed from 1995, and extrapolating etc for these years.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment in the *2006 IPCC Guidelines* was applied for production and use. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for production, use, and disposal. As a result, the uncertainties of the emissions for production and use were determined to be 32%, and 10% for disposal.

- ***Time-series Consistency***

See section 4.3.9.1. c).

### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.7.1.2. Commercial Refrigeration Production, Use and Disposal (2.F.1.-)

## 4.7.1.2.a. Commercial Refrigeration

### *a) Category Description*

#### *1) HFCs*

HFCs are emitted from the manufacturing, operation, maintenance, accidents, and disposal of commercial refrigeration.

#### *2) PFCs*

Emissions from manufacturing were reported as “NO” since Japan has no record from past to present of PFC use in the manufacturing of products. The emissions were also reported as “NO” for use and disposal, because according to survey results of Fluorocarbons in imported products in the past three years, no use of PFC was detected, and it is unlikely that PFCs are refilled into imported products.

### *b) Methodological Issues*

- ***Estimation Method***

Estimation is mainly conducted using a model, by taking into account the type of device and year of production etc, and based on the principles of the *2006 IPCC Guidelines*. Using the number of devices produced per type and amount of refrigerant per type contained etc for each year, emissions of each species of F-gases from 1) manufacturing, 2) installation, 3) operation and 4) disposal are estimated for the devices below, and then aggregated.

| |
|---|
| centrifugal refrigerating machine, screw refrigerating machine, refrigerator-freezer unit, transport refrigerator-freezer unit, separately placed showcase, built-in showcase, ice making machinery, water fountain, commercial refrigerator-freezer, all-in-one air conditioning system, gas heat pump, chilling unit |

Emission factors were determined by a large sample survey conducted on the amount of refrigerant charge and the occurrence of failure in a certain time-period, by each type of equipment[7]. (260,000 sample units, conducted from 2007 to 2009).

Methods below are applied to each type of device and refrigerant.

- ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma \left(N_{produced} \times m_{manufacturing} \times x_{manufacturing}\right)$$

| | |
|---|---|
| $E_{manufacturing}$ | : Emissions from manufacturing |
| $N_{produced}$ | : Number of devices produced |
| $m_{manufacturing}$ | : Amount of refrigerant contained |
| $x_{manufacturing}$ | : Fugitive refrigerant ratio from manufacturing |

- ***Emissions from installation***

$$E_{installation} = \Sigma \left(N_{installation} \times m_{installation} \times x_{installation}\right)$$

| | |
|---|---|
| $E_{installation}$ | : Emissions from installation |
| $N_{installation}$ | : Number of devices charged at installation site |
| $m_{installation}$ | : Amount of refrigerant contained |
| $x_{installation}$ | : Fugitive refrigerant ratio from installation |

- ***Emissions from operation***

$$E_{operation} = \Sigma \left(N_{operated} \times m_{operation} \times x_{operation}\right) - R_{operation}$$

| | |
|---|---|
| $E_{operation}$ | : Emissions from maintenance |
| $N_{operated}$ | : Number of devices operated |
| $m_{operation}$ | : Amount of refrigerant contained |
| $x_{operation}$ | : Fugitive refrigerant ratio from operation |
| $R_{operation}$ | : Amount collected during servicing |

- ***Emissions from disposal***

$$E_{disposal} = \Sigma \left(N_{disposed} \times x_{disposal}\right) - R_{disposal}$$

| | |
|---|---|
| $E_{disposal}$ | : Emissions from disposal |
| $N_{disposed}$ | : Number of devices disposed |
| $x_{disposal}$ | : Average amount of refrigerant contained |
| $R_{disposal}$ | : Amount collected after use |

Note: In estimating the emissions from maintenance, the yearly decrease is reflected in the "amount of refrigerant contained." The "number of devices operated" and "number of devices disposed" are estimated from the amount of shipment and lifetime of device.

The associated indices are given in the table below.

[7] For details, refer to *document 1-1 and 1-2 of the 21st meeting of the Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry*, held on March 17, 2009.

Table 4-64 Indices related to emissions of HFCs from commercial refrigeration

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of HFC devices produced | 1,000 devices | NO | 214 | 374 | 1,413 | 987 | 1,122 | 1,198 | 1,212 | 1,303 | 1,250 | 1,228 | 1,296 | 1,350 | 1,355 |
| Average amount of refrigerant charged at production | g/device | 372 | 372 | 597 | 3,378 | 3,276 | 3,280 | 3,360 | 3,462 | 3,413 | 3,539 | 3,473 | 3,358 | 3,329 | 3,480 |
| Fugitive refrigerant ratio at production | % | 0.2% | 0.2% | 0.2% | 0.2% | 0.1% | 0.2% | 0.2% | 0.2% | 0.2% | 0.1% | 0.3% | 0.2% | 0.2% | 0.2% |
| Number of devices charged in production place | 1,000 devices | NO | 9 | 32 | 138 | 175 | 171 | 190 | 239 | 225 | 260 | 240 | 246 | 249 | 229 |
| Average amount of refrigerant during installation | g/device | 17,806 | 17,806 | 9,221 | 23,914 | 25,955 | 24,527 | 24,276 | 22,826 | 20,754 | 20,394 | 20,073 | 19,520 | 18,388 | 18,816 |
| Fugitive refrigerant ratio during installation | % | 1% | 1% | 1% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% |
| Number of devices operated | 1,000 devices | NO | 375 | 1,957 | 6,770 | 10,847 | 11,743 | 12,678 | 13,616 | 14,568 | 15,414 | 16,134 | 16,859 | 17,571 | 18,183 |
| Amount of refrigerant during operation | g/device | 1,012 | 1,012 | 1,043 | 4,549 | 5,802 | 5,981 | 6,192 | 6,440 | 6,596 | 6,799 | 6,950 | 7,041 | 7,074 | 7,123 |
| Fugitive refrigerant ratio during use | % | 7.3% | 7.3% | 7.4% | 5.3% | 5.8% | 6.0% | 6.1% | 6.2% | 6.2% | 6.3% | 6.4% | 6.4% | 6.3% | 6.3% |
| Number of devices disposed | 1,000 devices | NO | 1 | 23 | 127 | 325 | 397 | 453 | 512 | 576 | 663 | 748 | 816 | 887 | 972 |
| Amount of HFCs collected under law during | t | NO | NO | NO | NO | 503 | 548 | 571 | 671 | 682 | 759 | 772 | 861 | 979 | 1,016 |
| Amount of HFCs collected under law after use | t | NO | NO | NO | 183 | 230 | 269 | 352 | 522 | 689 | 668 | 735 | 952 | 1,158 | 1,296 |
| Emissions from manufacturing | kt-$CO_2$ eq. | NO | 3 | 9 | 150 | 202 | 198 | 220 | 269 | 225 | 256 | 228 | 229 | 209 | 191 |
| Emissions from stocks | kt-$CO_2$ eq. | NO | 40 | 258 | 3,415 | 9,035 | 10,524 | 12,233 | 14,231 | 15,850 | 17,638 | 18,998 | 20,150 | 20,880 | 21,425 |
| Emissions from disposal | kt-$CO_2$ eq. | NO | 4 | 51 | 586 | 2,372 | 2,777 | 3,141 | 3,466 | 3,741 | 4,739 | 6,033 | 7,336 | 8,319 | 9,644 |
| Emissions | kt-$CO_2$ eq. | NO | 47 | 318 | 4,151 | 11,609 | 13,499 | 15,594 | 17,965 | 19,815 | 22,633 | 25,259 | 27,716 | 29,408 | 31,260 |

Reference: The *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the Ministry of Economy Trade and Industry, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note 1: From 2002 onward, "amount of refrigerant" and "fugitive refrigerant ratio from operation" increased because devices became larger with the increase of commercial package AC devices.

Note 2: The weighted average GWP for manufacturing in 2018 is 2,283, 2,626 for stocks, and 2,201 for disposal. Emissions are calculated by gas but are reported as an unspecified mix due to confidentiality reasons.

Table 4-65 Type of HFC and emission factors during use, by type of commercial refrigeration

| Type of commercial refrigeration | Type of HFC | Amount of refrigerant | Emission factor * | Share in the number of devices operated (2010) |
|---|---|---|---|---|
| Small-size refrigerators (built-ins etc) | R-404A, HFC-134a etc | 0.1 - 3 kg | 2% | 40% |
| Separately installed showcases | R-404A, R-407C etc | 20 - 41 kg | 16% | 3% |
| Mid-size refrigerators (excluding Separately installed showcases) | R-404A, R-407C etc | 2 - 30 kg | 13 - 17% | 6% |
| Large-size refrigerators | HFC-134a, R404A etc | 300 - 2,300 kg | 7 - 12% | 0.05% |
| All-in-one air conditioning systems for buildings | R-410A, R-407C etc | 37 kg | 3.5% | 7% |
| Other commercial air conditioning devices (excluding All-in-one air conditioning systems for buildings) | R-410A, R-407C etc | 3 - 43 kg | 3 - 5% | 44% |

Reference: *Documents of the 2nd Refrigerant Policy Working Group, Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry* (July 26, 2010), and data provided by the Ministry of Economy Trade and Industry

Note: * Includes for emissions during servicing, accidents, and breakdowns

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using HFC shipment amounts which is thought to be proportional to the number of HFC devices produced and number of devices charged in production place, and the average amount of refrigerant charged at production from 1995, fugitive refrigerant ratio at production from 1995, average amount of refrigerant during installation from 1995, fugitive refrigerant ration during installation from 1995, amount of refrigerant during operation from 1995, fugitive refrigerant ratio during use from 1995, and extrapolating, etc for these years.

The *2006 IPCC Guidelines* specifies estimation methods for fugitive emissions from refrigerant containers, however, upon consideration of emissions from non-refillable cylinders that are not captured under other sources, the emissions estimated by multiplying the remaining refrigerant per cylinder by the number of cylinders does not exceed 500,000 t-$CO_2$ eq. This combined with there being no statistics or survey data that can be used as activity data, estimation is not required, as determined by the Committee for Greenhouse Gas Emissions Estimation Methods. It is therefore reported as NE

(considered insignificant). (See Annex 5)

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment in the *2006 IPCC Guidelines* was applied for manufacturing. For use, a 5% value based on a METI survey was applied. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. As a result, the uncertainties of the emissions for manufacturing, use, and disposal were determined to be 32%, 11%, and 10%, respectively.

- ***Time-series Consistency***

See section 4.3.9.1. c). From 1995 onward, production amount is taken from the same industry organization of device manufacturers, and the EFs are values reported by the Ministry of Trade and Industry in 2009.

***d) Category-specific QA/QC and Verification***

See section 4.3.9.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.7.1.2.b. Automatic Vending machine Production, Use and Disposal

***a) Category Description***

***1) HFCs***

HFCs are emitted from manufacturing, accidents, and disposals of automatic vending machines.

***2) PFCs***

Emission from this source in the “production” category was reported as “NO” as Japan had no record of their use in production. The emissions were also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

***b) Methodological Issues***

- ***Estimation Method***

Emissions of F-gases from 1) manufacturing, 2) accidents and 3) disposals are estimated, based on production and shipment amounts and amounts of refrigerants charged. Emission factors are country-specific.

➢ ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma\ (N_{produced} \times m_{manufacturing} \times x_{manufacturing})$$

| | |
|---|---|
| $E_{manufacturing}$ | : Emissions from manufacturing |
| $N_{produced}$ | : Number of device produced |
| $m_{manufacturing}$ | : Amount of refrigerant contained |
| $x_{manufacturing}$ | : Fugitive refrigerant ratio from manufacturing |

➢ ***Emissions from accidents***

$$E_{accident} = \Sigma\ (N_{operated} \times m_{operation} \times A \times x_{accident})$$

| | |
|---|---|
| $E_{accident}$ | : Emissions from accident |
| $N_{operated}$ | : Number of devices operated |
| $m_{operation}$ | : Amount of refrigerant contained |
| $A$ | : Incidence rate |
| $x_{accident}$ | : Average fugitive rate in accident |

➢ ***Emissions from disposals***

(a) until 2001 $E_{disposal} = \Sigma\ \{N_{disposed} \times m_{disposal} \times (1-\eta)\}$

(b) from 2002 onward $E_{disposal} = \Sigma\ (N_{disposed} \times m_{disposal\text{-}avg}) - R$

| | |
|---|---|
| $E_{disposal}$ | : Emissions from disposal |
| $N_{disposed}$ | : Number of devices disposed |
| $m_{disposal}$ | : Amount of refrigerant contained |
| $\eta$ | : Collection rate |
| $M_{disposal\text{-}avg}$ | : Average amount of refrigerant contained |
| $R$ | : Amount collected |

For HFC emissions from automatic vending machines, the values shown in the *Documents of the Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry* is reported. The associated indices are given in the table below.

Table 4-66 Indices related to emissions of HFCs from automatic vending machines

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of HFC devices produced | 1,000 devices | NO | NO | 272 | 355 | 173 | 173 | 124 | 30 | 10 | 8 | 7 | 7 | 6 | 6 |
| Refrigerant charged per device | g | NO | NO | 300 | 220 | 219 | 219 | 219 | 219 | 219 | 219 | 219 | 219 | 219 | 219 |
| Fugitive refrigerant ratio at production | % | NO | 0.4% | 0.4% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.3% |
| Number of devices operated | 1,000 devices | NO | NO | 284 | 1,999 | 2,368 | 2,279 | 2,055 | 1,759 | 1,530 | 1,068 | 748 | 431 | 330 | 187 |
| Incidence rate | % | NO | 0.004 | 0.004 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| Fugitive refrigerant ratio (failure) | % | NO | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Fugitive refrigerant ratio (fixing) | % | NO | 0.009 | 0.009 | 0.005 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| Number of devices disposed | 1,000 devices | NO | NO | NO | NO | 293 | 286 | 347 | 277 | 273 | 299 | 266 | 264 | 196 | 188 |
| Emissions | t | NO | NO | 0 | 1 | 17 | 16 | 19 | 15 | 15 | 17 | 15 | 15 | 11 | 10 |
| | kt-$CO_2$ eq. | NO | NO | 1 | 1 | 30 | 29 | 34 | 22 | 22 | 24 | 21 | 21 | 16 | 15 |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

For the years 1990 to 1994, it was confirmed that no automatic vending machines with HFCs were used, and therefore emissions for these years are reported as NO. (Ministry of the Environment press release, July 31, 2000, *Projections of disposal etc of refrigerant CFCs, HCFCs, and HFCs (Reference material 1)*)

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was

applied for all manufacturing, use, and disposal. As a result, the uncertainties of the emissions for all manufacturing, use, and disposal were determined to be 32%.

- ***Time-series Consistency***

See section 4.3.9.1. c).

***d) Category-specific QA/QC and Verification***

See section 4.3.9.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.7.1.3. Transport Refrigeration Production, Use and Disposal (2.F.1.-)

***a) Category Description***

***1) HFCs***

HFCs are emitted from the manufacturing, operation, and disposal of transport refrigeration.

***2) PFCs***

Same as 4.7.1.2.a Commercial Refrigeration.

***b) Methodological Issues***

- ***Estimation Method***

Same as 4.7.1.2.a Commercial Refrigeration. The associated indices are given in the table below.

Table 4-67 Indices related to emissions of HFCs from transport refrigeration (railways)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of HFC devices produced[1)] | devices | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Refrigerant HFC charged per device at production[1)] | kg | 0 | 0 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Fugitive refrigerant ratio at production | % | 0% | 0% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% |
| Fugitive refrigerant ratio during use | % | 0% | 0% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% |
| Number of HFC devices disposed | devices | 0 | 0 | 0 | 0 | 10 | 14 | 9 | 13 | 14 | 17 | 21 | 23 | 19 | 0 |
| Refrigerant stock in device disposed | kg | 0 | 0 | 0 | 0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Collection rate | % | 0 | 0 | 0 | 0 | 30% | 31% | 29% | 34% | 34% | 32% | 38% | 39% | 38% | 39% |
| Emissions from manufacturing | kt-$CO_2$ eq. | NO | NO | 0.001 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Emissions from stocks | kt-$CO_2$ eq. | NO | NO | 0.080 | 0.395 | 0.665 | 0.648 | 0.644 | 0.644 | 0.634 | 0.619 | 0.600 | 0.596 | 0.596 | 0.596 |
| Emissions from disposal | kt-$CO_2$ eq. | NO | NO | NO | NO | 0.041 | 0.057 | 0.038 | 0.050 | 0.054 | 0.068 | 0.077 | 0.083 | 0.069 | NO |
| Emissions | kt-$CO_2$ eq. | NO | NO | 0.081 | 0.395 | 0.706 | 0.704 | 0.682 | 0.695 | 0.688 | 0.687 | 0.677 | 0.679 | 0.666 | 0.596 |

Reference: *Railway Statistical Yearbook*, IPCC default values. 1) are based on information from manufacturers.

Table 4-68 Indices related to emissions of HFCs from transport refrigeration (vessels)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fugitive refrigerant ratio at production | % | 0% | 0% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% |
| Fugitive refrigerant ratio during use | % | 0% | 0% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% |
| Collection rate | % | 0% | 0% | 0% | 0% | 30% | 31% | 29% | 34% | 34% | 32% | 38% | 39% | 38% | 39% |
| Emissions from manufacturing | kt-$CO_2$ eq. | NO | NO | 0.008 | 0.066 | 0.138 | 0.124 | 0.215 | 0.305 | 0.361 | 0.256 | 0.241 | 0.432 | 0.433 | 0.342 |
| Emissions from stocks | kt-$CO_2$ eq. | NO | NO | 1.163 | 23.783 | 61.934 | 77.103 | 94.722 | 124.018 | 161.961 | 176.000 | 191.411 | 207.277 | 223.892 | 250.081 |
| Emissions from disposal | kt-$CO_2$ eq. | NO | NO | NO | NO | 0.009 | 0.024 | 0.102 | 0.081 | 0.761 | 1.842 | 1.713 | 2.565 | 4.110 | 5.418 |
| Emissions | kt-$CO_2$ eq. | NO | NO | 1.171 | 23.850 | 62.081 | 77.250 | 95.039 | 124.404 | 163.082 | 178.098 | 193.366 | 210.274 | 228.435 | 255.841 |

Reference: IPCC default values, *Report on Maritime Affairs*, etc.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

Same as 4.7.1.2.a Commercial Refrigeration.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-.)). See section 4.3.9.1. c).

### *d) Category-specific QA/QC and Verification*

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-.)). See section 4.3.9.1. d).

### *e) Category-specific Recalculations*

The revision in the total amount of refrigerants charged at manufacturing for 2007, 2010, 2015, and 2017 and the revision in the total of refrigerants contained during operation for 2007 to 2017 resulted in recalculations of emissions from vessel refrigeration. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.7.1.4. Industrial Refrigeration Production, Use and Disposal (2.F.1.-)

### *1) HFCs*

HFCs emissions have been reported as “IE”, as they are included in 4.7.1.2. Commercial Refrigeration (2.F.1.-).

### *2) PFCs*

Emission from this source in the “production” category was reported as “NO” since Japan had no record of their use in the production of the products. The emission was also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

### 4.7.1.5. Stationary Air-Conditioning (Household) Production, Use and Disposal (2.F.1.-)

#### *a) Category Description*

#### *1) HFCs*

HFCs are emitted from the manufacturing, operation, and disposals of household stationary air-conditioning devices.

#### *2) PFCs*

Emission from this source in the "production" category was reported as "NO" since Japan had no record of their use in production. The emission was also reported as "NO" in the "use" and "disposal" categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

#### *b) Methodological Issues*

- ***Estimation Method***

In accordance with the IPCC Guidelines, emissions of each species of F-gases from 1) manufacturing, 2) operation, 3) disposals are estimated, based on production and shipment amounts and amounts of refrigerants charged. Emission factors are country-specific.

➢ ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma \left(N_{produced} \times m_{manufacturing\text{-}avg} \times x_{manufacturing}\right)$$

| | |
|---|---|
| $E_{manufacturing}$ | : Emissions from manufacturing |
| $N_{produced}$ | : Number of devices produced |
| $m_{manufacturing\text{-}avg}$ | : Average amount of refrigerant contained |
| $x_{manufacturing}$ | : Fugitive refrigerant ratio from manufacturing |

➢ ***Emissions from operation***

$$E_{operation} = \Sigma \left(N_{operated} \times m_{operation\text{-}avg} \times x_{operation}\right)$$

| | |
|---|---|
| $E_{operation}$ | : Emissions from operation |
| $N_{operated}$ | : Number of devices operated |
| $m_{operation\text{-}avg}$ | : Average amount of refrigerant contained |
| $x_{operation}$ | : Fugitive refrigerant ratio from operation |

➢ ***Emissions from disposal***

$$E_{disposal} = \Sigma \left(N_{disposed} \times m_{disposal\text{-}avg}\right) - R$$

| | |
|---|---|
| $E_{disposal}$ | : Emissions from disposal |
| $N_{disposed}$ | : Number of devices disposed |
| $m_{disposal\text{-}avg}$ | : Average amount of refrigerant contained |
| $R$ | : Amount collected |

Note: In the estimation of emissions from operation, the yearly decrease is reflected in the "average amount of refrigerant contained." The "number of devices for shipment" and "number of devices disposed" are estimated from amount of shipment and lifetime of device.

The associated indices are given in the table below.

Table 4-69 Indices related to emissions of HFCs from stationary air-conditioning (household)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of HFC devices produced | 1,000 devices | NO | NO | 1,077 | 3,981 | 2,618 | 3,169 | 3,155 | 3,263 | 3,581 | 3,076 | 8,166 | 8,528 | 9,055 | 9,815 |
| Refrigerant charged per device | g | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| Fugitive refrigerant ratio at production | % | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.1% | 0.1% | 0.1% | 0.1% |
| Number of devices operated | 1,000 devices | NO | NO | 1,726 | 26,091 | 53,966 | 61,540 | 68,769 | 75,833 | 83,349 | 89,020 | 94,197 | 99,157 | 104,067 | 109,193 |
| Average refrigerant charged during use | g/device | NO | NO | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| Fugitive refrigerant ratio during use | % | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% |
| Number of devices disposed | 1,000 devices | NO | NO | 2 | 83 | 524 | 764 | 1,075 | 1,456 | 1,907 | 2,423 | 2,990 | 3,567 | 4,145 | 4,688 |
| Average refrigerant stock in device disposed | g/device | NO | NO | 954 | 911 | 856 | 841 | 827 | 814 | 803 | 796 | 792 | 795 | 796 | 804 |
| Amount of HFCs collected under law | t/year | - | - | - | 10 | 122 | 231 | 264 | 322 | 466 | 508 | 570 | 700 | 892 | 1,181 |
| Emissions from manufacturing | kt-$CO_2$ eq. | NO | NO | 4 | 17 | 13 | 12 | 10 | 10 | 8 | 7 | 9 | 7 | 6 | 6 |
| Emissions from stocks | kt-$CO_2$ eq. | NO | NO | 72 | 1,089 | 2,253 | 2,569 | 2,871 | 3,165 | 3,424 | 3,534 | 3,549 | 3,523 | 3,480 | 3,425 |
| Emissions from disposal | kt-$CO_2$ eq. | NO | NO | 3 | 139 | 710 | 916 | 1,322 | 1,833 | 2,301 | 2,984 | 3,767 | 4,486 | 5,059 | 5,437 |
| Emissions | kt-$CO_2$ eq. | NO | NO | 80 | 1,245 | 2,976 | 3,498 | 4,204 | 5,008 | 5,733 | 6,524 | 7,325 | 8,015 | 8,546 | 8,868 |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

For the years 1990 to 1994, it was confirmed that no household stationary air-conditioning with HFCs were used, and therefore emissions for these years are reported as NO. (Ministry of the Environment press release, July 31, 2000, *Projections of disposal etc of refrigerant CFCs, HCFCs, and HFCs (Reference material 1)*)

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

See section 4.7.1.2.a.c).

- ***Time-series Consistency***

See section 4.3.9.1. c).

### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.7.1.6. Mobile Air-Conditioning Production, Use and Disposal (2.F.1.-)

### *a) Category Description*

#### *1) HFCs*

HFCs are emitted from manufacturing, operation, breakdowns, accidents, and disposals of mobile air-conditioning devices.

#### *2) PFCs*

Emission from this source in the “production” category was reported as “NO” since Japan had no record of their use in production. The emission was also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

### *b) Methodological Issues*

- ***Estimation Method***

In accordance with the IPCC Guidelines, emissions of each species of F-gases from 1) manufacturing, 2) operation, 3) breakdowns, 4) accidents and 5) disposals are estimated. Emission factors are country-specific. The below thinking is applied for each type of car. Emissions from railway and vessel air conditioning are also estimated based on similar methods.

➢ ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma\ (N_{produced} \times m_{manufacturing} \times x_{manufacturing})$$

| | |
|---|---|
| $E_{manufacturing}$ | : Emissions from manufacturing |
| $N_{produced}$ | : Number of devices produced |
| $m_{manufacturing}$ | : Amount of refrigerant contained |
| $x_{manufacturing}$ | : Fugitive refrigerant ratio from manufacturing |

➢ ***Emissions from operation***

$$E_{operation} = \Sigma\ (N_{operated} \times m_{operation} \times x_{operation})$$

| | |
|---|---|
| $E_{operation}$ | : Emissions from operation |
| $N_{operated}$ | : Number of cars operated |
| $m_{operation}$ | : Amount of refrigerant contained |
| $x_{operation}$ | : Fugitive refrigerant ratio from operation |

Note: In the estimation of emissions from operation, the yearly decrease is reflected in the "amount of refrigerant contained."

➢ ***Emissions from breakdowns***

$$E_{breakdowns} = \Sigma\ (N_{operated} \times m_{operation} \times A \times x_{accident})$$

| | |
|---|---|
| $E_{breakdowns}$ | : Emissions from maintenance |
| $N_{operated}$ | : number of cars operated |
| $m_{operation}$ | : amount of refrigerant contained |
| $A$ | : rate of breakdowns |
| $x_{accident}$ | : fugitive refrigerant ratio from breakdowns |

➢ ***Emissions from accident***

$$E_{accident} = \Sigma\ (N_{destroyed} \times m_{operation})$$

| | |
|---|---|
| $E_{accident}$ | : Emissions from accident |
| $N_{destroyed}$ | : number of cars in completely destroyed |
| $m_{operation}$ | : amount of refrigerant contained at time of accident |

➢ ***Emissions from disposal***

(a) until 2001 $E_{disposal} = \Sigma\ \{N_{disposed} \times m_{disposal} \times (1-\eta)\}$

(b) from 2002 onward $E_{disposal} = \Sigma\ (N_{disposed} \times m_{disposal\text{-}avg}) - R$

| | |
|---|---|
| $E_{disposal}$ | : Emissions from disposal |
| $N_{disposed}$ | : number of cars disposed |
| $m_{disposal}$ | : amount of refrigerant contained |
| $\eta$ | : collection rate |
| $m_{disposal\text{-}avg}$ | : average amount of refrigerant contained |
| $R$ | : amount collected |

Relevant indices are shown in Table below.

Table 4-70 Indices related to emissions of HFC-134a from car air conditioners

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of cars produced | 1,000 devices | 0 | 9,745 | 9,761 | 10,407 | 7,653 | 9,292 | 8,136 | 9,856 | 9,613 | 9,753 | 9,273 | 9,205 | 9,639 | 9,362 |
| Fugitive refrigirant during production | g | 4 | 4 | 4 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Number of cars operated with HFC air conditioners | 1,000 devices | 0 | 15,655 | 42,374 | 60,364 | 65,375 | 66,043 | 67,366 | 70,406 | 72,054 | 72,813 | 73,272 | 72,216 | 72,722 | 72,898 |
| Average refrigerant charged per device | g | 700 | 700 | 615 | 548 | 497 | 497 | 497 | 497 | 497 | 497 | 497 | 497 | 497 | 497 |
| Fugitive refrigerant ratio during use per year per device | g | 15 | 15 | 15 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Rate of breakdown incidences | % | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% |
| Fugitive refrigerant ratio from breakdown cars | % | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 50% |
| Number of cars completely destroyed | 1,000 devices | 0 | 50 | 136 | 193 | 209 | 211 | 216 | 225 | 231 | 233 | 234 | 231 | 233 | 233 |
| Average refrigerant charged in completely destroyed cars | g | 681 | 681 | 610 | 522 | 461 | 448 | 439 | 426 | 417 | 409 | 404 | 399 | 393 | 387 |
| Number of cars disposed | 1,000 devices | 0 | 116 | 789 | 2,058 | 2,498 | 2,895 | 2,235 | 2,709 | 2,835 | 2,839 | 2,694 | 2,666 | 2,927 | 2,941 |
| Average refrigerant charged at time of disposal | g | 676 | 676 | 593 | 522 | 456 | 444 | 427 | 404 | 412 | 393 | 380 | 370 | 360 | 349 |
| Amount of HFC collected (under law from FY2002) | t/year | - | - | - | 531 | 787 | 898 | 645 | 786 | 785 | 773 | 710 | 682 | 720 | 718 |
| Emissions from manufacturing | kt-$CO_2$ eq. | NO | 49 | 49 | 45 | 13 | 13 | 9 | 11 | 11 | 10 | 10 | 10 | 10 | 10 |
| Emissions from stocks | kt-$CO_2$ eq. | NO | 704 | 1,798 | 2,331 | 2,255 | 2,222 | 2,226 | 2,274 | 2,276 | 2,255 | 2,230 | 2,166 | 2,144 | 2,115 |
| Emissions from disposal | kt-$CO_2$ eq. | NO | 112 | 669 | 778 | 503 | 555 | 444 | 442 | 548 | 492 | 449 | 436 | 477 | 443 |
| Emissions | kt-$CO_2$ eq. | NO | 865 | 2,516 | 3,153 | 2,771 | 2,791 | 2,679 | 2,728 | 2,835 | 2,757 | 2,690 | 2,612 | 2,631 | 2,568 |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-71 Indices related to emissions of HFCs from air conditioners (railways)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fugitive refrigerant ratio at production | % | 0% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% |
| Fugitive refrigerant ratio during use | % | 0% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% |
| Emissions from manufacturing | kt-$CO_2$ eq. | NO | 0.003 | 0.033 | 0.062 | 0.081 | 0.075 | 0.065 | 0.052 | 0.060 | 0.059 | 0.058 | 0.049 | 0.063 | 0.073 |
| Emissions from stocks | kt-$CO_2$ eq. | NO | 0.710 | 3.224 | 13.734 | 27.336 | 31.015 | 34.290 | 36.833 | 39.667 | 42.601 | 45.451 | 48.087 | 51.158 | 54.168 |
| Emissions from disposal | kt-$CO_2$ eq. | NO | 0.066 | 0.134 | 0.091 | 0.100 | 0.191 | 0.146 | 0.106 | 0.060 | 0.078 | 0.082 | 0.047 | 0.050 | 0.073 |
| Emissions | kt-$CO_2$ eq. | NO | 0.779 | 3.391 | 13.887 | 27.516 | 31.281 | 34.502 | 36.991 | 39.787 | 42.737 | 45.591 | 48.184 | 51.270 | 54.314 |

Reference: *Railway Statistical Yearbook, Yearbook of Railway Car Production Statistics*, IPCC default values etc.

Table 4-72 Indices related to emissions of HFCs from air conditioners (vessels)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fugitive refrigerant ratio at production | % | 0% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% |
| Fugitive refrigerant ratio during use | % | 0% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% |
| Collection rate | % | 0% | 0% | 0% | 0% | 30% | 31% | 29% | 34% | 34% | 32% | 38% | 39% | 38% | 39% |
| Emissions from manufacturing | kt-$CO_2$ eq. | NO | 0.0003 | 0.004 | 0.070 | 0.200 | 0.246 | 0.263 | 0.223 | 0.186 | 0.177 | 0.153 | 0.142 | 0.114 | 0.111 |
| Emissions from stocks | kt-$CO_2$ eq. | NO | 0.077 | 0.739 | 19.384 | 66.696 | 80.925 | 92.989 | 103.133 | 110.083 | 116.936 | 121.421 | 127.563 | 131.859 | 135.694 |
| Emissions from disposal | kt-$CO_2$ eq. | NO | NO | NO | NO | 0.084 | 0.011 | 0.030 | 0.005 | 0.123 | 0.283 | 0.211 | 0.446 | 0.557 | 0.848 |
| Emissions | kt-$CO_2$ eq. | NO | 0.077 | 0.743 | 19.454 | 66.979 | 81.182 | 93.282 | 103.361 | 110.393 | 117.397 | 121.785 | 128.151 | 132.530 | 136.652 |

Reference: IPCC default values, *Report on Maritime Affairs,etc*.

For car air conditioners, due to the lack of data necessary to estimate emissions for the years 1992 to 1994 in which HFCs were used, estimates have been done by using HFC shipment amounts which is thought to be proportional to the number of car produced, and the fugitive refrigerant during production from 1995, average refrigerant charged per device from 1995, fugitive refrigerant ratio during use per year per device (normal car) from 1995, rate of breakdown incidences from 1995, fugitive refrigerant ratio from breakdown cars from 1995, number of cars completely destroyed in 1995, the number of cars operated with HFC air conditioners from 1995, average refrigerant charged in completely destroyed cars from 1995, number of cars disposed from 1995, average refrigerant charged at the time of disposal from 1995, and extrapolating etc for these years.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

See section 4.7.1.2.b.c).

- ***Time-series Consistency***

See section 4.3.9.1. c).

### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.7.2. Foam Blowing Agents (2.F.2.)

## 4.7.2.1. Closed Cells (2.F.2.-)

## 4.7.2.1.a. Urethane Foam (2.F.2.-)

### *a) Category Description*

HFC-134a, HFC-245fa, and HFC-365mfc are emitted as a result of foam blowing agent use.

### *b) Methodological Issues*

- ***Estimation Method***

In accordance with the IPCC Guidelines (closed-cell foams), emissions were calculated assuming that 10% of the emission from foam blowing agents used each year occurred within the first year after production, with the remainder emitted over 20 years at the rate of 4.5% per year. The data on the amount of foam blowing agents used each year was provided by the Japan Urethane Foam Association, Japan Urethane Raw Materials Association.

It is difficult to separate the "use" emission from that at the time of "disposal" because urethane foams were disposed of at various times. Accordingly, the emissions in the "use" and "disposal" categories were combined and reported under the "use" category, while the emission in the "disposal" category was reported as "IE".

$$E = E_{manufacturing} + E_{used}$$
$$= (M \times EF_{FYL}) + (Bank \times EF_{AL})$$

| | |
|---|---|
| $E$ | : HFC emissions [t] |
| $E_{manufacturing}$ | : Emissions during production [t] |
| $E_{use}$ | : Emissions during use [t] |
| $M$ | : Amount of HFC used [t] |
| $EF_{FYL}$ | : Leakage during foam blowing [%] |
| $Bank$ | : Total amount used up to the previous year [t] |
| $EF_{AL}$ | : Percentage of annual emissions during use [%] |

Table 4-73 Indices related to emissions of HFC from urethane foam

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HFC-134a use | t | NO | NO | 167 | 224 | 109 | 66 | 65 | 34 | 28 | 14 | 12 | NO | NO | NO |
| HFC-245fa use | t | NO | NO | NO | 3,893 | 2,440 | 2,365 | 2,597 | 2,613 | 2,570 | 2,533 | 2,230 | 2,577 | 2,596 | 2,365 |
| HFC-365mfc use | t | NO | NO | NO | 1311 | 847 | 900 | 960 | 977 | 921 | 866 | 779 | 794 | 802 | 744 |
| Leakage during foam blowing | % | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% |
| Annual emissions rate during use | % | 4.5% | 4.5% | 4.5% | 4.5% | 4.5% | 4.5% | 4.5% | 4.5% | 4.5% | 4.5% | 4.5% | 4.5% | 4.5% | 4.5% |
| HFC-134a emissions | kt-$CO_2$ eq. | NO | NO | 24 | 112 | 132 | 133 | 137 | 137 | 138 | 138 | 139 | 138 | 138 | 138 |
| HFC-245fa emissions | kt-$CO_2$ eq. | NO | NO | NO | 490 | 1,039 | 1,144 | 1,277 | 1,399 | 1,516 | 1,631 | 1,718 | 1,857 | 1,978 | 2,075 |
| HFC-365mfc emissions | kt-$CO_2$ eq. | NO | NO | NO | 130 | 284 | 318 | 355 | 391 | 421 | 450 | 474 | 503 | 532 | 556 |

Reference: *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: As regards HFC-245fa and HFC-365mfc, their use increased because they replaced HCFC-141b whose production ended in January 2004.

For the years 1990 to 1994, it was confirmed that no urethane foam with HFCs was used, and therefore emissions for these years are reported as NO. (Ministry of the Environment, "*FY2011 PRTR (Pollutant*

*Release and Transfer Register) Estimation methods for releases from sources not required to report*")

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainties of the emissions for both manufacturing and use, *the 2006 IPCC Guidelines* value of 50% was used.

- ***Time-series Consistency***

See section 4.3.9.1. c).

***d) Category-specific QA/QC and Verification***

See section 4.3.9.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.7.2.1.b. Extruded Polystyrene Foam (2.F.2.-)

***a) Category Description***

HFC-134a is emitted as a result of foam blowing agent use.

***b) Methodological Issues***

- ***Estimation Method***

Emissions were calculated assuming that 25% of the emission of foam blowing agents occurs within the first year after production, with the remainder emitted at the rate of 0.75% per year. The amount of foam blowing agents used each year was provided by the Extruded Polystyrene Foam Industry Association. This assumption is consistent with the *2006 IPCC Guidelines* and the estimation method under PRTR for the amount of transferred HCFC at polystyrene foam production sites.

It is difficult to separate the "use" emission from that at the time of "disposal" because heat insulation material is disposed of at various times such as the renovation and dismantling of buildings, and in times of disaster. Since disposed polystyrene foam is considered to be emitting HFCs as same as that in use, these emissions are combined and reported under "use", while the emissions from "disposal" were reported as "IE".

$$E = E_{manufacturing} + E_{used}$$
$$= (M \times EF_{FYL}) + (Bank \times EF_{AL})$$

| | |
|---|---|
| $E$ | : HFC-134a emissions [t] |
| $E_{manufacturing}$ | : Emissions during production [t] |
| $E_{use}$ | : Emissions during use [t] |
| $M$ | : Amount of HFC-134a used in particular year [t] |
| $EF_{FYL}$ | : Leakage during foam blowing (25%) |
| $Bank$ | : Total amount used in the past up to the previous year [t] |
| $EF_{AL}$ | : Annual emission rate during use [%] |

Table 4-74 Indices related to emissions of HFC-134a from extruded polystyrene foam

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HFC-134a use | t | NO | NO | NO | 26 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Foam productization rate | % | - | - | - | 75% | 75% | 75% | 75% | 75% | 75% | 75% | 75% | 75% | 75% | 75% |
| Annual emission rate during use | % | - | - | - | 0.8% | 0.8% | 0.8% | 0.8% | 0.8% | 0.8% | 0.8% | 0.8% | 0.8% | 0.8% | 0.8% |
| Emissions during production | t | NO | NO | NO | 6.50 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Emissions during use | t | NO | NO | NO | 9.00 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 |
| Emissions | t | NO | NO | NO | 15.50 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 | 9.23 |
| Emissions during production | kt-$CO_2$ eq. | NO | NO | NO | 9.30 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Emission during use | kt-$CO_2$ eq. | NO | NO | NO | 12.87 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 |
| Emissions | kt-$CO_2$ eq. | NO | NO | NO | 22.17 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 | 13.20 |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc*

For the years 1990 to 1994, it was confirmed that no extruded polystyrene foam with HFCs was used, and therefore emissions for these years are reported as NO. (Ministry of the Environment, "*FY2011 PRTR (Pollutant Release and Transfer Register) Estimation methods for releases from sources not required to report*")

#### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

See section 4.7.2.1.a. c).

- ***Time-series Consistency***

See section 4.3.9.1. c).

#### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

#### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

#### *f) Category-specific Planned Improvements*

No improvements are planned.

### 4.7.2.2. Open Cells (2.F.2.-)

### 4.7.2.2.a. High Expanded Polyethylene Foam (2.F.2.-)

#### *a) Category Description*

HFC-134a and HFC-152a is emitted as a result of foam blowing agent use.

#### *b) Methodological Issues*

- ***Estimation Method***

In accordance with the IPCC Guidelines (open-cell foams), emissions were calculated assuming that all of the emissions from foam blowing agents used occurred at the time of production. The amount of blowing agents used each year was provided by the High Expanded Polyethylene Foam Industry Association.

Table 4-75 Indices related to emissions of HFC-134a from high expanded polyethylene foam

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HFC-134a use | t | 1 | 346 | 322 | 128 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 98 |
| Emissions | t | 1 | 346 | 322 | 128 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 98 |
| | kt-$CO_2$ eq. | 1.34 | 494.78 | 460.46 | 183.04 | 140.29 | 140.29 | 140.29 | 140.29 | 140.29 | 140.29 | 140.29 | 140.29 | 140.29 | 140.29 |

Reference: *Documents of Fluorocarbons etc Measures Working Group,* and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-76 Indices related to emissions of HFC-152a from high expanded polyethylene foam

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HFC-152a use | t | 0.038 | 14 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Emissions | t | 0.038 | 14 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | kt-$CO_2$ eq. | 0.005 | 1.736 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic HFC shipment amounts which is thought to be proportional to use amounts of foam blowing agents, and extrapolating for these years.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

See section 4.7.2.1.a. c).

- ***Time-series Consistency***

See section 4.3.9.1. c).

### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.7.3. Fire Protection (2.F.3.)

### *a) Category Description*

HFCs are emitted by the use of halogen fire extinguishers.

### *b) Methodological Issues*

- ***Estimation Method***

HFC-23 and HFC-227ea are used for the production of fire extinguishers. However, as of 2004, only HFC-227ea is filled in the bottles for fire extinguishing equipment, and for HFC-23, each company purchases pre-filled HFC-23 fire extinguisher bottles, and therefore no emissions occur at production. HFCs emissions from this category was reported as “NO” by expert judgment since HFC-227ea was a very small amount, 0.0007 [t] when emission from production in FY2004 was estimated.

For use, in 1995, almost no HFC filled fire extinguishers existed on the market, and therefore it is

assumed that there was no use, resulting in NO for 1995 and earlier years. For 1996 and following years, calculations were performed using the following equation and based on the HFC extinguishing agent installations and stocks.

$$E = Bank \times EF$$

*E* : HFC emissions [t]
*Bank* : HFC extinguishing agent installations and stocks [t]
*EF* : Emission factor during use

Concerning the emission at the time of disposal of fire extinguishers, it is reported as "NO" because the use of HFC for fire extinguishers has just started, and also the expected lifetime of buildings is 30-40 years, and therefore they are unlikely to be disposed of as of present.

- ***Emission Factors***

There are still no findings on the emission factor of HFC extinguishing agents when using them. The emission rate (0.00088) determined from refills of halons (provided by the Fire and Disaster Management Agency), which are similar extinguishing agents, was adopted as the emission factor for this category.

Table 4-77 References for the Emission factor of fire extinguishers
(The emission ratio of halon fire extinguishers)

| | Unit | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Average |
|---|---|---|---|---|---|---|---|---|
| Installations of halon 1301 (A) | t | 17,094 | 17,090 | 17,060 | 16,994 | 17,075 | 16,889 | 17,034 |
| Refills of halon 1301 (B) | t | 13 | 13 | 22 | 13 | 14 | 15 | 15 |
| (B) / (A) | - | 0.00076 | 0.00076 | 0.00129 | 0.00076 | 0.00082 | 0.00089 | 0.00088 |

- ***Activity Data***

HFC stock amounts provided by the Fire Defense Agency were used as activity data for HFC emissions from fire extinguishing agents use.

Table 4-78 The amounts of the HFC extinguishing agent installations and stocks

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stocks of HFC-23 | t | NO | NO | 306 | 478 | 512 | 523 | 528 | 533 | 537 | 546 | 559 | 567 | 573 | 579 |
| HFC-23 emissions | t | NO | NO | 0.27 | 0.42 | 0.45 | 0.46 | 0.46 | 0.47 | 0.47 | 0.48 | 0.49 | 0.50 | 0.50 | 0.51 |
| | kt-$CO_2$ eq. | NO | NO | 3.99 | 6.23 | 6.67 | 6.81 | 6.87 | 6.94 | 6.99 | 7.11 | 7.29 | 7.38 | 7.46 | 7.54 |
| Stocks of HFC-227ea | t | NO | NO | 225 | 392 | 498 | 522 | 544 | 596 | 640 | 686 | 738 | 754 | 800 | 810 |
| HFC-227ea emissions | t | NO | NO | 0.20 | 0.34 | 0.44 | 0.46 | 0.48 | 0.52 | 0.56 | 0.60 | 0.65 | 0.66 | 0.70 | 0.71 |
| | kt-$CO_2$ eq. | NO | NO | 0.64 | 1.11 | 1.41 | 1.48 | 1.54 | 1.69 | 1.81 | 1.94 | 2.09 | 2.14 | 2.27 | 2.29 |
| Total emissions | kt-$CO_2$ eq. | NO | NO | 4.63 | 7.34 | 8.08 | 8.29 | 8.42 | 8.63 | 8.80 | 9.06 | 9.38 | 9.51 | 9.72 | 9.84 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainties of the emissions, *the 2006 IPCC Guidelines* value of 16% was used.

- ***Time-series Consistency***

Calculations are performed with a method consistently used from FY1995, based on an emission factor and activity data received from the Fire Defense Agency. For years 1990 to 1994, emissions are reported as NO, in light of the fact that HFC filled fire extinguishers were not in use in 1995.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d)

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.7.4. Aerosols (2.F.4.)

### 4.7.4.1. Metered Dose Inhalers (2.F.4.-)

### *a) Category Description*

HFCs are emitted from the manufacturing and use of metered dose inhalers (MDIs).

### *b) Methodological Issues*

- ***Estimation Method***

In accordance with the IPCC Guidelines, emissions were calculated on the assumption that from the amount used each year, 50% of the emission occurred in the year of production, with the remaining 50% emitted in the following year.

The amount of purchased gas, the amount of the use of domestically manufactured MDI and the use of imported MDI, and the amount of disposal of MDI were provided by the Federation of Pharmaceutical Manufacturers' Associations of Japan (FPMAJ). FPMAJ estimates the amount of HFC disposal by mainly including destructed MDI that were defective products.

$$E_n = E_{manufacturing} + E_{potential(n-1)} \times EF_{first} + E_{potential(n)} \times (1\text{-}EF_{first}) - R_{(n)}$$

| | |
|---|---|
| $E_n$ | : F-gas (HFC-134a, HFC-227ea) emissions in year n [t] |
| $E_{manufacturing}$ | : Fugitive emissions during manufacturing [t] |
| $E_{potential(n-1)}$, $E_{potential(n)}$ | : F-gas potential emissions in year (n - 1) or in year n [t] |
| $EF_{first}$ | : 50[%] |
| $R_{(n)}$ | : Amount of disposal of F-gas contained in MDI [t] |

$$E_{potential} = U_{domestic} + U_{import}$$

| | |
|---|---|
| $U_{domestic}$ | : Use amount of domestically manufactured MDI [t] |
| $U_{import}$ | : Use amount of imported MDI [t] |

The associated indices are given in the table below.

Table 4-79 Indices related to emissions of HFC-134a from MDI

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Usage of domestic MDI | t | NO | NO | 1.4 | 0.9 | 0.9 | 1.1 | 0.8 | 0.8 | 0.6 | 0.9 | 0.6 | 0.9 | 0.6 | 0.8 |
| Usage of imported MDI | t | NO | NO | 42.0 | 70.7 | 57.1 | 57.1 | 54.0 | 48.3 | 46.0 | 42.4 | 41.3 | 39.2 | 34.2 | 35.0 |
| Amount collected and destroyed | t | NO | NO | 0.1 | 1.9 | 0.4 | 2.5 | 2.4 | 0.8 | 0.7 | 0.2 | 3.6 | 0.4 | 0.1 | 0.0 |
| Emissions | t | NO | NO | 37.2 | 62.8 | 60.0 | 55.5 | 54.1 | 51.3 | 47.2 | 44.9 | 39.3 | 40.7 | 37.4 | 35.3 |
| | kt-$CO_2$ eq. | NO | NO | 53.2 | 89.7 | 85.7 | 79.4 | 77.4 | 73.3 | 67.5 | 64.2 | 56.3 | 58.2 | 53.5 | 50.5 |

Reference: *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-80 Indices related to emissions of HFC-227ea from MDI

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Usage of domestic MDI | t | NO | NO | NO | 41.0 | 27.8 | 36.0 | 30.9 | 25.8 | 25.1 | 21.0 | 23.0 | 21.4 | 17.8 | 18.4 |
| Usage of imported MDI | t | NO | NO | 3.6 | 2.1 | 1.6 | 0.4 | 0.8 | 0.7 | 0.7 | 0.4 | 18.8 | 20.2 | 27.5 | 26.2 |
| Amount collected and destroyed | t | NO | NO | NO | 1.2 | 0.9 | 0.8 | 0.9 | 0.8 | 0.8 | 0.5 | 0.7 | 0.2 | 0.3 | 0.3 |
| Emissions | t | NO | NO | 1.8 | 48.1 | 42.8 | 33.1 | 34.3 | 29.8 | 26.9 | 23.9 | 31.7 | 32.1 | 43.9 | 45.4 |
| | kt-$CO_2$ eq. | NO | NO | 5.8 | 154.7 | 137.7 | 106.7 | 110.4 | 96.0 | 86.7 | 77.1 | 102.1 | 135.0 | 141.5 | 146.2 |

Reference: *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the Ministry of Economy Trade and Industry, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: The production of MDIs using HFC-134a started in 1997, and those using HFC-227ea started in 2001 (with production using imported HFC-227ea starting in 2000).

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, emissions have been estimated to be NO for these years, since for HFC-134a, 1995 and 1996 amounts of usage of domestic MDI and usage of imported MDI are each zero, and for HFC-227ea, 1995 to 1999 amounts of usage of domestic MDI and usage of imported MDI are each zero.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainties of the emission factors, 0% was applied for all production, use and disposal, due to the fact that the amount of emissions is equal to the amount of MDI used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all production, use and disposal. As a result, the uncertainties of the emissions for all production, use and disposal were determined to be 10%.

- ***Time-series Consistency***

See section 4.3.9.1. c).

### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.7.4.2. Aerosols (2.F.4.-)

### *a) Category Description*

HFCs are emitted from the manufacturing and use of aerosols.

### *b) Methodological Issues*

- ***Estimation Method***

In accordance with the *2006 IPCC Guidelines*, emissions were calculated on the assumption that 50% of the emission from the amount of aerosol filled in the products (potential emissions) occurred in the year of production, with the remaining 50% emitted in the following year. Fugitive emissions from manufacturing is considered as the balance between the amount used for production and the actual

measurement amount filled in the products, and it is included in the emissions. The data on the amount used for production and the amount filled in the products were provided by the Aerosol Industry Association of Japan. HFC is considered to be actually remaining in disposed aerosols at some level. However, the amount of emission at the time of "disposal" was reported as "IE" since it is included in the calculation for the "use" category.

$$E_n = E_{manufacturing} + E_{potential(n-1)} \times EF_{first} + E_{potential(n)} \times (1\text{-}EF_{first})$$

$E_n$ : HFC emissions in year n [t]
$E_{manufacturing}$ : Fugitive emissions during manufacturing [t]
$E_{potential(n-1)}$, $E_{potential(n)}$ : HFC potential emissions in year (n-1) or in year n [t]
$EF_{first}$ : 50[%]

$$E_{manufacturing(n)} = M_{(n)} - E_{potential(n)}$$

$E_{manufacturing(n)}$ : Fugitive emissions during manufacturing [t]
$M_{(n)}$ : HFC consumed during manufacturing in year n [t]
$E_{potential(n)}$ : HFC potential emissions [t]

The associated indices are given in the table below.

Table 4-81 Indices related to emissions of HFC-134a from aerosols

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Potential emissions | t | NO | 1,300 | 2,044 | 604 | 230 | 200 | 190 | 168 | 168 | 223 | 206 | 236 | 193 | 159 |
| Fugitive emissions during production | t | NO | NO | 80 | 25 | 10 | 8 | 7 | 8 | 7 | 12 | 15 | 22 | 35 | 39 |
| Emissions in the year produced, during use | t | NO | 650 | 1,022 | 302 | 115 | 100 | 95 | 84 | 84 | 112 | 103 | 118 | 97 | 80 |
| Remaining (emissions in the next year) | t | NO | 650 | 1,022 | 302 | 115 | 100 | 95 | 84 | 84 | 112 | 103 | 118 | 97 | 80 |
| Emissions | t | NO | 1,050 | 2,137 | 908 | 297 | 223 | 202 | 187 | 175 | 208 | 230 | 243 | 250 | 215 |
| | kt-$CO_2$ eq. | NO | 1,502 | 3,056 | 1,299 | 424 | 319 | 289 | 268 | 250 | 297 | 328 | 347 | 357 | 307 |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc*

Note: Fugitive emissions from 1992 to 1997 are included in potential emissions.

Table 4-82 Indices related to emissions of HFC-152a from aerosols

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Potential emissions | t | NO | NO | 34 | 1,300 | 764 | 558 | 502 | 542 | 320 | 353 | 279 | 328 | 276 | 226 |
| Fugitive emissions during production | t | NO | NO | 1 | 29 | 494 | 638 | 730 | 464 | 249 | 185 | 109 | 68 | 89 | 75 |
| Emissions in the year produced, during use | t | NO | NO | 17 | 650 | 382 | 279 | 251 | 271 | 160 | 177 | 140 | 164 | 138 | 113 |
| Remaining (emissions in the next year) | t | NO | NO | 17 | 650 | 382 | 279 | 251 | 271 | 160 | 177 | 140 | 164 | 138 | 113 |
| Emissions | t | NO | NO | 18 | 1,217 | 1,584 | 1,299 | 1,260 | 986 | 680 | 522 | 425 | 372 | 391 | 326 |
| | kt-$CO_2$ eq. | NO | NO | 2.3 | 150.9 | 196.4 | 161.1 | 156.2 | 122.3 | 84.3 | 64.7 | 52.6 | 46.1 | 48.5 | 40.4 |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc*

Note: The production of aerosols using HFC-152a started in 2000.

Table 4-83 Indices related to emissions of HFC-245fa from aerosols

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Potential emissions | t | NO | NO | NO | 0.795 | 0.318 | 0.388 | 2.034 | 1.094 | 0.17 | 1.1 | 0.275 | 0 | 0 | 0 |
| Fugitive emissions during production | t | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Emissions in the year produced, during use | t | NO | NO | NO | 0.398 | 0.159 | 0.194 | 1.017 | 0.547 | 0.085 | 0.550 | 0.138 | NO | NO | NO |
| Remaining (emissions in the next year) | t | NO | NO | NO | 0.398 | 0.159 | 0.194 | 1.017 | 0.547 | 0.085 | 0.550 | 0.138 | NO | NO | NO |
| Emissions | t | NO | NO | NO | 0.547 | 0.493 | 0.353 | 1.211 | 1.564 | 0.632 | 0.635 | 0.688 | 0.138 | NO | NO |
| | kt-$CO_2$ eq. | NO | NO | NO | 0.5629 | 0.50728 | 0.36359 | 1.24733 | 1.61092 | 0.65096 | 0.65405 | 0.70813 | 0.14163 | NO | NO |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the second meeting of the Breakout Group on F-gases, FY2014 Committee for the Greenhouse Gas Emissions Estimation Methods etc*

Table 4-84 Indices related to emissions of HFC-365mfc from aerosols

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Potential emissions | t | NO | NO | NO | 1.115 | NO | NO | NO | 0.274 | NO | 0.244 | 0.24 | NO | NO | NO |
| Fugitive emissions during production | t | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Emissions in the year produced, during use | t | NO | NO | NO | 0.558 | NO | NO | NO | 0.137 | NO | 0.122 | 0.12 | NO | NO | NO |
| Remaining (emissions in the next year) | t | NO | NO | NO | 0.558 | NO | NO | NO | 0.137 | NO | 0.122 | 0.12 | NO | NO | NO |
| Emissions | t | NO | NO | NO | 0.74 | 0.28 | NO | NO | 0.137 | 0.137 | 0.122 | 0.242 | 0.12 | NO | NO |
| | kt-$CO_2$ eq. | NO | NO | NO | 0.58756 | 0.22232 | NO | NO | 0.10878 | 0.10878 | 0.09687 | 0.19215 | 0.09528 | NO | NO |

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the second meeting of the Breakout Group on F-gases, FY2014 Committee for the Greenhouse Gas Emissions Estimation Methods etc*

The *2006 IPCC Guidelines* specifies estimation methods for HFC-43-10mee emissions from this sub-category, however, emissions do not exceed the 3,000 t-$CO_2$ eq threshold for estimation, determined by the Committee for Greenhouse Gas Emissions Estimation Methods, and therefore is reported as NE (considered insignificant). (See Annex 5)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by domestic HFC shipment amounts which are thought to be proportional to potential emissions, and extrapolating etc for these years.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainties of the emission factors, 0% was applied for all production, use and disposal, due to the fact that the amount of emissions is equal to the amount of aerosols used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all production, use, and disposal. As a result, the uncertainties of the emissions for all production, use and disposal were determined to be 10%.

- ***Time-series Consistency***

See section 4.3.9.1. c).

### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.7.5. Solvents (2.F.5.)

### *a) Category Description*

Liquid HFC-365mfc is used as an industrial dry cleaning solvent by the name of Solkane Dry, and is released into the atmosphere through volatilization etc. HFCs and PFCs are also emitted from the use of solvents for the cleaning of general electronic parts, and semiconductor/liquid crystal manufacturing. The liquid PFCs used were $C_5F_{12}$ (PFC-41-12) and $C_6F_{14}$ (PFC-51-14). Data on HFCs used as solvents in the cleaning of general electronic parts, and semiconductor/liquid crystal manufacturing are confidential; therefore, these are reported as included under the total of PFCs.

### *b) Methodological Issues*

- ***Estimation Method***

➢ ***HFCs***

The annual use amount of Solkane Dry is estimated by multiplying the aggregate number of dry cleaning machines using Solkane Dry (from the domestic manufacturers, and subtracting out the number of machines disposed), by the average solvent amount used. All that is used (=solvent amount replenished) is assumed to have been emitted.

$$E = (N_{special} - D_{special}) \times U_{special} + (N_{partial} - D_{partial}) \times U_{partial}$$

| | |
|---|---|
| $E$ | : HFC-365mfc emissions |
| $N_{special}$ | : Aggregate number of dry cleaning machines specialized for Solkane Dry use |
| $D_{special}$ | : Aggregate number of specialized machines disposed |
| $U_{special}$ | : Average solvent amount used in specialized machines |
| $N_{partial}$ | : Aggregate number of dry cleaning machines partially using Solkane Dry |
| $D_{partial}$ | : Aggregate number of partial-use machines disposed |
| $U_{partial}$ | : Average solvent amount used in partial-use machines |

The average solvent amount used in dry cleaning machines using Solkane Dry is set based on the actual amounts of Solkane Dry sold and actual number of operating machines at a large manufacturer. (See the Table below) For the average solvent amount used in Solkane Dry-specialized dry cleaning machines in years 2011 and before, the average value for 2012 to 2017 is used. For the dry cleaning machines partially using Solkane Dry, the average solvent amount used is set by multiplying the amount for specialized machines by a ratio.

Since there is no shipment of dry cleaning machines using Solkane Dry for 2002 and before, emissions only start occurring in 2003.

Table 4-85 Number of dry cleaning machines using Solkane Dry and average solvent amount used

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cumulative number of specialized and mixed-use machines | units | 0 | 0 | 0 | 12 | 81 | 121 | 170 | 192 | 216 | 234 | 246 | 259 | 268 | 272 |
| Average solvent use per year (specialized) | kg/unit | 0 | 0 | 0 | 673 | 673 | 673 | 673 | 653 | 678 | 713 | 699 | 692 | 602 | 602 |

➢ ***PFCs***

Assuming that almost all of the total amount of liquid PFC shipment was used in cleaners and for cleaning purposes each year, the entire amount was reported in the ”use” category as the amount of emissions. (Average GWP for 2018 is 2,588. Emissions are calculated by gas but are reported as an unspecified mix due to confidentiality reasons.) Emission from manufacturing was reported as ”NO” since there is no practice to blend before use. Emission at the time of disposal was reported as “IE” on the assumption, from the point of view of conservativeness, that the entire amount including that was disposed of, was emitted during use, because of the difficulty in determining the status of the disposal of PFCs. It is confirmed that no disposals were identified in 1995.

Emissions from PFCs contained in railway rectifiers (Refer to 2.G.2. for details) are subtracted from liquid PFC emissions to yield the total PFC emissions.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic PFC shipment amounts which is thought to be proportional to PFC emissions, and extrapolating for these years.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainties of the HFC emission factors, -5% to +5% was applied. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be -11% to +11%.

For the uncertainties of the PFC emission factors, 0% was applied, due to the fact that the amount of emissions is equal to the amount of solvent used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be 10%.

- ***Time-series Consistency***

See section 4.3.9.1. c).

### *d) Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.7.6. Other applications (2.F.6.)

Refrigerants filled in research and medical equipment are captured and included in other refrigerant categories.

# 4.8. Other product manufacture and use (2.G.)

This category covers $N_2O$, PFC, and $SF_6$ emissions from other product manufacture and use. This section includes GHG emissions from the following sources: Electrical equipment (2.G.1.), Military applications (2.G.2.), Accelerators (2.G.2.), Other - Railway silicon rectifiers (2.G.2.), Medical applications (2.G.3.), and Use during Semiconductor/Liquid Crystal Manufacturing (2.G.3.).

In FY2018, emissions from this category were1,784kt-$CO_2$ eq. and represented 0.1% of Japan's total GHG emissions (excluding LULUCF). The total emissions of $N_2O$ from this category had increased by 27.2% compared to FY1990. The total of PFCs and $SF_6$ had decreased by 84.0% compared to 1990.

Table 4-86 Emissions from 2.G. other product manufacture and use

| Gas | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_2O$ | 2.G.3 | Medical applications | kt-$N_2O$ | 0.93 | 1.41 | 1.10 | 0.86 | 0.39 | 0.32 | 0.31 | 0.29 | 0.25 | 1.11 | 0.22 | 0.22 | 0.23 | 0.21 |
| | | Use during semiconductor/liquid crystal manufacturing | kt-$N_2O$ | 0.05 | 0.10 | 0.15 | 0.38 | 0.48 | 0.60 | 0.59 | 0.74 | 0.95 | 0.99 | 1.13 | 1.22 | 1.18 | 1.03 |
| | Total | | kt-$N_2O$ | 0.98 | 1.51 | 1.25 | 1.23 | 0.87 | 0.92 | 0.91 | 1.03 | 1.20 | 2.10 | 1.35 | 1.44 | 1.41 | 1.24 |
| | Total | | kt-$CO_2$ eq. | 291 | 449 | 371 | 368 | 259 | 275 | 270 | 308 | 359 | 627 | 402 | 429 | 420 | 370 |
| Gas | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| PFCs | 2.G.2 | Other-Railway silicon rectifiers | t | NO | NO | NO | 0.03 | 0.34 | 0.47 | 0.64 | NO | 1.11 | 0.97 | 0.84 | 2.24 | 2.10 | 4.22 |
| $SF_6$ | 2.G.1 | Electrical equipment | t | 355.8 | 460.5 | 127.6 | 39.4 | 31.2 | 27.3 | 31.0 | 31.5 | 28.2 | 26.4 | 26.8 | 28.7 | 27.2 | 25.1 |
| | 2.G.2 | Military applications | t | NO | NO | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| | | Accelerators | t | 30.8 | 35.2 | 34.5 | 35.7 | 35.5 | 33.8 | 34.1 | 35.1 | 35.1 | 35.1 | 34.3 | 33.4 | 33.9 | 34.0 |
| | Total | | t | 386.6 | 495.6 | 163.3 | 76.4 | 67.9 | 62.3 | 66.4 | 67.8 | 64.5 | 62.7 | 62.3 | 63.4 | 62.3 | 60.3 |
| Total of F-gases | | | kt-$CO_2$ eq. | 8,814 | 11,300 | 3,724 | 1,741 | 1,552 | 1,426 | 1,519 | 1,546 | 1,482 | 1,438 | 1,427 | 1,466 | 1,440 | 1,414 |

### 4.8.1. Electrical Equipment (2.G.1.)

#### *a) Category Description*

$SF_6$ are emitted during the manufacturing and use of electrical equipment.

#### *b) Methodological Issues*

- ***Estimation Method***

Emissions from producing electrical equipment were calculated by multiplying the amount of $SF_6$ purchased by assembly fugitive rate. Emissions from the use of electrical equipment were calculated based on the fugitive rate during the use of electrical equipment. Emission factors are country-specific. Emissions from the inspection and disposal of electrical equipment were obtained by actual measurements of $SF_6$.

In CRF, the emission was reported as "IE" after including the emission from disposal into the use of electrical equipment.

➢ ***Emissions from the production***

$$E_{manufacturing} = AD \times EF_{manufacturing}$$

$E_{manufacturing}$ : $SF_6$ emissions from the production
$AD$ : $SF_6$ purchased
$EF_{manufacturing}$ : Assembly fugitive rate [%]

➢ ***Emission from the use***

$$E_{use} = Stock \times EF_{use}$$

$E_{use}$ : $SF_6$ emission from the use
$Stock$ : Stocks of $SF_6$
$EF_{use}$ : Rate of emitted $SF_6$ into the environment during the use of electrical equipment (0.1%)

➢ ***Emission from the inspection***

$$E_{inspection} = E_{measured}$$

$E_{inspection}$ : $SF_6$ emission from the inspection
$E_{measured}$ : Actual measurements of $SF_6$

➢ ***Emission from the disposal***

$$E_{disposed} = E_{measured}$$

$E_{disposed}$ : $SF_6$ emission from the disposal
$E_{measured}$ : Actual measurements of $SF_6$

The associated indices are given in the table below.

Table 4-87 Indices related to emissions of $SF_6$ from electrical equipment

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emissions during manufacturing | kt-$CO_2$ eq. | 7,047.27 | 9,120.00 | 2,291.17 | 523.09 | 250.80 | 157.32 | 168.72 | 145.92 | 125.40 | 136.80 | 163.43 | 179.07 | 141.36 | 118.56 |
| $SF_6$ emissions during use, maintenance, and disposal | kt-$CO_2$ eq. | 1,065.20 | 1,378.49 | 618.52 | 376.32 | 460.35 | 464.91 | 537.87 | 572.98 | 517.35 | 464.91 | 446.67 | 476.31 | 478.59 | 453.51 |

Reference: the *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic $SF_6$ shipment amounts which is thought to be proportional to amounts of

$SF_6$ purchased and stocks of $SF_6$, amounts of $SF_6$ charged to electrical equipment from 1995, the assembly fugitive rate from 1995, and the operational fugitive rate from 1995, and extrapolating for these years.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

For the uncertainties of the emission factors, -30 - +30% was applied for manufacturing and use, and -20 - +40% was applied for disposal, in accordance with the *2006 IPCC Guidelines*' default value. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. As a result, the uncertainty of the emissions for manufacturing and use was determined to be -32 - +32%, and -22 - +41% for disposal.

- ***Time-series Consistency***

See section 4.3.9.1. c).

***d) Category-specific QA/QC and Verification***

See section 4.3.9.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

## 4.8.2. $SF_6$ and PFCs from other product use (2.G.2.)

### 4.8.2.1. Military applications (2.G.2.-)

***a) Category Description***

$SF_6$ is used as an insulating medium in the radar systems of AWACS (Airborne Warning and Control System). When the plane ascends, $SF_6$ is automatically released from the system and into the atmosphere to maintain the appropriate pressure difference between the system and the outside air. When the plane descends, $SF_6$ is automatically charged into the system from an $SF_6$ container on board.

***b) Methodological Issues***

- ***Estimation Method***

Emissions are calculated using a method corresponding to the Tier 2 method (user mass-balance method) in the *2006 IPCC Guidelines*.

$$E = D + M - R - I$$

*E* : $SF_6$ Emissions
*D* : Decrease of $SF_6$ in the container on board the AWACS
*M* : $SF_6$ leakage during acquisition/replacement of $SF_6$ container on AWACS
*R* : $SF_6$ collected/destroyed
*I* : Net increase in AWACS fleet charge

The four-fleet AWACS was officially authorized for use on March 24, 1999, and therefore $SF_6$ emissions

are considered to have started in 1999.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainty***

No emission factor is set, and therefore the uncertainty of emissions is assessed by assessing the uncertainty of activity data. A 10% uncertainty of metal production is taken for the uncertainty of activity data. As a result, the uncertainty of emissions is 10%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

***d) Category-specific QA/QC and Verification***

See section 4.2.1. d).

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 4.8.2.2. Accelerators (2.G.2.-)

***a) Category Description***

$SF_6$ is used in university and research facility-operated particle accelerators, and in industrial/medical accelerators (for cancer therapy) as an insulating gas. When the equipment requires maintenance, the $SF_6$ is transferred into storage tanks, and therefore losses occur primarily during gas transfer.

***b) Methodological Issues***

- ***Estimation Method***

Emissions are calculated using the Tier 1 method in the *2006 IPCC Guidelines*.

$$E = N \times U \times C \times EF$$

$E$ : $SF_6$ Emissions
$N$ : Number of accelerators
$U$ : $SF_6$ use factor
$C$ : $SF_6$ charge factor
$EF$ : $SF_6$ emission factor

The $SF_6$ use factor, $SF_6$ charge factor, $SF_6$ emission factor, and number of accelerators used for estimating emissions are shown below by type of accelerator.

Table 4-88 $SF_6$ use factor, $SF_6$ charge factor, $SF_6$ emission factor by type of accelerator

| Item | University and research operated particle accelerators | Industrial particle accelerators | Medical particle accelerators [1)] | Small-scale electron accelerators |
|---|---|---|---|---|
| $SF_6$ use factor | 33% | 100% | 100% | 100% |
| $SF_6$ charge factor | 2,400kg | 1,300kg | 0.5kg | 400kg [2)] |
| $SF_6$ emission factor | See below Table | 0.07kg/kg | 2.0kg/kg | 0.07kg/kg |

Note: 1) Among the medical particle accelerators, cyclotrons and synchrotrons are not considered to use $SF_6$, and therefore are not estimated for.
Reference: *2006 IPCC Guidelines* default values excluding the 2) value are from results of interviews with main accelerator manufacturers.

Table 4-89 $SF_6$ emission factor for particle accelerators at university/research facilities

| Item | 1990-2004 | 2005-2009 | 2010-2014 | 2015-2018 |
|---|---|---|---|---|
| $SF_6$ emission factor [kg/kg] | 0.070 | 0.063 | 0.063 | 0.052 |

(Reference) Calculated based on JAEA-Technology 2010-023: Operation and Management of the High-pressure Gas Facility for the Tandem Accelerator, and 2011-2018 Environmental Reports (Japan Atomic Energy Agency).

Table 4-90 Number of accelerators by type

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of particle accelerators (University/Research facilities) | 188 | 214 | 212 | 209 | 219 | 218 | 216 | 231 | 225 | 222 | 241 | 245 | 242 | 242 |
| Number of particle accelerators (Industrial use) | 143 | 164 | 145 | 181 | 181 | 174 | 179 | 184 | 188 | 190 | 193 | 183 | 191 | 191 |
| Number of particle accelerators (Medical use) | 531 | 641 | 754 | 857 | 936 | 926 | 986 | 1,028 | 1,068 | 1,081 | 1,108 | 1,114 | 1,116 | 1,116 |
| Number of small-scale (below 1MeV) electron accelerators | 243 | 276 | 314 | 282 | 255 | 218 | 215 | 203 | 201 | 197 | 201 | 196 | 192 | 196 |

Reference: *Statistics on the Use of Radiation in Japan* (Japan Radioisotope Association), except for the *Nuclear Yearbook* (The Japan Atomic Industrial Forum) etc for small-scale electron accelerators

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the EF, a -50 - +400% uncertainty from the *2006 IPCC Guidelines* (particle accelerators - medical use) was applied. A -10 - +10% uncertainty of metal production is taken for the uncertainty of activity data. As a result, the uncertainty of emissions is -51 - +400%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

The number of accelerators were updated for 2017 and the $SF_6$ EFs for university/research facilities were revised for 2005 onward, resulting in recalculations. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.8.2.3. Soundproof windows (2.G.2.-)

The *2006 IPCC Guidelines* specifies estimation methods for this this sub-category, however, emissions do not exceed the 3,000 t-$CO_2$ eq threshold for estimation, determined by the Committee for Greenhouse Gas Emissions Estimation Methods, and therefore is reported as NE (considered insignificant). (See Annex 5)

### 4.8.2.4. Adiabatic properties: shoes and types (2.G.2.-)

PFC and $SF_6$ use for rubber with adiabatic properties are not found in Japan, and therefore emissions are reported as NO.

### 4.8.2.5. Other - Railway Silicon Rectifiers (2.G.2.-)

#### *a) Category Description*

PFCs are emitted at disposal of railway silicon rectifiers.

#### *b) Methodological Issues*

- ***Estimation Method***

Based on the number of devices containing PFC-51-14, the amount of PFC-51-14 contained, and lifetime of the devices installed on ground and on car respectively, given in the *Survey on Management Methods of Halons/Liquid PFCs etc* (2006), and the *Survey on Destruction of Halons/PFCs etc* (2010), the amount of PFC-51-14 disposed after use in railway silicon rectifiers in each fiscal year was estimated. This was done by multiplying the number of railway silicon rectifiers disposed per year, by the amount of PFC contained in each device. PFC emissions are calculated by subtracting the amount of PFC-51-14 destroyed in a specific fiscal year from the PFC disposed after use in railway silicon rectifiers in the same fiscal year.

$$E = M_{disposal} - R$$

| | |
|---|---|
| $E$ | : PFC emissions at disposal of railway silicon rectifiers |
| $M_{disposal}$ | : PFC disposed after use in railway silicon rectifiers |
| $R$ | : PFC destroyed |

#### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

For the uncertainty of the emission factor from railway silicon rectifiers, the 0% value for solvents was applied since it is a similar source category. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be 10%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

#### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

#### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

#### *f) Category-specific Planned Improvements*

No improvements are planned.

## 4.8.3. $N_2O$ from product uses (2.G.3.)

### 4.8.3.1. Medical applications (2.G.3.a)

#### *a) Category Description*

Nitrous oxide is emitted during anesthetics (laughing gas) use. Since 2006, some hospitals have installed $N_2O$ destruction units, and the reductions achieved are reflected in the total emissions. $CO_2$ is not used as an anesthetic in Japan.

#### *a) Methodological Issues*

- ***Estimation Method***

In relation to emissions of $N_2O$ from use of anesthetics, the actual amount of $N_2O$ shipped as an anesthetic by pharmaceutical manufacturers or importers has been reported for 2005 and preceding years. For 2006 and beyond, the amount of $N_2O$ collected is calculated using the amount of laughing gas used in domestic hospitals equipped with $N_2O$ destruction units for anesthesia, and a destruction rate of 99.9 %. This is subtracted from the $N_2O$ shipped for medical use to yield the amount of $N_2O$ emitted.

$$E = S - (U \times DR)$$

$E$ : Amount of $N_2O$ emitted during the use of laughing gas
$S$ : $N_2O$ shipped for medical use
$U$ : Amount of laughing gas used in hospitals equipped with $N_2O$ destruction units
$DR$ : Destruction rate

- ***Emission Factors***

It is assumed that all of the $N_2O$ used as medical gas escapes into the atmosphere, unless collected. Therefore, no emission factor has been established.

- ***Activity Data***

The amount of shipments of $N_2O$ for anesthetics (on calendar year basis) is given in the Ministry of Health, Labour and Welfare's *Statistics of Production by Pharmaceutical Industry*. This is used for 2005 and preceding years, and for 2006 to 2009, the amount of $N_2O$ collected in three, and from 2010 and onward collected in four domestic hospitals equipped with $N_2O$ destruction units is subtracted from the above-mentioned shipment.

Table 4-91 Laughing gas shipment amount and $N_2O$ collected in domestic hospitals

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Laughing gas shipment amount | kg-$N_2O$ | 926,030 | 1,411,534 | 1,099,979 | 859,389 | 389,749 | 320,110 | 314,155 | 292,971 | 253,218 | 1,111,265 | 219,011 | 219,011 | 234,691 | 211,842 |
| $N_2O$ collected in domestic hospitals | kg-$N_2O$ | NO | NO | NO | NO | 1,049 | 914 | 779 | 450 | 509 | NO | NO | NO | NO | NO |

#### *b) Uncertainties and Time-series Consistency*

- ***Uncertainty***

Because all $N_2O$ used for anesthetics are assumed to escape into the atmosphere, no emission factor has been set. Therefore, the uncertainty for activity data is also the uncertainty for emissions. As *Statistics of Production by Pharmaceutical Industry* is a fundamental statistic based on statistical law, a 5% uncertainty was given for this emission source.

- ***Time-series Consistency***

The amount of shipments are taken from the *Statistics of Production by Pharmaceutical Industry* in a consistent manner throughout the time series.

### *c) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *d) Category-specific Recalculations*

Recalculations have been conducted for FY2017, based on updates made to the amounts of laughing gas shipment.

### *e) Category-specific Planned Improvements*

No improvements are planned.

## 4.8.3.2. Other (2.G.3.b)

## 4.8.3.2.a. Use during Semiconductor/Liquid Crystal Manufacturing (2.G.3.b.-)

### *a) Category Description*

$N_2O$ is used as an oxidizing agent to form an insulative oxide film during semiconductor/liquid crystal manufacturing, and the remaining is considered to be released into the atmosphere.

### *b) Methodological Issues*

- ***Estimation Method***

Emissions equal all $N_2O$ shipment amounts for semiconductor/liquid crystal manufacturing.

$$E = AD$$

$E$ : $N_2O$ emissions during semiconductor/liquid crystal manufacturing
$AD$ : $N_2O$ shipped for semiconductor/liquid crystal manufacturing use

- ***Emission Factors***

Emissions equal activity data, and therefore no emission factor has been established.

- ***Activity Data***

The $N_2O$ shipment amounts for semiconductor/liquid crystal manufacturing given in the website of the Japan Industrial and Medical Gases Association is used as activity data.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

Because all $N_2O$ used during semiconductor/liquid crystal manufacturing are assumed to escape into the atmosphere, no emission factor has been set. Therefore, the uncertainty for activity data is also the uncertainty for emissions. For the uncertainty of activity data, a 5% default value in the *2006 IPCC Guidelines* were used.

- ***Time-series Consistency***

The shipment amounts are taken from what is reported by the Japan Industrial and Medical Gases Association in a consistent manner throughout the time series.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

There is a possibility of over-estimation, since emissions are equal to all $N_2O$ shipment amounts for semiconductor/liquid crystal manufacturing.

## 4.9. Other (2.H.)

Table 4-92 Emissions from the food and beverages industry

| Gas | | | Units | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 2.H.2 | Food and beverages industry | kt-$CO_2$ | 64.27 | 71.54 | 86.50 | 90.05 | 71.29 | 75.85 | 75.81 | 76.41 | 82.33 | 80.44 | 83.04 | 79.41 | 85.07 | 80.41 |
| | 2.H.3 | Emissions from imported carbonated gas | kt-$CO_2$ | 0.34 | 0.31 | 0.17 | 0.18 | 0.89 | 0.94 | 12.31 | 23.50 | 11.20 | 10.16 | 13.69 | 27.54 | 25.57 | 24.92 |
| | Total | | kt-$CO_2$ | 64.61 | 71.85 | 86.67 | 90.23 | 72.19 | 76.79 | 88.12 | 99.91 | 93.53 | 90.60 | 96.74 | 106.95 | 110.64 | 105.33 |

### 4.9.1. Food and beverages industry (2.H.2.)

The $CO_2$ recovered, estimated together with the emissions from ethylene oxide production (2.B.8.d) is reported here.

Petroleum refining plants, ammonia production plants, and iron production plants are other sources of supply $CO_2$ for the production of carbonated gas and dry ice in Japan, however those emissions occurring from petroleum refining plants are reported under the Fuel combustion sector (1.A.), and those emissions occurring from ammonia production plants are reported under ammonia production (2.B.1.), and those emissions occurring from iron production plants are reported under the Fuel combustion sector (1.A.).

### 4.9.2. Emissions from imported carbonated gas (2.H.3.)

#### *a) Category Description*

$CO_2$ are emitted from the use of imported carbonated gas.

#### *b) Methodological Issues*

The total amount of imported carbonated gas was used for estimating emissions.

- ***Estimation Method***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The import quantities of carbon dioxide in the *Trade Statistics of Japan* (the Ministry of Finance) was used for estimating emissions.

#### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

No emission factor has been set because all $CO_2$ are emitted from the use of imported carbonated gas, and are assumed to escape into the atmosphere. Therefore, the uncertainty for activity data is also the

uncertainty for emissions. For the uncertainty of activity data, a 5% value, which is the uncertainty for the use of electric arc furnaces in steel production referred to in the *Trade Statistics of Japan*, was used.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

### *d) Category-specific QA/QC and Verification*

See section 4.2.1. d).

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

No improvements are planned.

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# Chapter 5. Agriculture (CRF sector 3)

## 5.1. Overview of Sector

Greenhouse gas emissions from the agricultural sector are calculated in seven categories: 3A, 3B, 3C, 3D, 3F, 3G, and 3H. In 3A: Enteric Fermentation, $CH_4$ gas generated and emitted by cattle, buffalo, sheep, goats, horses, and swine as the result of enteric fermentation is reported. In 3B: Manure Management, $CH_4$ and $N_2O$ generated by treatment of manure excreted by cattle, buffalo, sheep, goats, horses, swine, poultry (hen and broiler), rabbit, and mink are reported. In 3C: Rice Cultivation, $CH_4$ emissions from paddy fields (continuously flooded and intermittently flooded) cultivated for rice production are reported. In 3D: Agricultural Soils, $N_2O$ emitted directly and indirectly from agricultural soil are reported. Emissions for 3E: Prescribed Burning of Savannas are reported as NO, since Japan has no emission source in this category, while $CH_4$ and $N_2O$ (as well as CO and $NO_X$, which is described in Annex 3) emissions from field burning of grains, legumes, root crops, and sugar cane during agricultural activities are reported in 3F: Field Burning of Agricultural Residues. 3G: Liming and 3H: Urea Application, $CO_2$ emissions by application of limestone and urea to soil are reported.

GHG emissions in the agricultural sector in FY2018 were 33,252 kt-$CO_2$ eq., comprising 2.7% of total emissions (excluding LULUCF). The value represents a reduction by 11.1% from FY1990.

Tier of methodology used in Agriculture sector are showed in Table 5-1.

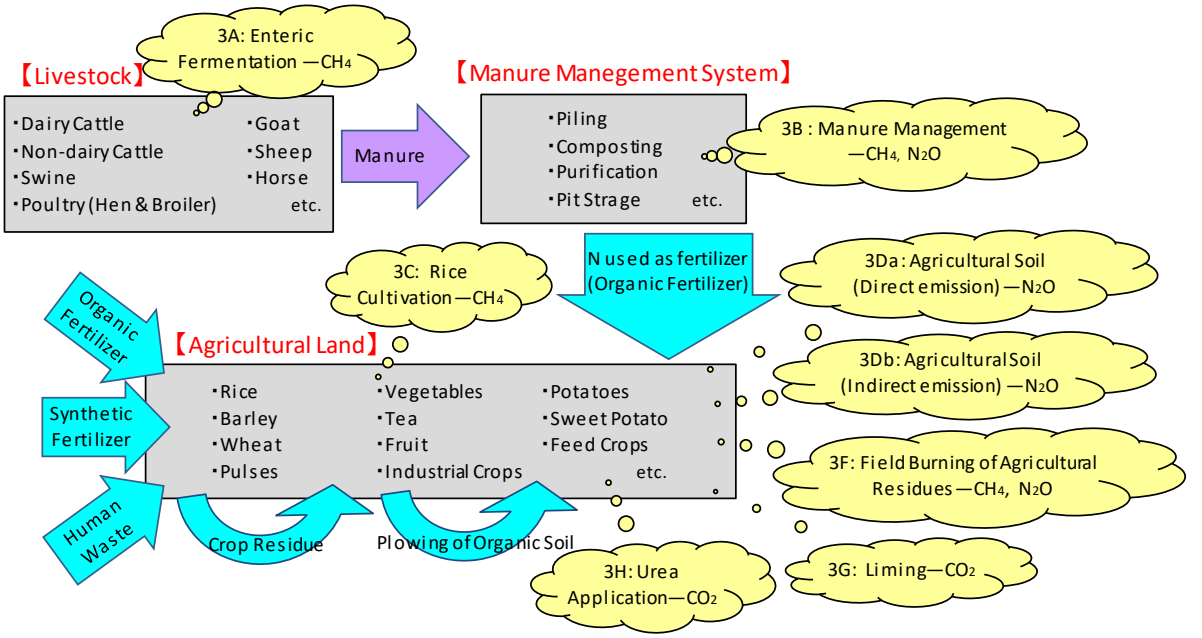


Figure 5-1 Relationships among the categories in the agricultural sector

Table 5-1 Tier of methodology used in Agriculture sector

| GREENHOUSE GAS CATEGORIES | $CO_2$ | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| 3.A. Enteric fermentation | | | CS,T1 | CS,D | | |
| 3.B. Manure management | | | CS,T1 | CS,D | CS,T1 | CS,D |
| 3.C. Rice cultivation | | | T3 | CS | | |
| 3.D. Agricultural soils | | | | | CS,T2 | CS,D |
| 3.F. Field burning of agricultural residues | | | T1 | D | T1 | D |
| 3.G. Liming | T1 | D | | | | |
| 3.H. Urea application | T1 | D | | | | |

Note: D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country-specific method or emission factor

## 5.2. Enteric Fermentation (3.A.)

Ruminants such as cattle, buffalo, sheep, and goats have multi-chamber stomachs. The rumen carries out anaerobic fermentation to decompose cellulose and other substances, thereby releasing $CH_4$. Horses and swine are not ruminants and have monogastric stomachs, but fermentations in their digestive tracts produce a small amount of $CH_4$, which is released into the atmosphere. These $CH_4$ emissions are calculated and reported in the Enteric Fermentation (3.A.) section.

GHG emissions from enteric fermentation in FY2018 were 7,466 kt-$CO_2$ eq., comprising 0.6% of total emissions (excluding LULUCF). The value represents a reduction by 20.8% from FY1990. Main driver of the emission reduction from FY1990 is a reduction of cattle population.

Table 5-2 $CH_4$ emissions from enteric fermentation

| Gas | Livestock species | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 3.A.1.- Dairy cattle | kt-$CH_4$ | 192.1 | 184.4 | 171.2 | 162.9 | 149.5 | 146.3 | 146.2 | 143.4 | 139.7 | 137.0 | 136.4 | 133.5 | 133.5 | 133.5 |
| | 3.A.1.- Non-dairy cattle | | 166.6 | 172.2 | 171.7 | 168.0 | 174.3 | 166.5 | 164.7 | 159.6 | 154.8 | 150.0 | 150.3 | 151.1 | 151.7 | 150.7 |
| | 3.A.2. Sheep | | 0.167 | 0.115 | 0.097 | 0.071 | 0.113 | 0.159 | 0.160 | 0.129 | 0.138 | 0.140 | 0.140 | 0.143 | 0.158 | 0.162 |
| | 3.A.3. Swine | | 15.9 | 13.9 | 13.7 | 13.5 | 13.8 | 13.7 | 13.6 | 13.6 | 13.4 | 13.2 | 13.0 | 13.1 | 12.9 | 12.8 |
| | 3.A.4.- Buffalo | | 0.011 | 0.007 | 0.006 | 0.005 | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| | 3.A.4.- Goats | | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 3.A.4.- Horses | | 2.1 | 2.1 | 1.9 | 1.6 | 1.5 | 1.3 | 1.4 | 1.3 | 1.3 | 1.2 | 1.3 | 1.3 | 1.4 | 1.4 |
| | Total | kt-$CH_4$ | 376.9 | 372.7 | 358.7 | 346.0 | 339.2 | 328.1 | 326.2 | 318.1 | 309.5 | 301.7 | 301.4 | 299.2 | 299.8 | 298.6 |
| | | kt-$CO_2$eq | 9,423 | 9,318 | 8,966 | 8,651 | 8,480 | 8,202 | 8,154 | 7,953 | 7,737 | 7,543 | 7,534 | 7,481 | 7,494 | 7,466 |

### 5.2.1. Cattle (3.A.1.)

#### *a) Category Description*

This section provides the estimation methods for $CH_4$ emissions from enteric fermentation in Cattle.

#### *b) Methodological Issues*

- ***Estimation Method***

In accordance with decision tree of the *2006 IPCC Guidelines* (Volume 4, Page 10.25, Figure 10.2), calculations for dairy and non-dairy cattle should be performed using the Tier 2 method. In the Tier 2 method, emission factors are calculated by multiplying the total energy intake of livestock by the $CH_4$ conversion factor. However, estimation using amount of dry matter intake has been practiced in Japan on livestock-related research. It is considered that, by applying the results of previous researches, the estimation method using amount of dry matter intake provides more accurate results. For that reason, a technique similar to the Tier 2 method but specific to Japan was used for the calculation of $CH_4$ emissions associated with enteric fermentation by cattle. The emissions were calculated by multiplying

the cattle population (dairy and non-dairy) by the emission factors established based on their dry matter intake.

$$E = \sum (EF_i \times A_i)$$

| | |
|---|---|
| $E$ | : $CH_4$ emissions from enteric fermentation for cattle [kg-$CH_4$] |
| $EF_i$ | : $CH_4$ emission factor of enteric fermentation of cattle type *i* [kg-$CH_4$ /head] |
| $A_i$ | : Cattle population of each cattle type *i* [head] |

As cattle begin to eat coarse feed for real at the age about three months, the calculation of the $CH_4$ emissions associated with enteric fermentation includes cattle aged three months or older (cattle under three months are excluded from estimation). To reflect the actual situation of emissions in Japan, categorization of cattle is defined as shown in the below Table 5-3, and $CH_4$ emissions are estimated by type and age.

Table 5-3 Categorization and assumptions underlying calculation of $CH_4$ emissions associated with enteric fermentation in cattle

| Type of cattle | | | | | Assumptions for calculation of emissions | Additional information for each animal type |
|---|---|---|---|---|---|---|
| Dairy cattle | Lactating | Primipara | | | Population by calving time: calculated by multiplying the ratio of population by calving in *Record of Dairy Herd Performance Test* by the population in *Livestock Statistics*. | Lactating cattle. Population of over 2 years old are written in *the Livestock Statistics*. |
| | | Secundipara | | | | |
| | | Multipara (3 and more) | | | | |
| | Non-lactating | | | | — | Cattle in non-lactating period at present. |
| | Heifers | Under 2 years old and over 6 months old | | | Calculation excludes 6/24 of the population which was assumed to be 6 months old or younger; therefore covering 18/24 of the population under 2 years old. | Dairy cattle which are under 2 years old. Population of under 2 years old are described in *the Livestock Statistics*. |
| | | 3 to 6 months old | | | Calculation covers 3 to 6 months old comprising 4/24 of the population under 2 years old. | |
| | | Under 3 months old | | | Covering 2/24 of the population under 2 years old. Excluded from $CH_4$ emission estimation. | |
| Non-dairy cattle | Breeding cows | 2 year old and over | | | — | Breeding cow excluding dairy breeds. Population of under 1 year old, 1year old, 2years old, and 3 years old and more are described in *the Livestock Statistics*. |
| | | Under 2 year old and over 6 months old | | | Calculation exclude 6/12 of the population which was assumed to be 6 months to 1 year old for under 1 year old and addition of the population under 1 year old. | |
| | | 3 to 6 months old | | | Calculation covers 3 to 6 months old comprising 4/12 of the population under 1 year old. | |
| | | Under 3 months old | | | Covering 2/12 of the population under 1 year old. Excluded from $CH_4$ emission estimation. | |
| | Fattening cattle | Wagyu (Male) | 1 year old and over | | — | Cattle of native breeds in Japan called "Wagyu", which breeds for meat only. Population of under 1 year, 1 year and 2 years old are described as beef cattle (Male) in *the Livestock Statistics*. |
| | | | Under 1 year old and over 6 months old | | Calculation excludes 6/12 of the population which was assumed to be 6 months old or younger; therefore covering 6/12 of the population under 1 year old. | |
| | | | 3 to 6 months old | | Calculation covers 3 to 6 months old comprising 4/12 of the population under 1 year old. | |
| | | | Under 3 months old | | Covering 2/12 of the population under 1 year old. Excluded from $CH_4$ emission estimation. | |
| | | Wagyu (Female) | 1 year old and over | | — | Cattle of native breeds in Japan called "Wagyu", which breeds for meat only. Population of under 1 year, 1 year and over 1 year old (8 categories) are described as beef cattle (Female) in *the Livestock Statistics*. |
| | | | Under 1 year old and over 6 months old | | Same as same month age of Wagyu (Male) | |
| | | | 3 to 6 months old | | Same as same month age of Wagyu (Male) | |
| | | | Under 3 months old | | Same as same month age of Wagyu (Male) | |
| | | Dairy breeds | Dairy breeds | Over 6 months old | Calculation excludes 6/24 of the population which was assumed to be 6 months old or younger; therefore covering 18/24 of the population under 2 years old. | Cattle of dairy breeds for meat such as Holsteins. |
| | | | | 3 to 6 months old | Calculation covers 3 to 6 months old comprising 4/24 of the population under 2 years old. | |
| | | | | Under 3 months old | Covering 2/24 of the population under 2 years old. Excluded from $CH_4$ emission estimation. | |
| | | | Hybrid | Over 6 months old | Same as same month age of Dairy breeds | F1 hybrid for beef which female dairy breeds are delivered with crossing with male beef breed cattle. |
| | | | | 3 to 6 months old | Same as same month age of Dairy breeds | |
| | | | | Under 3 months old | Same as same month age of Dairy breeds | |

- ***Emission Factors***

The emission factor for $CH_4$ associated with enteric fermentation in cattle has been established on the basis of the result of breath testing of ruminant livestock in Japan: the measured data for volume of $CH_4$ per dry matter intake. Results of measurements have made clear that it is possible to estimate $CH_4$ from enteric fermentation in ruminant livestock using the equation given below, which uses dry matter intake

as the explanatory variable (Shibata et al. 1993).

$$EF = Y / L_{CH4} \times Mol_{CH4} \times Day$$

$$Y = -17.766 + 42.793 \times DMI - 0.849 \times (DMI)^2$$

| | |
|---|---|
| $EF$ | : $CH_4$ emission factor associated with enteric fermentation in cattle [kg-$CH_4$/head] |
| $Y$ | : Volume of $CH_4$ generated per head per day [l/day/head] |
| $L_{CH4}$ | : Volume of 1 mol $CH_4$ [l/mol] (=22.4) |
| $Mol_{CH4}$ | : Molecular weight of $CH_4$ [kg/mol] (=0.016) |
| $Day$ | : Days in a year [day] (=365 or 366) |
| $DMI$ | : Dry matter intake [kg/day/head] |

Annual emission factors by cattle types were established by applying the dry matter intake (DMI) to the above equation. The DMI was calculated by substituting body weight, and daily weight gain by growth into the equation established for each type of cattle in *Japan Feed Standards* compiled by National Agriculture and Food Research Organization (NARO). Fat corrected milk amount (FCM) is also used for DMI calculation for dairy cattle. The equations to estimate DMI were revised in 2006 for dairy cattle (lactating and non-lactating) and in 2008 for non-dairy cattle (Wagyu(M)).

The amount of fat corrected milk was calculated by estimated milk yield from data in the *Statistics on Milk and Dairy Products* (Ministry of Agriculture, Fisheries and Forestry; MAFF) and the *Livestock Statistics* (MAFF), and from the fat content in milk data in the *Statistics of Livestock Production Costs* (MAFF). Both sets of the data are updated on a yearly basis.

The average body weights of cattle by each calving time which were firstly calculated by applying the average ages in month by calving time described in the *Record of dairy herd performance test* (Livestock Improvement Association of Japan) into the growth curve of cattle described in *Japan Feed Standard* was adopted to the body weight for lactating and non-lactating dairy cattle. Average ages in month for primipara for all years were described in the *Record of dairy herd performance test*, however, the record of average ages in month for over second calving has started after 2015. Therefore, the values of average ages for over second calving for 2015 were substituted for before 2015. The regression equation expressing growth curve of dairy cattle have been revised in 1994, 1999, 2006 and each revised regression equation was applied after the revision Data for body weight and weight gain by daily growth for heifer and non-dairy cattle were obtained from the table of weight by age in month for each type of cattle included in the *Japanese Feeding Standards*.

Table 5-4 Equation to estimate dry matter intake (*DMI*) by cattle

| Type of cattle | | Equation |
|---|---|---|
| Dairy cattle | Lactating | After 2006 : $DMI = 1.3922 + 0.05839 \times W^{0.75} + 0.40497 \times FCM$<br>$DMI = 1.9120 + 0.07031 \times W^{0.75} + 0.34923 \times FCM$ (Primipara)<br>$FCM = (15 \times FAT / 100 + 0.4) \times MILK$<br>Before 2005 : $DMI = 2.98120 + 0.00905 \times W + 0.41055 \times FCM$<br>$FCM = (15 \times FAT / 100 + 0.4) \times MILK$ |
| | Non-lactating | $DMI = 0.017 \times W$ |
| | Heifers | $DMI = 0.49137 + 0.01768 \times W + 0.91754 \times DG$ |
| Non-dairy cattle | Breeding cows | For under 49mths old: $DMI = [0.1067 \times W^{0.75} + (0.0639 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$<br>$q = 0.4213 + 0.1491 \times DG$<br>For 49mths old and over: $DMI = [0.1119 \times W^{0.75} + (0.0639 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / 1.81$<br>Additional daily nutrient requirements for pregnant cows while last 2 months of pregnant:<br>+ 1.0 kg / day on calculated DMI<br>Additional daily nutrient requirements for lactating cows while 5 months of lactation:<br>+ 0.5 kg / day to calculated DMI<br>* Target ages are till 120 months old |
| | Wagyu (M) | After 2008: $DMI = -3.481 + 2.668 \times DG + 4.548 \times 10^{-2} \times W - 7.207 \times 10^{-5} \times W^2 + 3.867 \times 10^{-8} \times W^3$<br>Before 2007: $DMI = [0.1124 \times W^{0.75} + (0.0546 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / \{q \times (1.653 - 0.00123 \times W)\} / (q \times 4.4)$<br>$q = 0.5304 + 0.0748 \times DG$ |
| | Wagyu (F) | $DMI = [0.1108 \times W^{0.75} + (0.0609 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$<br>$q = 0.5018 + 0.0956 \times DG$ |
| | Dairy breeds (over 6 months old) | $DMI = [0.1291 \times W^{0.75} + (0.0510 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$<br>$q = (0.933 + 0.00033 \times W) \times (0.498 + 0.0642 \times DG)$ |
| | Dairy breeds (3 to 6 months old) | $DMI = [0.1291 \times W^{0.75} + \{(1.00 + 0.030 \times W^{0.75}) \times DG\} / (0.78 \times q + 0.006)] / (q \times 4.4)$<br>$q = (0.859 - 0.00092 \times W) \times (0.790 + 0.0411 \times DG)$ |
| | Hybrid | $DMI = [0.1208 \times W^{0.75} + (0.0531 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$<br>$q = (0.933 + 0.00033 \times W) \times (0.498 + 0.0642 \times DG)$ |

Note: *W* : Weight, *FCM* : Fat Corrected Milk, *FAT* : Fat content in milk, *MILK* : Milk Yield, *DG* : Daily Gain, *q* : Energy metabolic rate

Reference: *Japan Feed Standards*

Table 5-5 Fat content in milk (*FAT*) and milk yield (*MILK*) of cattle

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Milk yield (Multipara (3 and more)) | kg/head/day | 21.9 | 23.6 | 24.7 | 26.6 | 27.1 | 26.9 | 26.9 | 27.3 | 27.4 | 28.0 | 28.6 | 28.7 | 28.8 | 28.8 |
| Milk yield (Secundipara) | kg/head/day | 21.4 | 23.1 | 24.2 | 26.0 | 26.5 | 26.4 | 26.3 | 26.8 | 26.9 | 27.3 | 27.9 | 28.0 | 28.1 | 28.1 |
| Milk yield (Primipara) | kg/head/day | 18.5 | 19.9 | 20.9 | 22.4 | 22.8 | 22.7 | 22.7 | 23.0 | 23.1 | 23.5 | 24.0 | 24.2 | 24.5 | 24.4 |
| Fat content in milk | % | 3.7 | 3.8 | 3.9 | 4.0 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 |

Table 5-6 Weight by cattle (*W*) [kg head$^{-1}$]

| Type of cattle | | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | | Lactating (Multipara (3 and more)) | 653.8 | 653.5 | 673.7 | 673.4 | 685.8 | 685.6 | 685.9 | 685.7 | 685.2 | 684.7 | 684.7 | 684.3 | 683.9 | 683.8 |
| | | Lactating (Secundipara) | 598.4 | 601.6 | 622.6 | 622.6 | 623.9 | 623.9 | 623.9 | 623.9 | 623.9 | 623.9 | 623.9 | 623.4 | 622.5 | 622.5 |
| | | Lactating (Primipara) | 517.2 | 528.0 | 551.1 | 538.3 | 524.6 | 523.6 | 525.6 | 524.6 | 524.6 | 523.6 | 523.6 | 522.6 | 521.6 | 520.5 |
| | | Non-lactating | 601.0 | 602.4 | 625.3 | 618.5 | 625.6 | 623.3 | 621.3 | 619.9 | 620.1 | 618.7 | 617.4 | 616.8 | 616.9 | 616.6 |
| | | Heifer: under 2 yr, over 6 mth | 342.4 | 349.3 | 364.9 | 374.2 | 376.1 | 376.1 | 376.1 | 376.1 | 376.1 | 376.1 | 376.1 | 376.1 | 376.1 | 376.1 |
| | | Heifer: 3 to 6 mth | 118.9 | 119.2 | 123.0 | 135.3 | 137.8 | 137.8 | 137.8 | 137.8 | 137.8 | 137.8 | 137.8 | 137.8 | 137.8 | 137.8 |
| Non-dairy cattle | Breeding | 2 yr and over | 471.1 | 471.1 | 512.8 | 512.8 | 512.8 | 512.8 | 512.8 | 512.8 | 512.8 | 512.8 | 512.8 | 512.8 | 512.8 | 512.8 |
| | | Under 2 yr, over 6 mth | 314.9 | 314.9 | 383.0 | 383.0 | 383.0 | 383.0 | 383.0 | 383.0 | 383.0 | 383.0 | 383.0 | 383.0 | 383.0 | 383.0 |
| | | 3 to 6 mth | 118.4 | 118.4 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 |
| | Fattening cattle | Wagyu (M): 1 yr and over | 562.8 | 562.8 | 562.8 | 562.8 | 562.8 | 562.8 | 562.8 | 562.8 | 562.8 | 562.8 | 562.8 | 562.8 | 562.8 | 562.8 |
| | | Wagyu (M): under 1 yr, over 6 mth | 257.0 | 257.0 | 257.0 | 257.0 | 257.0 | 257.0 | 257.0 | 257.0 | 257.0 | 257.0 | 257.0 | 257.0 | 257.0 | 257.0 |
| | | Wagyu (M): 3 to 6 mth | 120.5 | 120.5 | 120.5 | 120.5 | 120.5 | 120.5 | 120.5 | 120.5 | 120.5 | 120.5 | 120.5 | 120.5 | 120.5 | 120.5 |
| | | Wagyu (F): 1 yr and over | 382.4 | 382.4 | 456.4 | 456.4 | 456.4 | 456.4 | 456.4 | 456.4 | 456.4 | 456.4 | 456.4 | 456.4 | 456.4 | 456.4 |
| | | Wagyu (F): under 1 yr, over 6 mth | 219.8 | 219.8 | 266.0 | 266.0 | 266.0 | 266.0 | 266.0 | 266.0 | 266.0 | 266.0 | 266.0 | 266.0 | 266.0 | 266.0 |
| | | Wagyu (F): 3 to 6 mth | 118.4 | 118.4 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 | 127.2 |
| | | Dairy breed: over 6 mth | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 |
| | | Dairy breed: 3 to 6 mth | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 |
| | | Hybrid: over 6 mth | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 | 479.8 |
| | | Hybrid: 3 to 6 mth | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 | 160.4 |

Table 5-7 Daily Gain by cattle (*DG*) [kg head$^{-1}$ day$^{-1}$]

| Type of cattle | | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | | Lactating | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | | Non-lactating | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | | Heifer: under 2 yr, over 6 mth | 0.60 | 0.63 | 0.65 | 0.59 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 | 0.58 |
| | | Heifer: 3 to 6 mth | 0.70 | 0.71 | 0.76 | 0.91 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 |
| Non-dairy cattle | Breeding | 2 yr and over | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | Under 2 yr, over 6 mth | 0.50 | 0.50 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 |
| | | 3 to 6 mth | 0.74 | 0.74 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 |
| | Fattening cattle | Wagyu (M): 1 yr and over | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 |
| | | Wagyu (M): under 1 yr, over 6 mth | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 |
| | | Wagyu (M): 3 to 6 mth | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 |
| | | Wagyu (F): 1 yr and over | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| | | Wagyu (F): under 1 yr, over 6 mth | 0.71 | 0.71 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| | | Wagyu (F): 3 to 6 mth | 0.74 | 0.74 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 |
| | | Dairy breed: over 6 mth | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 |
| | | Dairy breed: 3 to 6 mth | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 |
| | | Hybrid: over 6 mth | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 |
| | | Hybrid: 3 to 6 mth | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 |

Table 5-8 Dry matter intake by cattle (*DMI*) [kg day$^{-1}$]

| Type of cattle | | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | | Lactating (Multipara (3 and more)) | 17.5 | 18.3 | 19.1 | 19.9 | 20.1 | 20.0 | 20.0 | 20.1 | 20.1 | 20.3 | 20.6 | 20.7 | 20.7 | 20.7 |
| | | Lactating (Secundipara) | 16.9 | 17.7 | 18.4 | 19.3 | 19.3 | 19.2 | 19.2 | 19.4 | 19.4 | 19.6 | 19.8 | 19.8 | 19.9 | 19.9 |
| | | Lactating (Primipara) | 14.9 | 15.7 | 16.4 | 17.0 | 17.5 | 17.4 | 17.5 | 17.6 | 17.6 | 17.7 | 17.9 | 17.9 | 18.0 | 18.0 |
| | | Non-lactating | 10.2 | 10.2 | 10.6 | 10.5 | 10.6 | 10.6 | 10.6 | 10.5 | 10.5 | 10.5 | 10.5 | 10.5 | 10.5 | 10.5 |
| | | Heifer: under 2 yr, over 6 mth | 7.1 | 7.2 | 7.5 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 |
| | | Heifer: 3 to 6 mth | 3.2 | 3.2 | 3.4 | 3.7 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 |
| Non-dairy cattle | Breeding | 2 yr and over | 7.7 | 7.7 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| | | Under 2 yr, over 6 mth | 6.3 | 6.3 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 |
| | | 3 to 6 mth | 3.4 | 3.4 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 |
| | Fattening cattle | Wagyu (M): 1 yr and over | 8.2 | 8.2 | 8.2 | 8.2 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 |
| | | Wagyu (M): under 1 yr, over 6 mth | 6.5 | 6.5 | 6.5 | 6.5 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 |
| | | Wagyu (M): 3 to 6 mth | 3.6 | 3.6 | 3.6 | 3.6 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 |
| | | Wagyu (F): 1 yr and over | 5.6 | 5.6 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 |
| | | Wagyu (F): under 1 yr, over 6 mth | 4.7 | 4.7 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 |
| | | Wagyu (F): 3 to 6 mth | 3.0 | 3.0 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 |
| | | Dairy breed: over 6 mth | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| | | Dairy breed: 3 to 6 mth | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 |
| | | Hybrid: over 6 mth | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 |
| | | Hybrid: 3 to 6 mth | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 |

Table 5-9 Emission factors associated with enteric fermentation by cattle [kg-$CH_4$ head$^{-1}$ yr$^{-1}$]

| Type of cattle | | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | | Lactating (Multipara (3 and more)) | 122.9 | 125.9 | 127.7 | 129.8 | 130.1 | 129.9 | 130.3 | 130.3 | 130.3 | 130.7 | 131.6 | 131.4 | 131.5 | 131.5 |
| | | Lactating (Secundipara) | 120.5 | 123.8 | 125.8 | 128.1 | 128.3 | 128.0 | 128.4 | 128.4 | 128.5 | 128.9 | 129.9 | 129.6 | 129.7 | 129.7 |
| | | Lactating (Primipara) | 112.7 | 116.4 | 118.9 | 121.1 | 122.9 | 122.6 | 123.0 | 123.0 | 123.0 | 123.4 | 124.4 | 124.3 | 124.5 | 124.4 |
| | | Non-lactating | 86.3 | 86.6 | 89.0 | 88.2 | 89.0 | 88.7 | 88.8 | 88.4 | 88.4 | 88.2 | 88.3 | 88.0 | 88.0 | 88.0 |
| | | Heifer: under 2 yr, over 6 mth | 63.4 | 64.7 | 66.9 | 67.8 | 68.0 | 68.0 | 68.1 | 68.0 | 68.0 | 68.0 | 68.1 | 68.0 | 68.0 | 68.0 |
| | | Heifer: 3 to 6 mth | 29.1 | 29.3 | 30.4 | 33.8 | 34.4 | 34.4 | 34.5 | 34.4 | 34.4 | 34.4 | 34.5 | 34.4 | 34.4 | 34.4 |
| Non-dairy cattle | Breeding | 2 yr and over | 68.3 | 68.5 | 70.7 | 70.7 | 70.7 | 70.7 | 70.9 | 70.7 | 70.7 | 70.7 | 70.9 | 70.7 | 70.7 | 70.7 |
| | | Under 2 yr, over 6 mth | 56.9 | 57.0 | 66.0 | 66.0 | 66.0 | 66.0 | 66.1 | 66.0 | 66.0 | 66.0 | 66.1 | 66.0 | 66.0 | 66.0 |
| | | 3 to 6 mth | 30.3 | 30.3 | 33.7 | 33.7 | 33.7 | 33.7 | 33.8 | 33.7 | 33.7 | 33.7 | 33.8 | 33.7 | 33.7 | 33.7 |
| | Fattening cattle | Wagyu (M): 1 yr and over | 72.1 | 72.3 | 72.1 | 72.1 | 68.5 | 68.5 | 68.7 | 68.5 | 68.5 | 68.5 | 68.7 | 68.5 | 68.5 | 68.5 |
| | | Wagyu (M): under 1 yr, over 6 mth | 58.8 | 59.0 | 58.8 | 58.8 | 61.7 | 61.7 | 61.8 | 61.7 | 61.7 | 61.7 | 61.8 | 61.7 | 61.7 | 61.7 |
| | | Wagyu (M): 3 to 6 mth | 33.0 | 33.1 | 33.0 | 33.0 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 | 29.4 |
| | | Wagyu (F): 1 yr and over | 51.0 | 51.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.3 | 57.2 | 57.2 | 57.2 | 57.3 | 57.2 | 57.2 | 57.2 |
| | | Wagyu (F): under 1 yr, over 6 mth | 43.1 | 43.2 | 53.7 | 53.7 | 53.7 | 53.7 | 53.8 | 53.7 | 53.7 | 53.7 | 53.8 | 53.7 | 53.7 | 53.7 |
| | | Wagyu (F): 3 to 6 mth | 26.7 | 26.8 | 30.9 | 30.9 | 30.9 | 30.9 | 31.0 | 30.9 | 30.9 | 30.9 | 31.0 | 30.9 | 30.9 | 30.9 |
| | | Dairy breed: over 6 mth | 74.2 | 74.4 | 74.2 | 74.2 | 74.2 | 74.2 | 74.4 | 74.2 | 74.2 | 74.2 | 74.4 | 74.2 | 74.2 | 74.2 |
| | | Dairy breed: 3 to 6 mth | 5.4 | 4.4 | 2.7 | 2.9 | 2.6 | 2.5 | 2.4 | 2.3 | 2.2 | 2.1 | 2.0 | 1.9 | 1.8 | 1.7 |
| | | Hybrid: over 6 mth | 73.0 | 73.2 | 73.0 | 73.0 | 73.0 | 73.0 | 73.2 | 73.0 | 73.0 | 73.0 | 73.2 | 73.0 | 73.0 | 73.0 |
| | | Hybrid: 3 to 6 mth | 42.1 | 42.2 | 42.1 | 42.1 | 42.1 | 42.1 | 42.2 | 42.1 | 42.1 | 42.1 | 42.2 | 42.1 | 42.1 | 42.1 |

- ***Activity Data***

For activity data of this source, the population of each type of cattle at 1 February in each year, recorded by the MAFF in its *Livestock Statistics* is used.

Table 5-10 Livestock population for cattle [1000 head]

| Type of cattle | | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | | Lactating (Multipara (3 and more)) | 510 | 467 | 447 | 391 | 392 | 374 | 364 | 347 | 334 | 324 | 317 | 308 | 309 | 308 |
| | | Lactating (Secundipara) | 260 | 250 | 241 | 229 | 208 | 196 | 197 | 203 | 202 | 191 | 194 | 193 | 194 | 193 |
| | | Lactating (Primipara) | 313 | 318 | 283 | 280 | 230 | 235 | 251 | 248 | 236 | 235 | 241 | 234 | 228 | 228 |
| | | Non-lactating | 332 | 299 | 249 | 231 | 200 | 195 | 200 | 194 | 185 | 184 | 185 | 179 | 176 | 171 |
| | | Heifer: under 2 yr, over 6 mth | 491 | 445 | 379 | 379 | 341 | 351 | 328 | 323 | 328 | 328 | 306 | 307 | 316 | 323 |
| | | Heifer: 3 to 6 mth | 109 | 99 | 84 | 84 | 76 | 78 | 73 | 72 | 73 | 73 | 68 | 68 | 70 | 72 |
| | | Heifer: under 3 mth | 55 | 49 | 42 | 42 | 38 | 39 | 36 | 36 | 36 | 36 | 34 | 34 | 35 | 36 |
| **Dairy cattle total** | | | **10,187** | **9,266** | **8,515** | **7,745** | **7,219** | **7,106** | **6,984** | **6,858** | **6,762** | **6,699** | **5,328** | **3,983** | **3,330** | **2,002** |
| Non-dairy cattle | Breeding | 2 yr and over | 612 | 591 | 555 | 536 | 588 | 575 | 560 | 541 | 520 | 505 | 511 | 511 | 517 | 528 |
| | | Under 2 yr, over 6 mth | 84 | 69 | 68 | 71 | 79 | 78 | 68 | 64 | 62 | 61 | 64 | 69 | 75 | 79 |
| | | 3 to 6 mth | 12 | 9 | 8 | 9 | 11 | 11 | 9 | 9 | 9 | 9 | 9 | 12 | 12 | 13 |
| | | Under 3 mth | 6 | 4 | 4 | 5 | 6 | 5 | 5 | 4 | 5 | 4 | 5 | 6 | 6 | 6 |
| | Fattening cattle | Wagyu (M): 1 yr and over | 368 | 412 | 385 | 374 | 425 | 409 | 405 | 396 | 381 | 368 | 371 | 374 | 379 | 380 |
| | | Wagyu (M): under 1 yr, over 6 mth | 125 | 133 | 114 | 119 | 132 | 127 | 123 | 116 | 115 | 112 | 109 | 110 | 116 | 120 |
| | | Wagyu (M): 3 to 6 mth | 83 | 89 | 76 | 80 | 88 | 85 | 82 | 77 | 77 | 75 | 72 | 73 | 77 | 80 |
| | | Wagyu (M): under 3 mth | 42 | 44 | 38 | 40 | 44 | 42 | 41 | 39 | 38 | 37 | 36 | 37 | 39 | 40 |
| | | Wagyu (F): 1 yr and over | 197 | 265 | 246 | 290 | 339 | 336 | 343 | 337 | 328 | 313 | 293 | 310 | 312 | 310 |
| | | Wagyu (F): under 1 yr, over 6 mth | 102 | 105 | 93 | 89 | 106 | 101 | 98 | 93 | 91 | 89 | 86 | 81 | 84 | 89 |
| | | Wagyu (F): 3 to 6 mth | 68 | 70 | 62 | 59 | 70 | 67 | 65 | 62 | 60 | 59 | 57 | 54 | 56 | 60 |
| | | Wagyu (F): under 3 mth | 34 | 35 | 31 | 30 | 35 | 34 | 33 | 31 | 30 | 30 | 29 | 27 | 28 | 30 |
| | | Dairy breed: over 6 mth | 665 | 541 | 333 | 351 | 316 | 309 | 294 | 282 | 276 | 259 | 249 | 235 | 221 | 206 |
| | | Dairy breed: 3 to 6 mth | 148 | 120 | 74 | 78 | 70 | 69 | 65 | 63 | 61 | 58 | 55 | 52 | 49 | 46 |
| | | Dairy breed: under 3 mth | 74 | 60 | 37 | 39 | 35 | 34 | 33 | 31 | 31 | 29 | 28 | 26 | 25 | 23 |
| | | Hybrid: over 6 mth | 140 | 267 | 511 | 438 | 410 | 362 | 374 | 373 | 363 | 362 | 379 | 391 | 388 | 371 |
| | | Hybrid: 3 to 6 mth | 31 | 59 | 114 | 97 | 91 | 81 | 83 | 83 | 81 | 80 | 84 | 87 | 86 | 82 |
| | | Hybrid: under 3 mth | 16 | 30 | 57 | 49 | 46 | 40 | 42 | 41 | 40 | 40 | 42 | 43 | 43 | 41 |
| **Non-dairy cattle total** | | | **2,805** | **2,901** | **2,806** | **2,755** | **2,892** | **2,763** | **2,723** | **2,642** | **2,567** | **2,489** | **2,479** | **2,499** | **2,515** | **2,503** |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainties for emission factors were calculated by finding the 95% confidence interval in accordance with the equation indicated in the section Emission Factors (Dairy cattle: -26% to +32%, non-dairy cattle: -40% to +49%). Populations of cattle (activity data) are decided by survey of total population in the *Livestock Statistics*, but standard error for cattle is not described. Therefore, the uncertainties for activity data were substituted by 1% of swine in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -26% to +32% for dairy cattle and -40% to +49% for non-dairy cattle.

- ***Time-series Consistency***

Emission factors were calculated consistently from FY1990 onward by the method mentioned in the section on Emission Factors. Activity data were used consistently from FY1990 onward from the data in the *Livestock Statistics*.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

It was pointed out by implementation of QA activity (QAWG) in FY2016 that ablactation of dairy cattle is at the age about three months, and $CH_4$ was actively generated from them. By taking into account it and discussions within the Committee for Greenhouse Gas Emission Estimation Methods, improvement

to estimate the emission from cattle at the age three and four months was conducted in 2017 submission inventory.

Comparison between results of Japan's estimation method and IPCC Tier 2 method was conducted. For Tier2 method, equations indicated in the *2006 IPCC Guidelines* (Vol.4, Chapter 10, Equation 10.3~10.16) are used, and estimation is conducted by classification described in Table 5-3 above. If data is available, Japan's data are used (e.g. values of Table 5-4 to Table 5-8 above and values of DE calculated from data described in the *Japan Feed Standards*. If not available, default data described in the *2006 IPCC Guidelines* are used (e.g. $Y_m$, $Cf_i$ and $C_{pregnancy}$).

As a result, for both dairy cattle and non-dairy cattle, considering the error of $CH_4$ conversion factor ($Y_m$ = 6.5%±1.0%), the emissions based on Japan's method were in the range calculated by IPCC Tier 2 method. Therefore, it is considered that there were no significant differences between emissions of Japan's method and IPCC Tier 2 method.

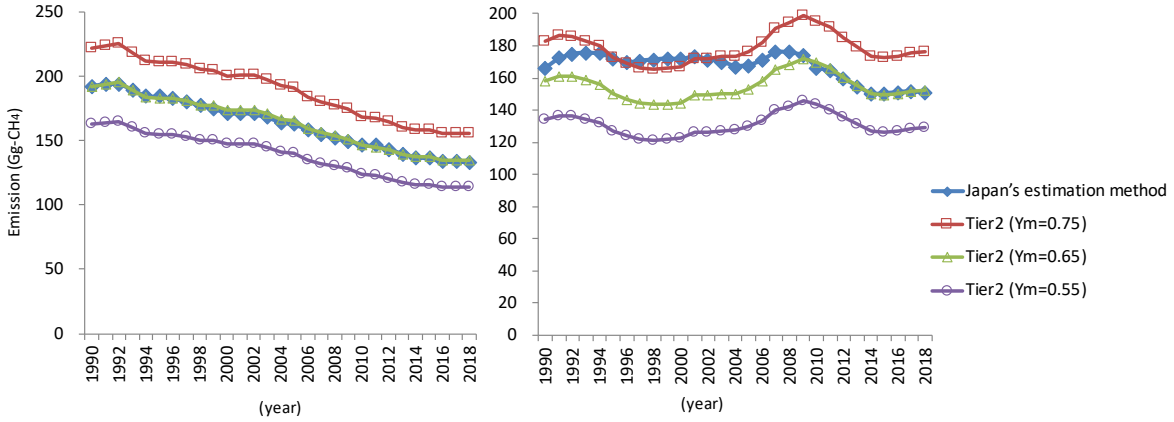


Figure 5-2 Comparison between results of Japan's estimation method and IPCC Tier 2 method (Left: Dairy cattle, Right: Non-dairy cattle)

### *e) Category-specific Recalculations*

Since the categorization of cattle types for calculation methods were revised for all years, emissions from all years were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

It is planned to discuss the development of the estimation method, which reflects the emissions reduction with technologies that suppress methane emission by controlling the rumen fermentation (such as by the addition of fatty acid calcium to feed) and by improving the feed efficiency with the total mixed ration (TMR) feeding.

## 5.2.2. Buffalo, Sheep, Goats, Horses & Swine (3.A.2., 3.A.3., 3.A.4.)

### *a) Category Description*

This section provides the estimation methods for $CH_4$ emissions from enteric fermentation in buffalo, sheep, goats, horses and swine.

### *b) Methodological Issues*

- ***Estimation Method***

$CH_4$ emissions were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines*.

$$E = EF \times A$$

| | |
|---|---|
| $E$ | : $CH_4$ emissions from enteric fermentation for each livestock [kg-$CH_4$] |
| $EF$ | : $CH_4$ emission factor for enteric fermentation of each livestock [kg-$CH_4$ /head] |
| $A$ | : Livestock population of each livestock [head] |

- ***Emission Factors***

The emission factors for swine have been established on the basis of results of research conducted in Japan. The emission factor for sheep, goats, horses and buffalo are the default values given in the *2006 IPCC Guidelines*.

Table 5-11 Emission factors for $CH_4$ associated with enteric fermentation in swine, sheep, goats, horses and buffalo

| Livestock species | $CH_4$ emission factor [kg/year/head] | Reference |
|---|---|---|
| Swine | 1.4 | Estimated from Saito (1988) |
| Sheep | 8 | *2006 IPCC Guidelines* |
| Goats | 5 | |
| Horses | 18.0 | |
| Buffalo | 55.0 | |

- ***Activity Data***

For activity data of sheep and goats, livestock population data given in the *Statistical Document of Livestock Breeding* offered by the Japan Livestock Industry Association before FY2009 and the *Status Report regarding Health Management for Livestock Feeding* by the MAFF from FY2010 onward are used. For swine, population at February 1st in each year recorded in the *Livestock Statistics* by the MAFF are used. The data in 2004, 2009 and 2014 were interpolated. For horses, livestock population given in the *Statistical Document of Horse* offered by the MAFF before FY2009 and the *Status Report regarding Health Management for Livestock Feeding* by the MAFF from FY2010 onward are used. For buffalo, livestock population given in the *Survey Result of Feeding Livestock and Poultry* by Okinawa Prefecture are used.

Table 5-12 Livestock population for buffalo, sheep, goats, swine, and horses [1000 heads]

| Livestock species | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sheep | 21 | 14 | 12 | 9 | 14 | 20 | 20 | 16 | 17 | 17 | 18 | 18 | 20 | 20 |
| Goats | 26 | 19 | 22 | 16 | 14 | 19 | 19 | 19 | 20 | 20 | 17 | 16 | 19 | 19 |
| Swine | 11,336 | 9,900 | 9,788 | 9,621 | 9,834 | 9,768 | 9,736 | 9,684 | 9,536 | 9,424 | 9,313 | 9,346 | 9,190 | 9,157 |
| Horses | 116 | 118 | 105 | 87 | 81 | 75 | 75 | 74 | 74 | 69 | 74 | 75 | 76 | 78 |
| Buffalo | 0.21 | 0.12 | 0.10 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 | 0.10 | 0.11 | 0.11 | 0.12 | 0.11 | 0.11 |

Note: For swine, data in 2009 and 2014 were interpolated.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

An uncertainty assessment was conducted by each livestock category. The uncertainties for emission factors for swine were decided by the Committee of GHG Emissions Estimation Methods. The uncertainties for emission factors of livestock other than swine were applied 50% of default data given

in the *2006 IPCC Guidelines*. As the uncertainty for activity data of swine, 1% of standard error for swine given in the *Livestock Statistic* was applied. For activity data of livestock other than swine, uncertainty was substituted by the value of broiler (9%) described in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -72% to +157% for swine and 51% for buffalo, sheep and goats and horses.

- ***Time-series Consistency***

For emission factors, same values were used consistently. For activity data, the data given in the Statistical Document of Livestock Breeding, the Livestock Statistics, the Statistical Document of Horse, the Survey Result of feeding Livestock and Poultry, and the Status Report regarding Health Management for Livestock Feeding are used, and consistent estimation method by each livestock are used since FY1990.

#### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

#### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

#### *f) Category-specific Planned Improvements*

There are no improvement plans.

### 5.2.3. Other Livestock (3.A.4.-)

Deer, alpaca, which are not reported above, but default emission factors are reported in the *2006 IPCC Guidelines*, are farmed as livestock in Japan. However, their population size is small, and the emissions from each of them are lower than 3,000t-$CO_2$ equivalent, which is the threshold to estimate in this GHG inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was reported as "NE" as considered insignificant (See Annex 5).

## 5.3. Manure Management (3.B.)

In livestock manure management process, $CH_4$ is generated by decomposing organic content in livestock manure with $CH_4$ fermentation. In addition, $CH_4$ generated by enteric fermentation dissolved in manure is released by aeration or agitation. In manure management, $N_2O$ is produced mainly by microorganism via nitrification and denitrification processes.

$CH_4$ and $N_2O$ emissions from manure management in FY2018 are 2,324 kt-$CO_2$ eq. and 3,922 kt-$CO_2$ eq., comprising 0.2% and 0.3% of total emissions (excluding LULUCF), respectively. The value represents a reduction by 25.5% for $CH_4$ and a decrease by 6.8% for $N_2O$ from FY1990. Main driver of the $CH_4$ emission decrease from FY1990 is a reduction of dairy cattle population, and of the $N_2O$ emission decrease from FY1990 is a reduction for indirect $N_2O$ emission by atmospheric deposition because of a reduction of livestock population.

Table 5-13 $CH_4$ and $N_2O$ emissions from livestock manure management

| Gas | Livestock species | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 3.B.1.- Dairy cattle | kt-$CH_4$ | 106.7 | 102.8 | 96.2 | 94.2 | 88.8 | 86.7 | 86.6 | 85.1 | 83.0 | 81.5 | 81.4 | 79.8 | 79.9 | 79.8 |
| | 3.B.1.- Non-dairy cattle | | 4.3 | 4.5 | 4.5 | 5.2 | 6.2 | 6.0 | 5.9 | 5.7 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 |
| | 3.B.2. Sheep | | 0.006 | 0.004 | 0.003 | 0.002 | 0.004 | 0.006 | 0.006 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.006 | 0.006 |
| | 3.B.3. Swine | | 11.1 | 9.7 | 9.1 | 6.6 | 5.1 | 5.0 | 5.0 | 5.0 | 4.9 | 4.9 | 4.8 | 4.8 | 4.7 | 4.7 |
| | 3.B.4.- Buffalo | | 0.0004 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| | 3.B.4.- Goats | | 0.005 | 0.004 | 0.004 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.003 | 0.003 | 0.004 | 0.004 |
| | 3.B.4.- Horses | | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | 3.B.4.- Poultry | | 2.3 | 2.2 | 2.1 | 2.4 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 |
| | 3.B.4.- Rabbit | | 0.001 | 0.001 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | 3.B.4.- Mink | | 0.105 | 0.007 | 0.004 | 0.0004 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| | Total | kt-$CH_4$ | 124.8 | 119.5 | 112.2 | 108.7 | 102.9 | 100.5 | 100.3 | 98.6 | 96.2 | 94.6 | 94.5 | 92.9 | 93.0 | 92.9 |
| | | kt-$CO_2$eq | 3,121 | 2,988 | 2,804 | 2,717 | 2,573 | 2,513 | 2,508 | 2,465 | 2,406 | 2,364 | 2,362 | 2,321 | 2,324 | 2,324 |
| $N_2O$ | 3.B.1.- Dairy cattle | kt-$N_2O$ | 2.1 | 2.1 | 2.1 | 2.4 | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |
| | 3.B.1.- Non-dairy cattle | | 2.3 | 2.4 | 2.4 | 2.5 | 2.8 | 2.7 | 2.6 | 2.6 | 2.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| | 3.B.2. Sheep | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 3.B.3. Swine | | 3.7 | 3.2 | 3.2 | 3.8 | 4.4 | 4.5 | 4.5 | 4.4 | 4.3 | 4.2 | 4.1 | 4.1 | 4.3 | 4.2 |
| | 3.B.4.- Buffalo | | 0.00012 | 0.00007 | 0.00006 | 0.00005 | 0.00005 | 0.00004 | 0.00005 | 0.00005 | 0.00005 | 0.00006 | 0.00006 | 0.00007 | 0.00006 | 0.00006 |
| | 3.B.4.- Goats | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 3.B.4.- Horses | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 3.B.4.- Poultry | | 1.4 | 1.4 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 |
| | 3.B.4.- Rabbit | | 0.004 | 0.004 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| | 3.B.4.- Mink | | 0.0223 | 0.0016 | 0.0008 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | 3.B.5. Indirect emissions | | 4.6 | 4.3 | 3.9 | 3.5 | 3.2 | 3.1 | 3.0 | 3.0 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 |
| | Total | kt-$N_2O$ | 14.1 | 13.4 | 12.9 | 13.4 | 14.2 | 13.9 | 13.7 | 13.5 | 13.2 | 13.0 | 12.9 | 12.9 | 13.2 | 13.2 |
| | | kt-$CO_2$eq | 4,208 | 3,983 | 3,850 | 3,994 | 4,218 | 4,136 | 4,093 | 4,024 | 3,927 | 3,865 | 3,849 | 3,847 | 3,926 | 3,922 |
| Total of all gases | | kt-$CO_2$eq | 7,329 | 6,971 | 6,654 | 6,711 | 6,791 | 6,649 | 6,601 | 6,489 | 6,334 | 6,229 | 6,210 | 6,169 | 6,250 | 6,245 |

### 5.3.1. Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.)

#### *a) Category Description*

This section provides the estimation methods for $CH_4$ and $N_2O$ emissions for manure management from cattle (dairy cattle and non-dairy cattle), swine and poultry (hen and broilers). For grazing animal, $CH_4$ emissions were reported in this category and $N_2O$ emissions were reported in "3.D.a.3. Urine and dung deposited by grazing animals".

#### *b) Methodological Issues*

- ***Estimation Method***

$CH_4$ emissions associated with the manure management were calculated by multiplying the amount of organic matter contained in manure from each type of livestock by the emission factor for each type of treatment method.

$$E_{CH4} = \sum \left( EF_{CH4-n} \times A_{CH4-n} \right)$$

$E_{CH4\text{-}n}$ : $CH_4$ emissions associated with the management of manure excreted by cattle, swine and poultry [kt-$CH_4$]

$EF_{CH4\text{-}n}$ : Emission factor for treatment method *n* [g-$CH_4$/g-organic matter]

$A_{CH4\text{-}n}$ : Amount of organic matter contained in manure treated by method *n* [kt-organic matter]

$N_2O$ emissions were calculated by multiplying the amount of nitrogen contained in manure of each type of animal by the emission factor for each type of treatment method.

$$E_{N2O} = \sum (EF_{N2O-n} \times A_{N2O-n}) \times 44/28$$

$E_{N2O}$ : $N_2O$ emission associated with management of manure excreted by cattle, swine and poultry [kt-$N_2O$]
$EF_{N2O-n}$ : Emission factor for treatment method *n* [g-$N_2O$-N/g-N]
$A_{N2O-n}$ : Amount of nitrogen contained in manure treated by method *n* [kt-N]

- ***Emission Factors***

Emission factors for $CH_4$ and $N_2O$ associated with Animal Waste Management System (hereafter, AWMS) have been established for each treating method of for each type of livestock on the basis of the results of research by actual measurements carried out in Japan after reviewing its validity in accordance with the decision tree shown in Figure 5-3, Table 5-14 and Table 5-15 show those emission factors.

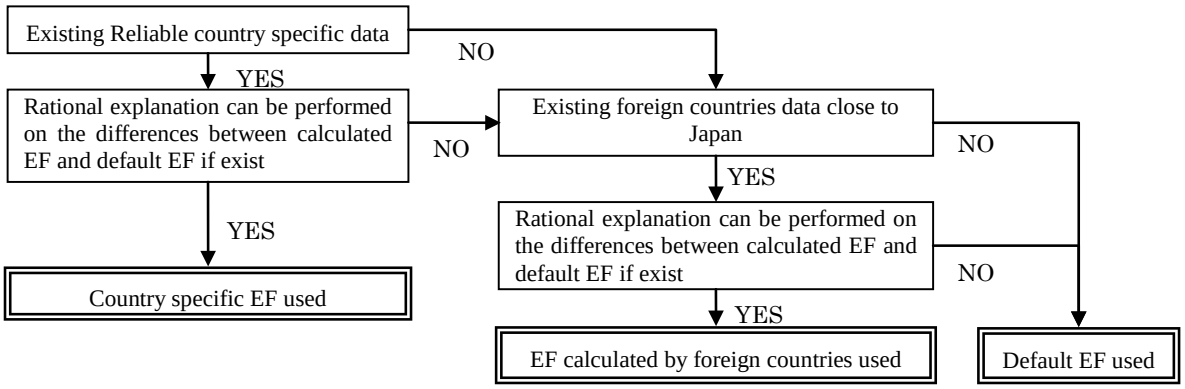


Figure 5-3 Decision tree for determination of EF

Emission factors for $CH_4$ indicated by "D (default value)" in Table 5-14 and Table 5-15 were calculated by following equation with *Bo* (maximum methane producing capacity) (Dairy cattle: 0.13, Non-dairy cattle: 0.10, Swine: 0.29) and MCF (methane conversion factor, Table 5-16) in "Asia" indicated in the *2006 IPCC Guidelines*. Since MCF for pit storage and composting are described by each temperature in the *2006 IPCC Guidelines*, MCF values are calculated with weighted average by regional livestock population and regional MCF decided by the average temperature in each region. Average temperature by region used for development of MCF values is shown in the following Table 5-17. These temperatures were established by using the average temperatures in each municipality where livestock are mainly housed.

For country-specific emission factors, MCF values are not established because emission factors are estimated directly from results of actual measurement data.

$$EF_{CH4-n} = Bo \times 0.67 \times MCF$$

$EF_{CH4-n}$ : Emission factor for treatment method *n* [g-$CH_4$/g-organic matter]
*Bo* : Maximum methane producing capacity [$m^3$-$CH_4$/kg-organic matter]
*0.67* : Conversion factor from volume to weight [kg-$CH_4$/$m^3$-$CH_4$]
*MCF* : Methane conversion factor [%]

For $CH_4$ emission factors of "Pit storage" and "Methane fermentation" for dairy cattle, regional emission factors of 9 regions in Japan were established by using air temperature as a parameter, and based on actual measurement data on pit storage system and methane fermentation system by using measurement technique such as floating chamber method (*The Report of Project on Survey and Investigation for Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within*

*the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2011*, 2012.). Therefore, integrated emission factors for all Japan, which are weighted averages of the regional emission factors with dairy cattle population in each region (described in the *Livestock Statistics*), are used (see Table 5-18). Emission factors in latest year are lower than 1990 because ratio of livestock population in Hokkaido region, where temperature is low and emission factor is low, has gradually increased (1990: 42% and 2018: 60%).

For "Sun drying" for hen and broiler, emission factors were established on the basis of actual measurement data at poultry manure management facility with drying system (Poultry manure is dried out with agitation on conveyer belt machinery in tunnel ventilation barn). Detail method is described in the paper by Tsuchiya et al. (2014).

For "Composting (feces)" and "Composting (feces and urine mixed)" for swine, emission factor is referred to *Project Report of Survey on Prevention of Global Warming in the Agriculture, Forest and Fisheries Sector within the Environment and Biomass Comprehensive Strategy Promotion Project in FY2008* (Nationwide Survey) (Hereinafter called "*Report of Survey Project in FY2008* (Nationwide Survey)").

For emission factors of Composting (feces) for hen and broiler, emission factor for swine is applied by expert judgment.

For "Piling", the most major manure management practice in Japan, Osada et al. (2005) measured actual $CH_4$ and $N_2O$ emissions by using chamber system covering compost heap, and Japan's emission factors for dairy cattle, non- dairy cattle and swine were set from these data.

For "Piling" of hen and broiler, emission factors were established on the basis of actual GHG measurement data using chamber, which covers piled up manure, at piling composting management facility in three areas of Japan. Detail method is described in the report by MAFF (2014).

For "Incineration", emission factor written in *GHGs emissions control in livestock industry Summary* (Japan Livestock Technology Association, 2002) is used.

For "Purification" for cattle, Shiraishi et al. (2017) measured actual $CH_4$ and $N_2O$ emissions for urine and the mixture of feces and urine of dairy cattle from a purification plant. Emission factors based on the result of this study were applied to the purification of urine and the mixture of feces and urine from dairy and non-dairy cattle.

For "Purification" for swine, emission factor is from *Project on Survey and Investigation for Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2012* (MAFF 2013) (Hereinafter called ″*the Report of Project* (MAFF 2013)").

For "Pasture, range and paddock" of dairy cattle and non-dairy cattle, emission factors were established by actual measurement data of collected manure set in chamber in grazing area. Detail method is described in the paper by Mori et al. (2015).

Table 5-14 $CH_4$ Emission factors for each method of treating manure from cattle, swine, hen & broiler

[g-$CH_4$/g-organic matter]

| Treating method | Dairy cattle | | Non-dairy cattle | | Swine | | Hen, broiler | |
|---|---|---|---|---|---|---|---|---|
| Pit storage | Table 5-18 | J[9)] | 1.6 % | D[1)] | 4.9 % | D[1)] | - | |
| Sun drying | 0.20 % | J[3)] | 0.20 % | J[3)] | 0.20 % | J[3)] | 0.14 % | J[11)] |
| Thermal drying | 0 % | | | | | | | Z[4)] |
| Composting (feces) | 0.052 % | D[1)] | 0.054 % | D[1)] | 0.080 % | J[8)] | 0.080% | Sw |
| Piling | 3.8 % | J[5)] | 0.13 % | J[5)] | 0.16 % | J[5)] | Hen: 0.13 %, Broiler 0.02 % | J[13)] |
| Incineration | 0.4 % | | | | | | | O[4),)] |
| Composting (urine) | 0.052 % | D[1)] | 0.054 % | D[1)] | 0.097 % | D[1)] | - | |
| Composting (feces and urine mixed) | | | | | 0.080 % | J[8)] | | |
| Purification | 0.3% | | | J[14)] | 0.91 % | J[12)] | | |
| Methane fermentation (feces) | 3.8% | Pl | 0.13% | Pl | 0.16% | Pl | Hen: 0.13 %, Broiler 0.02 % | Pl |
| Methane fermentation (feces and urine mixed) | Table 5-18 | J[9)] | 3.5% | DC | 3.6% | DC | - | |
| Pasture, range and paddock | 0.076% | | | J[10)] | - | | 0.14% | SD |
| Other (feces) | 3.8% | M | 0.4% | M | 0.4% | M | 0.4% | M |
| Other (feces and urine mixed) | 3.8% | M | 3.5% | M | 4.9% | M | - | |

Note: See notation and sources of Table 5-15 below.

Table 5-15 $N_2O$ Emission factors for each method of treating manure from cattle, swine hen & broiler

[g-$N_2O$-N/g-N]

| Treating method | Dairy cattle | | Non-dairy cattle | | Swine | | Hen, Broiler | |
|---|---|---|---|---|---|---|---|---|
| Pit storage | 0.02% | J[9)] | 0 % | | | D[1)] | - | |
| Sun drying | 2.0 % | | | | | D[1)] | 0.33% | J[11)] |
| Thermal drying | 2.0 % | | | | | | | D[1)] |
| Composting (feces) | 0.25 % | | | J[6)] | 0.16 % | J[8)] | 0.16 % | Sw |
| Piling | 2.4 % | J[5)] | 1.60 % | J[5)] | 2.50 % | J[5)] | Hen: 0.54%, Broiler 0.08% | J[13)] |
| Incineration | 0.1 % | | | | | | | O[4)] |
| Composting (urine) | 0.6% | | | | | D[1] | - | |
| Composting (feces and urine mixed) | 0.6% | D[1)] | 0.25% | J[6)] | 0.16% | J[8)] | | |
| Purification | 2.88 % | | | J[74] | 2.87% | J[12] | - | |
| Methane fermentation (feces) | 2.4 % | Pl | 1.60 % | Pl | 2.5 % | Pl | Hen: 0.54%, Broiler 0.08% | Pl |
| Methane fermentation (feces and urine mixed) | 0.15% | J[9)] | 0.15% | | | DC | - | |
| Pasture, range and paddock | 0.684% | | | J[10)] | - | | 0.33% | SD |
| Other (feces) | 2.4% | M | 2.0% | M | 2.5% | M | 2.0% | M |
| Other (feces and urine mixed) | 2.88% | M | 2.88% | M | 2.87% | M | - | |

Note: Manure excreted by hen and broiler was categorized as feces since it contains a very small amount of urine.

D: Default value of the *2006 IPCC Guidelines*
J: Established by data of Japan
O: Established by data of other countries
Z: No emission occurrence because of the mechanism
Pl: Application of the value of "Piling"
SD: Application for the value of "Sun drying"
Sw: Application for the value of "Swine"
DC: Estimated from regional EFs of "Dairy cattle" ($N_2O$: Application for the value of "Dairy cattle")
M: Application of the maximum values of the treating methods for "feces" or "feces and urine mixed"

Reference for Table 5-14 and Table 5-15:
1: *2006 IPCC Guidelines*
2: Ishibashi et al., (2003)
3: Japan Livestock Technology Association, (2002)
4: Osada et al., (2005)
5: Osada et al., (2000)
6: Osada (2003)
7: Report of Survey Project in FY2008 (Nationwide Survey).
8: MAFF, *the Report of Project on Survey and Investigation in FY2011*, (2012)
9: Mori (2015)
10: Tsuchiya (2014)
11: MAFF, *the Report of Project on Survey and Investigation in FY2012*, (2013)
12: MAFF, *the Report of Project on Survey and Investigation in FY2013*, (2014)
13: Shiraishi et al., (2017)

Table 5-16 MCFs (methane conversion factor) used for calculation of default emission factors

| Treating method | MCF | System in the 2006 IPCC Guidelines |
|---|---|---|
| Pit storage (non-dairy cattle) | 24% | Liquid/ Slurry- Without natural crust (calculated by weighted average) |
| Pit storage (swine) | 25% | Liquid/ Slurry- Without natural crust (calculated by weighted average) |
| Composting (dairy cattle) | 0.6% | Composting - In-vessel (calculated by weighted average) |
| Composting (non-dairy cattle) | 0.8% | Composting - In-vessel (calculated by weighted average) |

Note: For other treating method than the above, MCF values are not established because country-specific emission factors are used.
Reference: *2006 IPCC Guidelines*, Vol.4 Table10.17

Table 5-17 Average temperature by region used for development of MCF values [°C]

| Region | Dairy cattle | Non-dairy cattle | Swine |
|---|---|---|---|
| Hokkaido | 5.3 | 6.2 | 7.4 |
| Tohoku | 8.5 | 11.0 | 10.1 |
| Kanto | 11.9 | 12.1 | 14.4 |
| Hokuriku | 14.0 | 14.0 | 12.7 |
| Tokai | 16.0 | 14.3 | 15.0 |
| Kinki | 15.9 | 16.0 | 13.5 |
| Chugoku | 14.6 | 15.0 | 14.4 |
| Shikoku | 16.3 | 16.1 | 15.5 |
| Kyusyu and Okinawa | 15.8 | 16.5 | 16.3 |

Table 5-18 $CH_4$ Emission factors for "Pit storage" and "Methane fermentation" for dairy cattle [g-$CH_4$/ g-organic matter]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pit storage | 2.47% | 2.44% | 2.42% | 2.40% | 2.38% | 2.37% | 2.37% | 2.37% | 2.37% | 2.37% | 2.36% | 2.36% | 2.36% | 2.35% |
| Methane fermentation | 3.22% | 3.17% | 3.14% | 3.11% | 3.07% | 3.06% | 3.06% | 3.06% | 3.06% | 3.05% | 3.05% | 3.04% | 3.03% | 3.03% |

Note: These figures are weighted averages of regional emission factors from *the Report of Project in FY2011*, (MAFF 2012) with dairy cattle population in each region.

- ***Activity Data***

The values used for the activity data are estimates of the amount of organic matter and the amount of nitrogen excreted annually by various type of livestock, respectively.

$$A_{CH4\text{-}n} = P \times Ex \times Day \times Org \times Mix_n \times MS_n / 1000$$

$$A_{N2O\text{-}n} = P \times Nex \times Day \times Mix_n \times MS_n / 1000$$

$A_{CH4\text{-}n}$ : Amount of organic matter excreted [kt]
$A_{N2O\text{-}n}$ : Amount of nitrogen excreted by each type of livestock [kt]
$P$ : Livestock population [1000 head]
$Ex$ : Amount of feces and urine excreted per head per day [kg/head/day]
$Org$ : Organic matter content in feces and urine [%]
$Nex$ : Nitrogen content of feces and urine excreted per head per day [kg-N/head/day]
$Day$ : Days in a year [day]
$Mix_n$ : Proportion of feces and urine separated [%]

$MS_n$ : Share of each treating method [%]

Total annual amount of organic matter by livestock was calculated by multiplying the population of each type of animal by the amount of manure per head by the proportion of organic matter in feces or urine. Total nitrogen amount was calculated by multiplying the population of each type of animal by the nitrogen content amount of feces or urine excreted per head (Table 5-25, Table 5-26, Table 5-27, Table 5-28). The amount of organic matter and nitrogen were allocated to each category of manure management by multiplying the total amount by the percentage of manure treated separately and the percentage per treatment method.

For livestock population, same references indicated in '3.A. Enteric Fermentation' for dairy cattle non-dairy cattle and swine are used.

Livestock population for hen described in the *Livestock Statistics* and *Statistics on Livestock Products Marketing* are used (see the following Table 5-19) but the data in 2004, 2009 and 2014 are interpolated. For broiler from 1990 to 2008, livestock population described in the *Statistics on Livestock Products Marketing* are used. For 2009 onwards, as livestock population are not surveyed in the statistics, livestock population are estimated by using the number of shipment of broiler in the same statistics (see the following Table 5-20). 5-year average (0.170) from FY2004 to FY2008 of "livestock population" / "annual number of shipment", is multiplied by the number of shipment of each year in particular. In addition, days of feeding to shipment are shorter than past. Therefore, 0.919 (=49days/53.3days), ratio of feeding days until shipment of present (*Planning for Breeding Improvement of Poultry* (2015) and past (*Questionnaire Survey on Current Feeding Status for Broiler* (2008)) is multiplied.

Amount of feces per head per day for dairy cattle is calculated by using the multiple regression equation which is written in *Japanese Feed Standard* and has two explanatory variables, DMI and Natural Detergent Fiber of organic matter (%) (NDFom). Amount of urine excreted per head per day for dairy cattle is calculated by the multiple regression equation which is written in Otani et al. (2010) and has three explanatory variables, Nitrogen Intake (NI), potassium Intake (KI) and milk yield. DMI and milk yield are used same data described in '3.A. Enteric Fermentation'. NDFom was set at 35% referred to *Japanese Feed Standard*. NI was calculated by dividing Crude Protein (CP) by 6.25. CP were calculated following with formulas in *Japanese Feed Standard* with DMI, milk yield, weight, fat content in milk and daily gain which are same data in '3.A. Enteric Fermentation'. The preferable CP content in feed dry matter is 12% and over for the most effective digestion of feed and fermentation by microorganism in rumen, described in *Japanese Feed Standard*. Therefore, CP values are adjusted to be 12% of DMI when the calculated CP was lower than 12% of DMI. KI was set with referring to Kume et al (2010) (Table 5-21).

Nitrogen contents in excretion per head per day for dairy cattle, for both in feces and urine, were calculated with the regression equation in Choumei et al. (2006) (Table 5-21). DMI and CP used in calculation for nitrogen contents are common to feces and urine.

For non-dairy cattle also, nitrogen contents in excretion per head per day were calculated with the regression equation in Choumei et al. (2006) for both feces and urine (Table 5-22). Nitrogen content in feces is calculated in formula with a variable of DMI and nitrogen content in urine is calculated with formula with a variable CP. DMI is from Table 5-8 described above. CP is calculated with formula in Table 5-23. CP is adjusted to be 12% of DMI as same as in case of dairy cattle.

Nitrogen contents in excretion from swine is calculated by subtracting amount of nitrogen accumulated

in body from amount of nitrogen intake for each body weight class written in *Japanese feed standard* according to the result of consideration in the Agriculture Breakout Group on the Committee of GHG Emission Estimation Methods. Nitrogen contents in excretion per day are calculated by dividing the total nitrogen of every class by total days of raising. Nitrogen contents in feces and urine per day are calculated by multiplying the ratio of them to nitrogen contents in excretion per day (Table 5-24). Nitrogen intake is calculated using the amount and CP contents of feed intake. Categorization for calculation is for 2 types as growing-finishing pig and breeding pig.

For "Percentage of manure management by type of animal" and "Proportion of separated and mixed treatment of manure, by type of livestock", there are two results of surveys in 1997, *GHGs emissions control in livestock industry Summary* (2002) and 2009, *Survey of current status for livestock manure management system* (MAFF 2009). The 1997 survey is data before enforcement of the "Act on the Appropriate Treatment and Promotion of Utilization of Livestock Manure" which has been in force since 1999 and prohibits inappropriate manure management and induced changes of percentage of manure management. Therefore, the 1997 survey results were applied before 1999 and the 2009 survey results were applied after 2009. For 2000 to 2008, interpolation was used (Table 5-29, Table 5-30 and Table 5-31)).

Table 5-19 Livestock population for hen [1000 heads]

| Livestock species | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hen | 188,786 | 190,634 | 186,202 | 180,697 | 179,770 | 178,546 | 177,607 | 174,784 | 174,806 | 175,270 | 175,733 | 178,900 | 184,350 | 184,917 |

Note: Data of non-surveyed year (in 2009 and 2014) are interpolated.
Reference: *The Livestock Statistics*, *The Statistics on Livestock Products Marketing*

Table 5-20 Livestock population for broiler [1000 heads]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Livestock Population in statistics (broiler) | 142,740 | 118,123 | 106,311 | 103,687 | | | | | | | | | | |
| Number of Shipment (broiler) | | | | 606,898 | 634,692 | 633,799 | 617,176 | 649,629 | 653,999 | 661,030 | 666,859 | 677,332 | 685,105 | 700,571 |
| Livestock Population used in this inventory (broiler) | 142,740 | 118,123 | 106,311 | 103,687 | 99,053 | 98,913 | 96,319 | 101,384 | 102,066 | 103,163 | 104,073 | 105,707 | 106,920 | 109,334 |

Note: From 1990 to 2008, livestock population data in the statistics are used. In 2009 onwards, estimated data by using the number of shipment are used.
Reference: MAFF, *Statistics on Livestock Products Marketing*

Table 5-21 Equation to estimate amount of excretion and nitrogen content in excretion for dairy cattle

| | Equation |
|---|---|
| Amount of feces[1)] | $F = -8.4753 + 1.8657 \times DMI + 0.4948 \times NDFom$ ($NDFom$ : 35%) |
| Amount of urine[2)] | $U = -2.2870 + 0.0231 \times NI + 0.0581 \times KI - 0.3350 \times MILK$ ($NI = CP / 6.25$) |
| Potassium Intake[3)] | $KI$ = : 380g/day (Primipara) : 350g/day (2nd calving and over)<br>: 250g/day (Non-lactating) : 220g/day (Heifer: over 6 months)<br>: 100g/day (Heifer: 3 to 6 months) |
| Nitrogen content in feces[4)] | $N_f = 5.01 \times DMI^{1.2}$ (Lactating)<br>$N_f = 4.97 \times DMI^{1.21}$ (Non-lactating and Heifer) |
| Nitrogen content in urine[4)] | $N_u = 16.57 \times (CP / 1000 / DMI) \times 100 - 138.6$ (Lactating)<br>$N_u = 0.24 \times (CP / 6.25)^{1.14}$ (Non-lactating and Heifer) |

Note: See notation and sources of Table 5-23 below.

Table 5-22 Equation to estimate amount of nitrogen content in excretion for non-dairy cattle

| | Equation |
|---|---|
| Nitrogen content in feces[4)] | $N_f = 7.22 \times DMI^{1.00}$ (for dairy breeds)<br>$N_f = 4.97 \times DMI^{1.21}$ (for other non-dairy cattle) |
| Nitrogen content in urine[4)] | $N_u = -14.96 + 0.60 \times NI$ (for dairy breeds)<br>$N_u + N_m = 0.24 \times NI^{1.14}$ (for other non-dairy cattle) ($N_m = 0$, $NI = CP / 6.25$) |

Note: See notation and sources of Table 5-23 below.

Table 5-23 Equation to estimate crude protein (*CP*)[1)]

| | Equation |
|---|---|
| Lactating | $CP = (CP1 + CP2) \times CFA$<br>$CP1 = 2.71 \times W^{0.75} / 0.6 \times$ Correction factor by calving<br>Correction factor by calving: primipara:1.3, 2nd calving:1.15, over 3rd calving:1<br>$CP2 = (26.6 + 5.3 \times \mathrm{FAT}) \times MILK / 0.65$<br>$CFA = 1 + MILK / 15 \times 0.04$ |
| Non-lactating | $CP = 2.71 \times W^{0.75} / 0.6$ |
| Heifer | $CP = NP / EP$<br>$NP = FN \times 6.25 + UN \times 6.25 + SP + RP$<br>$FN = 30 \times DMI / 6.25$<br>$UN = 2.75 \times W^{0.5} / 6.25$<br>$SP = 0.2 \times W^{0.6}$<br>$RP = 10 \times DG \times 23.5505 \times W^{-0.0645}$<br>$EP = 0.51$ (for body weight 120kg and over) 0.63 (for body weight 67−119kg) |
| Non-dairy cattle (Before 2008) | $CP = NP / EP$<br>$NP = FN \times 6.25 + UN \times 6.25 + SP + RP$<br>$FN = 4.80 \times DMI$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$<br>$RP = DG \times (235 - 0.195 \times W)$ (Dairy breeds)<br>$RP = DG \times (235 - 0.234 \times W)$ (Hybrid and Wagyu (male))<br>$RP = DG \times (235 - 0.293 \times W)$ (Wagyu (female) and Breeding cows (before 49 months old)<br>$RP = 0$ (Breeding cows (after 49 months old)<br>$EP$ : 0.51 (for body weight 150kg and over) : 0.56 (for body weight 101−149kg) : 0.66 (for body weight 51−100kg)<br><br>(Breeding cows, additional *CP* for pregnant while last 2 months of pregnant)<br>$CP = DCPR / 0.75$<br>$DCPR = TP / 38.5 \times 30.0 / 63 / 0.6 \times 1000 + FN \times 6.25$<br>$TP = TP(t) - TP(t- 63)$<br>$TP(t) = (1.486 \times 10^{-4} \times t^3 - 4.247 \times 10^{-2} \times t^2 + 3.173 \times t - 0.328) \times$<br>$(-0.323 \times 10^{-6} \times t^3 + 3.000 \times 10^{-4} \times t^2 - 9.430 \times 10^{-2} \times t + 11.263) \times 6.25$<br>$FN = 4.80 \times 3.21 / 2.7$<br><br>(Breeding cows, additional *CP* for lactating while 5 months of lactation)<br>$CP = DCPR / 0.65$<br>$DCPR = 53 \times MILK$ |
| Non-dairy cattle (After 2008) | $CP = (MCP / 0.85 + MPu / 0.80) / 1.15$<br>$MCP = 100 \times TDN$ (except Breeding cows) $MCP = 130 \times TDN$ (Breeding cows)<br>$MPu = MPR - MPd$<br>$MPR = MPm + MPg$<br>$MPd = 0.8 \times 0.8 \times MCP$<br>$MPm = (FN \times 6.25 + UN \times 6.25 + SP) / 0.67$<br>$FN = 4.80 \times DMI - Adj$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$<br>$MPg = RP / 0.492$<br>$RP = DG \times (235 - 0.195 \times W)$ (Dairy breeds)<br>$RP = DG \times (235 - 0.234 \times W)$ (Hybrid and Wagyu (male))<br>$RP = DG \times (235 - 0.293 \times W)$ (Wagyu (female) and Breeding cows (before 49 months old)<br>$RP = 0$ (Breeding cows (after 49 months old))<br>$Adj = (100 \times TDN \times 0.64 \times 0.25 \times 0.5) / 6.25$<br>$Adj = (130 \times TDN \times 0.64 \times 0.25 \times 0.5) / 6.25$ (Breeding cows)<br><br>(Dairy breeds under 200kg of body weight)<br>$CP = NP / EP$<br>$NP = FN \times 6.25 + UN \times 6.25 + SP + RP$<br>$FN = 4.80 \times DMI$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$<br>$RP = DG \times (235 - 0.234 \times W)$<br>$EP$ : 0.51<br><br>(Breeding cows, additional *CP* for pregnant at last 2 months of pregnant) |

| | |
|---|---|
| | $MPc = PP(t) / 0.65$<br>$PP(t) = BW / 40 \times TP(t) \times 34.37e^{-0.00262t}$<br>$TP(t) = 10^{\ 3.707-5.698e^{\wedge}0.0022t}$<br><br>（Breeding cows, additional *CP* for lactating at 5 months of lactation)<br>$MP\ell = (38 \times MILK) / 0.65$ |

Note: for Table 5-21, Table 5-22 and Table 5-23

*F*: Feces weight (kg/day), *DMI*: Dry matter intake (kg/day), *NDFom*: Natural detergent fiber of organic matter (%), *U*: Urine weight (kg/day), *NI*: Nitrogen intake (kg/day), *KI*: Potassium intake (kg/day), *MILK*: Milk yield (kg/day), $N_f$: Nitrogen content in feces (kg/day), *Nu*: Nitrogen content in urine (kg/day), *CP*: Crude protein (g), *CFA*: Correction factor, *W*: weight (kg), *FAT*: Fat content in milk (%), *NP*: Net protein for preservation and gain for growth, *EP* : Conversion efficiency of crude protein to net protein on growth, *FN*: metabolic fecal nitrogen for growth after ablactation (g/day), *UN*: Endogenous urinary nitrogen (g/day), *SP*: Shedding skin protein (g/day), *RP*: protein accumulation associate with gain (g/day), *DG*: Daily gain (kg/day), *DCPR*: Digestible crude protein requirement, *PP(t)*: Protein accumulation in pregnant uterus at (t) days after conception, *t*: Days after conception, *MCP*: Microbial crude protein (g/day), *TP(t)*: Protein accumulation in pregnant uterus until (t) days after conception, *BW:* Birth weight, *MPu*: Undigestible crude protein from feed (g/day), *MPd*: Metabolic protein delivered by microbial, *MPm*: Metabolic protein requirement for maintenance, *MPg*: Metabolic protein requirement for growth, *MPc*: Metabolic protein requirement for conception (g/day), *TDN*: Total digestible nutrients, *MPR*: Metabolic protein requirement (g/day), *MPℓ*: Metabolic protein for lactation (g/day), *Adj*: adjustment value

Reference:

1) *Japanese Feed Standard*
2) Otani et al., (2010)
3) Kume et al., (2010)
4) Chomei et al., (2006)

Table 5-24 Equation to estimate amount of nitrogen content in excretion for swine

| | Equation |
|---|---|
| Nitrogen content in feces | $N_f = N_{out} \times f$ |
| Nitrogen content in urine | $N_u = N_{out} \times u$ |
| Nitrogen content in excretion | $N_{out} = N_{in} - N_{PR}$<br>$N_{out} = N_{in} - N_M$ (Lactating sow)<br>$N_{in} = (CP \times F_{intake}) / 6.25$<br>$F_{intake} = F_{demand} \times Day$ |

Note:

$N_f$ : Nitrogen content in feces (kg/day), *Nu*: Nitrogen content in urine (kg/day), $f$ : proportion of feces, $u$ : proportion of urine, $N_{out}$ : Nitrogen content in excretion (g), $N_{in}$ : Nitrogen content in feed intake (g), $N_{PR}$ : Nitrogen amount in accumulated protein in body (g), $N_M$ : Nitrogen amount in milk, CP : crude protein contents in feed intake (%), $F_{intake}$ : Feed intake (kg), $F_{demand}$ : Daily demand of feed intake (kg / day)

Table 5-25 Amount of feces and urine excreted (*Ex*) for non-dairy cattle and swine

| Type of livestock | | Amount of feces and urine excreted [kg/head/day] | |
|---|---|---|---|
| | | Feces | Urine |
| Non-dairy cattle | Under two yr. | 17.8 | 6.5 |
| | Over two yr. | 20.0 | 6.7 |
| | Dairy breed | 18.0 | 7.2 |
| Swine | Growing-finishing | 2.1 | 3.8 |
| | Breeding | 3.3 | 7.0 |

Reference: Tsuiki et al., (1997)

Table 5-26 Amount of feces and urine from dairy cattle (*Ex*) and nitrogen content by livestocks (*Nex*)

| Item | | | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amount of excretion | Dairy Cattle | Feces | Lactating (Multipara (3 and more)) | kg/head/day | 41.5 | 43.1 | 44.5 | 46.0 | 46.3 | 46.1 | 46.1 | 46.4 | 46.4 | 46.8 | 47.3 | 47.4 | 47.5 | 47.5 |
| | | | Lactating (Secundipara) | kg/head/day | 40.3 | 41.8 | 43.3 | 44.8 | 44.9 | 44.7 | 44.7 | 45.0 | 45.0 | 45.3 | 45.8 | 45.9 | 46.0 | 46.0 |
| | | | Lactating (Primipara) | kg/head/day | 36.7 | 38.2 | 39.5 | 40.6 | 41.5 | 41.4 | 41.4 | 41.6 | 41.6 | 41.8 | 42.2 | 42.3 | 42.5 | 42.4 |
| | | | Non-lactating | kg/head/day | 27.9 | 27.9 | 28.7 | 28.5 | 28.7 | 28.6 | 28.5 | 28.5 | 28.5 | 28.5 | 28.4 | 28.4 | 28.4 | 28.4 |
| | | | Heifer: under 2 yr, over 6 mth | kg/head/day | 22.1 | 22.4 | 22.9 | 23.1 | 23.2 | 23.2 | 23.2 | 23.2 | 23.2 | 23.2 | 23.2 | 23.2 | 23.2 | 23.2 |
| | | | Heifer: 3 to 6 mth | kg/head/day | 14.9 | 14.9 | 15.1 | 15.8 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 |
| | | Urine | Lactating (Multipara (3 and more)) | kg/head/day | 16.9 | 16.9 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 16.9 | 16.9 | 16.9 | 16.9 | 16.9 |
| | | | Lactating (Secundipara) | kg/head/day | 17.1 | 17.1 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 17.2 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 | 17.1 |
| | | | Lactating (Primipara) | kg/head/day | 18.8 | 18.8 | 18.9 | 18.9 | 18.8 | 18.8 | 18.8 | 18.8 | 18.8 | 18.7 | 18.7 | 18.7 | 18.7 | 18.7 |
| | | | Non-lactating | kg/head/day | 82.7 | 83.0 | 86.8 | 85.6 | 86.8 | 86.4 | 86.1 | 85.9 | 85.9 | 85.7 | 85.5 | 85.4 | 85.4 | 85.3 |
| | | | Heifer: under 2 yr, over 6 mth | kg/head/day | 12.3 | 12.3 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 |
| | | | Heifer: 3 to 6 mth | kg/head/day | 4.4 | 4.4 | 4.8 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 |
| Nitrogen content | Dairy Cattle | Feces | Lactating (Multipara (3 and more)) | g-N/head/day | 155.7 | 164.4 | 172.7 | 181.7 | 183.2 | 182.1 | 182.2 | 183.8 | 184.0 | 186.0 | 189.1 | 189.6 | 190.1 | 190.3 |
| | | | Lactating (Secundipara) | g-N/head/day | 148.5 | 157.4 | 165.5 | 174.3 | 175.0 | 173.9 | 174.0 | 175.6 | 175.7 | 177.6 | 180.5 | 180.8 | 181.3 | 181.4 |
| | | | Lactating (Primipara) | g-N/head/day | 128.6 | 136.7 | 144.1 | 150.2 | 155.6 | 154.7 | 155.0 | 156.0 | 156.1 | 157.4 | 159.5 | 160.1 | 160.9 | 160.5 |
| | | | Non-lactating | g-N/head/day | 82.7 | 83.0 | 86.8 | 85.6 | 86.8 | 86.4 | 86.1 | 85.9 | 85.9 | 85.7 | 85.5 | 85.4 | 85.4 | 85.3 |
| | | | Heifer: under 2 yr, over 6 mth | g-N/head/day | 53.3 | 54.5 | 57.2 | 58.3 | 58.5 | 58.5 | 58.5 | 58.5 | 58.5 | 58.5 | 58.5 | 58.5 | 58.5 | 58.5 |
| | | | Heifer: 3 to 6 mth | g-N/head/day | 20.6 | 20.7 | 21.6 | 24.3 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 | 24.9 |
| | | Urine | Lactating (Multipara (3 and more)) | g-N/head/day | 76.1 | 81.0 | 83.2 | 87.9 | 89.9 | 89.5 | 89.4 | 90.5 | 90.8 | 92.1 | 93.5 | 93.9 | 94.2 | 94.2 |
| | | | Lactating (Secundipara) | g-N/head/day | 85.8 | 90.2 | 92.2 | 96.6 | 98.7 | 98.4 | 98.4 | 99.3 | 99.6 | 100.7 | 102.1 | 102.3 | 102.6 | 102.6 |
| | | | Lactating (Primipara) | g-N/head/day | 88.8 | 92.5 | 94.4 | 98.7 | 93.2 | 92.8 | 92.7 | 93.9 | 94.2 | 95.5 | 97.2 | 97.9 | 98.8 | 98.5 |
| | | | Non-lactating | g-N/head/day | 98.6 | 98.8 | 103.1 | 101.9 | 103.2 | 102.8 | 102.4 | 102.1 | 102.2 | 101.9 | 101.7 | 101.5 | 101.6 | 101.5 |
| | | | Heifer: under 2 yr, over 6 mth | g-N/head/day | 65.1 | 66.6 | 69.7 | 70.9 | 71.1 | 71.1 | 71.1 | 71.1 | 71.1 | 71.1 | 71.1 | 71.1 | 71.1 | 71.1 |
| | | | Heifer: 3 to 6 mth | g-N/head/day | 27.4 | 27.6 | 37.4 | 43.1 | 44.2 | 44.2 | 44.2 | 44.2 | 44.2 | 44.2 | 44.2 | 44.2 | 44.2 | 44.2 |
| | Non-dairy cattle | Feces | Breeding: 2 yr and over | g-N/head/day | 58.9 | 58.9 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 |
| | | | Breeding: under 2 yr, over 6 mth | g-N/head/day | 46.1 | 46.1 | 56.2 | 56.2 | 56.2 | 56.2 | 56.2 | 56.2 | 56.2 | 56.2 | 56.2 | 56.2 | 56.2 | 56.2 |
| | | | Breeding: 3 to 6 mth | g-N/head/day | 21.5 | 21.5 | 24.3 | 24.3 | 24.3 | 24.3 | 24.3 | 24.3 | 24.3 | 24.3 | 24.3 | 24.3 | 24.3 | 24.3 |
| | | | Wagyu (M): 1 yr and over | g-N/head/day | 63.5 | 63.5 | 63.5 | 63.5 | 59.1 | 59.1 | 59.1 | 59.1 | 59.1 | 59.1 | 59.1 | 59.1 | 59.1 | 59.1 |
| | | | Wagyu (M): under 1 yr, over 6 mth | g-N/head/day | 48.1 | 48.1 | 48.1 | 48.1 | 51.3 | 51.3 | 51.3 | 51.3 | 51.3 | 51.3 | 51.3 | 51.3 | 51.3 | 51.3 |
| | | | Wagyu (M): 3 to 6 mth | g-N/head/day | 23.7 | 23.7 | 23.7 | 23.7 | 20.7 | 20.7 | 20.7 | 20.7 | 20.7 | 20.7 | 20.7 | 20.7 | 20.7 | 20.7 |
| | | | Wagyu (F): 1 yr and over | g-N/head/day | 40.1 | 40.1 | 46.4 | 46.4 | 46.4 | 46.4 | 46.4 | 46.4 | 46.4 | 46.4 | 46.4 | 46.4 | 46.4 | 46.4 |
| | | | Wagyu (F): under 1 yr, over 6 mth | g-N/head/day | 32.5 | 32.5 | 42.7 | 42.7 | 42.7 | 42.7 | 42.7 | 42.7 | 42.7 | 42.7 | 42.7 | 42.7 | 42.7 | 42.7 |
| | | | Wagyu (F): 3 to 6 mth | g-N/head/day | 18.7 | 18.7 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 |
| | | | Dairy breed: over 6 mth | g-N/head/day | 61.3 | 61.3 | 61.3 | 61.3 | 61.3 | 61.3 | 61.3 | 61.3 | 61.3 | 61.3 | 61.3 | 61.3 | 61.3 | 61.3 |
| | | | Dairy breed: 3 to 6 mth | g-N/head/day | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 | 31.8 |
| | | | Hybrid: over 6 mth | g-N/head/day | 60.2 | 60.2 | 60.2 | 60.2 | 60.2 | 60.2 | 60.2 | 60.2 | 60.2 | 60.2 | 60.2 | 60.2 | 60.2 | 60.2 |
| | | | Hybrid: 3 to 6 mth | g-N/head/day | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 |
| | | Urine | Breeding: 2 yr and over | g-N/head/day | 73.9 | 73.9 | 76.7 | 76.7 | 74.9 | 74.9 | 74.9 | 74.9 | 74.9 | 74.9 | 74.9 | 74.9 | 74.9 | 74.9 |
| | | | Breeding: under 1 yr, over 6 mth | g-N/head/day | 57.5 | 57.5 | 69.4 | 69.4 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 |
| | | | Breeding: 3 to 6 mth | g-N/head/day | 35.5 | 35.5 | 43.6 | 43.6 | 54.3 | 54.3 | 54.3 | 54.3 | 54.3 | 54.3 | 54.3 | 54.3 | 54.3 | 54.3 |
| | | | Wagyu (M): 1 yr and over | g-N/head/day | 76.9 | 76.9 | 76.9 | 76.9 | 71.9 | 71.9 | 71.9 | 71.9 | 71.9 | 71.9 | 71.9 | 71.9 | 71.9 | 71.9 |
| | | | Wagyu (M): under 1 yr, over 6 mth | g-N/head/day | 65.1 | 65.1 | 65.1 | 65.1 | 71.6 | 71.6 | 71.6 | 71.6 | 71.6 | 71.6 | 71.6 | 71.6 | 71.6 | 71.6 |
| | | | Wagyu (M): 3 to 6 mth | g-N/head/day | 41.0 | 41.0 | 41.0 | 41.0 | 48.2 | 48.2 | 48.2 | 48.2 | 48.2 | 48.2 | 48.2 | 48.2 | 48.2 | 48.2 |
| | | | Wagyu (F): 1 yr and over | g-N/head/day | 49.8 | 49.8 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 |
| | | | Wagyu (F): under 1 yr, over 6 mth | g-N/head/day | 44.8 | 44.8 | 57.5 | 57.5 | 60.4 | 60.4 | 60.4 | 60.4 | 60.4 | 60.4 | 60.4 | 60.4 | 60.4 | 60.4 |
| | | | Wagyu (F): 3 to 6 mth | g-N/head/day | 33.9 | 33.9 | 42.3 | 42.3 | 51.6 | 51.6 | 51.6 | 51.6 | 51.6 | 51.6 | 51.6 | 51.6 | 51.6 | 51.6 |
| | | | Dairy breed: over 6 mth | g-N/head/day | 84.2 | 84.2 | 84.2 | 84.2 | 85.5 | 85.5 | 85.5 | 85.5 | 85.5 | 85.5 | 85.5 | 85.5 | 85.5 | 85.5 |
| | | | Dairy breed: 3 to 6 mth | g-N/head/day | 57.2 | 57.2 | 57.2 | 57.2 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 |
| | | | Hybrid: over 6 mth | g-N/head/day | 82.0 | 82.0 | 82.0 | 82.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 |
| | | | Hybrid: 3 to 6 mth | g-N/head/day | 57.0 | 57.0 | 57.0 | 57.0 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 | 65.8 |
| | Swine | Feces | Growing-finishing | g-N/head/day | 4.6 | 4.6 | 4.4 | 4.0 | 3.9 | 4.0 | 4.0 | 4.0 | 3.9 | 3.9 | 3.9 | 3.9 | 4.1 | 4.1 |
| | | | Breeding | g-N/head/day | 4.9 | 4.9 | 4.9 | 4.6 | 4.5 | 4.6 | 4.6 | 4.6 | 4.5 | 4.5 | 4.5 | 4.4 | 4.4 | 4.4 |
| | | Urine | Growing-finishing | g-N/head/day | 11.3 | 11.3 | 10.8 | 10.1 | 9.9 | 10.0 | 10.1 | 10.1 | 9.9 | 9.8 | 9.7 | 9.7 | 10.3 | 10.3 |
| | | | Breeding | g-N/head/day | 15.6 | 15.5 | 15.5 | 14.8 | 14.4 | 14.6 | 14.7 | 14.7 | 14.3 | 14.2 | 14.2 | 14.1 | 14.1 | 14.1 |

Table 5-27 Nitrogen content in feces excreted for Hen and Broiler (*Nex*)

| Type of livestock | | Nitrogen content in feces [kg-N/head/day] | Nitrogen content in feces excreted [g-N/head/day] | | |
|---|---|---|---|---|---|
| | | | 1990~1997 | 1998~2011 | 2012~ |
| Hen | Poult | 0.059 | 1.54 | 1.54 | 1.54 |
| | Adult | 0.136 | 3.28 | Interpolation | 2.20 |
| Broiler | | 0.130 | 2.62 | Interpolation | 1.87 |

Reference: Hen - Poult: Tsuiki et al.,（1997)

Hen - Adult and Broiler: 1990~1997: Tsuiki et al., (1997), 2012~: Ogino et al., (2016)

Table 5-28 Organic matter content in feces and urine, by type of livestock (wet base) (*Org*)

| Livestock species | Organic matter content | |
|---|---|---|
| | Feces | Urine |
| Dairy cattle | 16% | 0.5% |
| Non-dairy cattle | 18% | 0.5% |
| Swine | 20% | 0.5% |
| Hen | 15% | — |
| Broiler | 15% | — |

Reference: Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*. (2002)

Table 5-29 Proportion of separated and mixed treatment of manure, by type of livestock ($Mix_n$)

| Livestock species | Separated | | | Mixed | | |
|---|---|---|---|---|---|---|
| | ~1999 | 2000~2008 | 2009~ | ~1999 | 2000~2008 | 2009~ |
| Dairy cattle | 60% | Interpolation | 45.5% | 40% | Interpolation | 54.5% |
| Non-dairy cattle | 7% | Interpolation | 4.8% | 93% | Interpolation | 95.2% |
| Swine | 70% | Interpolation | 73.9% | 30% | Interpolation | 26.1% |
| Hen | 100% | Interpolation | 100% | — | — | — |
| Broiler | 100% | Interpolation | 100% | — | — | — |

Reference: Until 1999: Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*. (2002)
From 2009 onward: MAFF, *Survey of current status for livestock manure management system* (2009)

Table 5-30 Percentage of manure management by type of animal (dairy cattle, non-dairy cattle and swine) ($MS_n$)

| State of Manure (Separated or Mixed) | | Treating method | Dairy cattle | | | Non-dairy cattle | | | Swine | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ~1999 | 2000~2008 | 2009~ | ~1999 | 2000~2008 | 2009~ | ~1999 | 2000~2008 | 2009~ |
| Separated | Feces | Sun drying | 2.8% | Interpolation | 2.0% | 1.5% | Interpolation | 0.9% | 7.0% | Interpolation | 0.7% |
| | | Thermal drying | 0% | — | 0% | 0% | — | 0% | 0.7% | Interpolation | 0.1% |
| | | Composting | 9.0% | Interpolation | 6.6% | 11.0% | Interpolation | 8.1% | 62.0% | Interpolation | 48.2% |
| | | Piling | 88.0% | Interpolation | 90.1% | 87.0% | Interpolation | 89.8% | 29.6% | Interpolation | 49.3% |
| | | Incineration | 0.2% | Interpolation | 0% | 0.5% | Interpolation | — | 0.7% | Interpolation | 0.6% |
| | | Methane fermentation | — | — | — | — | — | — | — | Interpolation | 0.1% |
| | | public sewage | — | — | 0% | — | — | — | — | — | — |
| | | Pasturage | — | — | 0% | — | — | — | — | — | — |
| | | Other | — | Interpolation | 1.3% | — | Interpolation | 1.2% | — | Interpolation | 1.0% |
| | Urine | Sun drying | — | — | 0% | — | — | 0% | — | — | 0% |
| | | Composting (urine) | 1.5% | Interpolation | 1.7% | 9.0% | Interpolation | 1.2% | 10.0% | Interpolation | 5.4% |
| | | Purification | 2.5% | Interpolation | 5.1% | 2.0% | Interpolation | 4.4% | 45.0% | Interpolation | 76.3% |
| | | Pit storage | 96.0% | Interpolation | 89.6% | 89.0% | Interpolation | 91.5% | 45.0% | Interpolation | 15.3% |
| | | Methane fermentation | — | Interpolation | 1.9% | — | — | 0% | — | Interpolation | 0.5% |
| | | Public sewage | — | Interpolation | 0.8% | — | Interpolation | 0.6% | — | Interpolation | 0.4% |
| | | Other | — | Interpolation | 0.9% | — | Interpolation | 2.4% | — | Interpolation | 2.1% |
| Mixed | | Sun drying | 4.4%* | Interpolation | 1.1% | 3.4%* | Interpolation | 0.7% | 6.0% | Interpolation | 0.2% |
| | | Thermal drying | 0% | — | 0% | 0% | — | 0% | 0% | — | 0% |
| | | Composting (urine) | 18.7%* | Interpolation | 22.9% | 21.8%* | Interpolation | 10.8% | 29.0% | Interpolation | 21.3% |
| | | Piling | 13.1%* | Interpolation | 50.9% | 73.2%* | Interpolation | 85.6% | 20.0% | Interpolation | 51.3% |
| | | Purification | 0.3%* | Interpolation | 0.2% | 0% | — | 0% | 22.0% | Interpolation | 18.5% |
| | | Pit storage | 57.1%* | Interpolation | 15.4% | 0.6%* | Interpolation | 0.1% | 23.0% | Interpolation | 4.0% |
| | | Incineration | — | Interpolation | 0.1% | — | — | 0% | — | — | 0% |
| | | Methane fermentation | — | Interpolation | 1.7% | — | — | 0% | — | Interpolation | 2.0% |
| | | Public sewage | — | Interpolation | 0.1% | — | — | 0% | — | Interpolation | 0.7% |
| | | Pasturage | 6.5%* | Interpolation | 6.5% | 1.1%* | Interpolation | 1.1% | — | — | 0% |
| | | Other | — | Interpolation | 1.2% | — | Interpolation | 1.6% | — | Interpolation | 1.9% |

Reference: ~1999: Japan Livestock Technology Association, *GHGs emissions control in livestock Part4*. (1999)
2009~: MAFF, *Survey of current status for livestock manure management system* (2009)

Note: For dairy cattle and non-dairy cattle, percentage of "Pasturage" are not indicated in Japan Livestock Association data (1999) but are indicated in MAFF (2009). Therefore, the percentages of "Pasturage" indicated in MAFF (2009) are applied to all the years consistently. In addition, each percentage of the mixed management of dairy cattle and non-dairy cattle is adjusted so that the sum of the percentages can be 100%.

Table 5-31 Percentage of manure management by type of animal (hen and broiler) ($MS_n$)

| State of Manure (Separated or Mixed) | | Treating method | Hen | | | Broiler | | |
|---|---|---|---|---|---|---|---|---|
| | | | ~1999 | 2000~2008 | 2009~ | ~1999 | 2000~2008 | 2009~ |
| Separated | Feces | Sun drying | 30.0% | Interpolation | 8.2% | 15.0% | Interpolation | 2.5% |
| | | Thermal drying | 3.0% | Interpolation | 2.2% | 0% | Interpolation | 1.1% |
| | | Composting | 42.0% | Interpolation | 49.6% | 5.1% | Interpolation | 19.3% |
| | | Piling | 23.0% | Interpolation | 36.8% | 66.9% | Interpolation | 36.7% |
| | | Incineration | 2.0% | Interpolation | 1.6% | 13.0% | Interpolation | 30.5% |
| | | Methane fermentation | — | — | — | — | Interpolation | 0.1% |
| | | public sewage | — | — | — | — | — | — |
| | | Pasturage | — | — | 0% | — | Interpolation | 0.1% |
| | | Other | — | Interpolation | 1.6% | — | Interpolation | 9.9% |

Reference: See Table 5-30 above

- ***Background information for livestock manure management in Japan***

In Europe, slurry spreading (liquid system) is major manure management system. On the other hand, in Japan, composting system ("Composting" and "Piling") are major management system. Osada et al., (2005), which investigated emission factors by actual measurement for "Piling", described that "Proper recycling of nutritive salts from livestock compost cannot be completed only by circulation in an area where the livestock density per unit area is especially high. Thus, livestock excrement can be made more manageable through the composting process, and the resulting product can be distributed over a wide area". Composting ("Composting" and "Piling") is widely practiced in Japan because, among other things: (1) it is essential for Japanese livestock farmers to facilitate transportation and handling, because the lack of space required for the on-site reduction of manure makes it necessary to direct the manure for uses outside their farms; and (2) compost is in considerably higher demand as a fertilizer for various crops than slurry or liquid manure in Japan where fertilizers tend to be lost by heavy rain and the expectations of the protection of water quality, prevention of odor, and sanitary management are high.

- ***Reporting in Common Reporting Format (CRF)***

In the CRF, with regard to nitrogen amount of manure (MMS) from this category, it is required to report emissions by AWMS ("Anaerobic Lagoons", "Liquid Systems", "Daily Spread", "Solid Storage and Dry Lot", "Pasture, Range and Paddock", "Composting", "Digesters", "Burned for Fuel or as Waste", and "Other").

For cattle, swine, and poultry, Japan's country-specific manure management categories and the implementation rates of the management categories have been established for each type of animal. For details, see Table 5-32.

"Anaerobic Lagoons" have been reported as "NO". Because there are quite small number of livestock farmers who has enough area of field to spread manure, and it is assumed that there are no livestock farmers who use anaerobic lagoons. There are cases when manure is spread to fields in Japan, but even in these cases, stirring is conducted before the spreading. Therefore, there are no anaerobic manure management systems.

Table 5-32 Correspondence between the Japanese and CRF manure management categories

| Sub-categories in Japan | | | Classification in CRF | Description of treatment |
|---|---|---|---|---|
| Manure treatment | | Manure management category | | |
| Separate treatment | Feces | Sun drying | Solid storage and dry lot | Dried under sunlight to facilitate handling (for storage and odor prevention). |
| | | Thermal drying | Other system | Dried by heat to facilitate handling. |
| | | Composting | Composting | Fermented for several days to several weeks with forced aeration and agitation in lidded or closed tanks. |
| | | Piling | Composting | Piling system is a method of composting. Piled about 1.5-2m height on compost bed or in shed to ferment for several months with occasional turning. |
| | | Incineration | Burned for fuel or as waste | For amount reduction, disposal, or use as an energy source (e.g. chicken manure boiler). |
| | | Methane fermentation | Digesters | Slurry livestock manure is fermented under anaerobic conditions. Generated methane gas is used as an energy source. |
| | | Public sewage | — | Released into public sewage without purification or aeration management. Emissions are included in the Waste sector. |
| | | Pasture, range and paddock | Pasture, range and paddock | Livestock are fed on a land with vegetation to eat. $N_2O$ Emissions are reported in the 'Urine and dung deposited by grazing animals (3.D.a.3.)'. |
| | | Other | Other system | Treated with the method not mentioned above. |
| | Urine | Liquid composting | Composting | Treated in an aeration storage tank. |
| | | Purification | Aerobic treatment | Separate pollutants using aerobic microbes, such as activated sludge. |
| | | Pit storage | Liquid systems | Stored in a storage tank. |
| | | Methane fermentation | Digesters | Same as above (Methane fermentation). |
| | | Public sewage | — | Same as above (Public sewage). |
| | | Other | Other system | Treated with the method not mentioned above. |
| Mixed treatment | | Sun drying | Solid storage and dry lot | Dried under sunlight to facilitate handling. |
| | | Thermal drying | Other system | Same as above, Thermal drying. |
| | | Liquid composting | Composting | Treated in an aeration storage tank. |
| | | Piling | Composting | Same as above, Piling. |
| | | Purification | Aerobic treatment | Same as above, Purification. |
| | | Pit storage | Liquid systems | Stored in a storage tank (e.g. slurry storage). |
| | | Methane fermentation | Digesters | Same as above (Methane fermentation). |
| | | Public sewage | — | Same as above (Public sewage). |
| | | Pasture, range and paddock | Pasture, range and paddock | Same as above (Pasture, range and paddock). |
| | | Other | Other system | Treated with method not mentioned above. |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the uncertainties of the $CH_4$ emission factors, Tier 2 values (20%) described in the *2006 IPCC Guidelines* were applied. For $N_2O$ emission factors, uncertainty was calculated by synthesis of default uncertainties of each parameter described in the *2006 IPCC Guidelines* uncertainty.

For the uncertainties of the activity data, 1% (the standard error for swine given in the *Livestock Statistics*) was applied to swine, and 9% (the standard error for boiler given in the *Livestock Statistics*) was applied to poultry. For cattle, 1% is adopted, same as "Enteric Fermentation, Cattle".

As a result, the uncertainties of the emissions for dairy cattle, non-dairy cattle and swine were determined to be -20% to +20% for $CH_4$ and -71% to +112% for $N_2O$, and emissions for poultry were determined to be -22% to +22% for $CH_4$ and -72% to +112% for $N_2O$.

- ***Time-series Consistency***

Emission factors were used consistently from FY1990 onward by the method. Activity data were calculated consistently from FY1990 onward from the data in the *Livestock Statistics*.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1. For some country-specific emission factors, there were significant differences between the default emission factors. In the case, the factors of differences were analyzed. QA/QC activities are summarized in Chapter 1.

Country-specific emission factors are used for $CH_4$ and $N_2O$ emission factors for grazing cattle, and these values are lower than the value calculated from the default data described in the *2006 IPCC Guidelines*. It is guessed that andosol and brown forest soil, which drainage is well, are dominant for grazing land in Japan. Therefore, $CH_4$ and $N_2O$ emission factors are low in Japan.

Country-specific emission factors are used for $CH_4$ and $N_2O$ emission factors by pit storage for dairy cattle, and these values are lower than the value calculated from the default data described in *2006 IPCC Guidelines*. For $CH_4$, the reasons are assumed that pit storage period of slurry in Japan is comparatively shorter than other countries and the short period stored slurry is spread to agriculture and grazed meadow soil before further activation of $CH_4$ emissions. For $N_2O$, the inferred reason of lower value of the emission factor is the same as $CH_4$, the Japanese shorter period pit storage doesn't reach to occurrence of scum which is guessed as $N_2O$ source.

In the inventory review, the ERT pointed out that Japan's IEFs for dairy cattle are very higher than other Annex I Parties. This reason is that "Piling" is major manure management system in Japan, and EF for "Piling" is very high. Moisture for dairy cattle feces is high, and they easily make anaerobic condition. It is considered to be the reason for high $CH_4$ emission factor of piling.

For emission factors by piling for poultry, hen's EF is higher than broiler's one. For $CH_4$, the reason is guessed to be that moisture content of manure for hen is higher than for broiler. Country-specific emissions factors of $N_2O$ by pilling for poultry is lower than the default emission factors. The reason is guessed to be that the default emission factors include not only poultry but also other animals (such as cattle and swine) (Nitrification is less likely to occur in poultry manure than cattle or swine manure).

Country-specific emissions factors of $N_2O$ for sun drying of poultry is lower than the default emission factors. The reason is guessed to be that the default emission factors include not only poultry but also other animals which are the same reason for emission factors by piling for poultry.

### *e) Category-specific Recalculations*

Since the population of dairy cattle by calving on 2017 in *Record of Dairy Herd Performance Test* was revised, the emissions from dairy cattle for 2017 were recalculated. Since the calculation methods of nitrogen content in excretion for non-dairy cattle and swine have been revised, the emissions for non-dairy cattle and swine for the whole time-series were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

As research on actual emissions and information collection for emission reduction method has been continuously conducted by the organizations and agencies concerned, a review of emission factors and parameters will be implemented when the new data are obtained.

## 5.3.2. Buffalo, Sheep, Goats, Horses, Rabbit and Mink (3.B.2., 3.B.4.)

### *a) Category Description*

This section provides the estimation methods for $CH_4$ and $N_2O$ emissions for manure management from buffalo, sheep, goats, horses, rabbit and mink.

### *b) Methodological Issues*

- ***Estimation Method***

$CH_4$ and $N_2O$ emissions were calculated by using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 4, Page 10.36, Fig 10.3 and Page 10.55, Fig. 10.4).

$$E_{CH_4} = EF_{CH_4} \times P$$

$$E_{N_2O} = \sum (EF_{N_2O\text{-}n} \times P \times Nex \times MS_n)$$

| | |
|---|---|
| $E_{CH_4}$ | : $CH_4$ emissions associated with manure management [kg-$CH_4$] |
| $E_{N_2O}$ | : $N_2O$ emission associated with livestock manure [kg-$N_2O$] |
| $EF_{CH_4}$ | : $CH_4$ emission factor [kg-$CH_4$ head$^{-1}$ year$^{-1}$] |
| $EF_{N_2O\text{-}n}$ | : $N_2O$ emission factor of manure management *n* [kg-$N_2O$ (kg-N)$^{-1}$] |
| $P$ | : Livestock population [head] |
| $Nex$ | : Nitrogen content in manure [kg-N head$^{-1}$] |
| $MS_n$ | : Percentage of manure management *n* [%] |

- ***Emission Factors***

For the emission factors for $CH_4$, the default values for temperate zones in industrialized nations, given in the *2006 IPCC Guidelines* were used. For buffalo, the default value given for the temperate zone in Asia was used (Table 5-33).

For the emission factors for $N_2O$, the default values given in the *2006 IPCC Guidelines* were used (Table 5-34).

Table 5-33 $CH_4$ emission factors for sheep, goats, horses, rabbit and mink

| Livestock species | $CH_4$ Emission factors [kg-$CH_4$ head$^{-1}$ year$^{-1}$] | Reference |
|---|---|---|
| Sheep | 0.28 | *2006 IPCC Guidelines*, Vol. 4, p. 10.40, Table 10.15 |
| Goats | 0.20 | |
| Horses | 2.34 | |
| Buffalo | 2 | *2006 IPCC Guidelines*, Vol. 4, p. 10.39, Table 10.14 |
| Rabbit | 0.08 | *2006 IPCC Guidelines*, Vol. 4, p. 10.41, Table 10.16 |
| Mink | 0.68 | |

Table 5-34 $N_2O$ Emission factors for buffalo, sheep, goats, horses, rabbit and mink

| Manure management category | $N_2O$ Emission factors [kg-$N_2O$-N (kg-N)$^{-1}$] |
|---|---|
| Dry lot | 2.0% |
| Pasture Range and Paddock (buffalo) | 2.0% |
| Pasture Range and Paddock (sheep, goats, horses) | 1.0% |
| Daily Spread | 0% |
| Burned for fuel | 0% |

Reference: Dry lot, Daily Spread: *2006 IPCC Guidelines* Vol.4, page 10.62, Table 10.21,
Pasture Range and Paddock: *2006 IPCC Guidelines* Vol.4, page 11.11, Table 11.1

- ***Activity Data***

For livestock population for sheep, goats, horses and buffalo, same data described in '3.A. Enteric Fermentation' are used (See Table 5-12). For rabbit and mink, population data in the *Statistical Document for small animals and laboratory animals* by MAFF are used (See Table 5-35 below).

For $N_2O$, in order to determine the total nitrogen amount for each livestock, first, it was calculated by multiplying the population of each type of animal by the nitrogen content of manure per head of animal (or by the nitrogen amount in manure per weight and livestock weight). Then, the amount of nitrogen per manure management category was calculated by multiplying the total nitrogen by the percentage of each management category (Table 5-36). For the percentage of manure management category for buffalo, the default values given in the *2006 IPCC Guidelines* were used (classification is "Asia") (Table 5-37).

For rabbit and mink, percentage of manure management system usage ($MS_n$) is considered by expert judgment that all manure are managed by "Dry lot" because default values are not described in the *2006 IPCC Guidelines.*

For the percentage of manure management system usage ($MS_n$) for sheep, goats and horses, the *2006 IPCC Guidelines* (Vol.4, p.10.61) described that "Manure from other animal categories is typically managed in pasture and grazing operations". Therefore, it is assumed that their livestock manures are managed by grazing system.

Table 5-35 Livestock population for rabbit and mink [1000 heads]

| Livestock Species | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rabbit | 15 | 16 | 21 | 19 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| Mink | 155 | 11 | 6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Reference: *Statistical Document for small animals and laboratory animals*, MAFF

Table 5-36 Body weight and N excretion rate for buffalo, sheep, goats, horses, rabbit and mink (*Nex*)

| Livestock species | Body weight [kg] | N excretion rate per weight [kg-N (1000kg-body weight)$^{-1}$ day$^{-1}$] | N excretion rate [kg-N head$^{-1}$ year$^{-1}$] |
|---|---|---|---|
| Buffalo | 380 | 0.32 | (44.4) |
| Sheep | 48.5 | 1.17 | (20.7) |
| Goats | 38.5 | 1.37 | (19.3) |
| Horses | 377 | 0.46 | (63.3) |
| Rabbit | - | - | 8.10 |
| Mink | - | - | 4.59 |

Note: Values in parentheses are calculated values.
Reference: *2006 IPCC Guidelines* Vol.4, page 10.79, Table 10A-6, page 10.82, Table 10A-9, page 10.59, Table 10.19

Table 5-37 Percentage of each manure management category for buffalo ($MS_n$)

| Manure management category | Percentage |
|---|---|
| Lagoons | 0% |
| Liquid /Slurry | 0% |
| Solid Storage | 0% |
| Dry lot | 41% |
| Pasture Range and Paddock | 50% |
| Daily Spread | 4% |
| Digester | 0% |
| Burned for Fuel | 5% |
| Other | 0% |

Reference: *2006 IPCC Guidelines*, Vol.4, page 10.79, Table 10A-6

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

An uncertainty assessment was conducted for individual livestock categories. With respect to the uncertainties for emission factors for $CH_4$, Tier 1 default value (30%) described in the *2006 IPCC Guidelines* was applied. For $N_2O$, the uncertainty was calculated by synthesis of default values of each parameter described in the *2006 IPCC Guidelines*. For the activity data, uncertainty was substituted by the value of broiler (9%) described in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -31% to +31% for $CH_4$, and -72% to +112% for $N_2O$ for each livestock.

- ***Time-series Consistency***

For emission factors, same values were used consistently for all the years. For Activity data were calculated consistently for all the years from the data in the *Statistical Document of Livestock Breeding*, the *Statistical Document of Horse*, the *Survey Result of Feeding Livestock and Poultry* by Okinawa and the *Status Report regarding Health Management for Livestock Feeding*.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

There have been no source-specific recalculations.

### *f) Category-specific Planned Improvements*

There are no improvement plans.

### 5.3.3. Other Livestock (3.B.4.-)

Deer, reindeer, fox, and other poultries (duck, turkey, etc.), which are other livestock than those listed above, are reported in the *Statistical Document for Small Animals and Laboratory Animals* (MAFF). However, their population size is small, and each emission was lower than 3000t-$CO_2$ equivalent, which is the threshold to estimate in this GHG inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was not reported (See Annex 5).

### 5.3.4. Indirect $N_2O$ emissions (3.B.5.)

#### 5.3.4.1. Atmospheric Deposition (3.B.5.-)

***a) Category Description***

This section provides the estimation methods for $N_2O$ indirect emissions caused by atmospheric deposition of nitrogen volatilized as $NH_3$ and NOx from livestock manure management.

***b) Methodological Issues***

- ***Estimation Method***

$N_2O$ emissions have been calculated by Tier 2 method in accordance with decision tree of the *2006 IPCC Guidelines* (Vol.4, Page 10.55, Fig. 10.4).

$$E = N_{Volatilization\text{-}MMS} \times \mathrm{EF} \times 44 / 28$$

| | |
|---|---|
| $E$ | : $N_2O$ emissions by atmospheric deposition in the process of livestock manure management [kg-$N_2O$] |
| $N_{Volatilization\text{-}MMS}$ | : Nitrogen amount volatilized as $NH_3$ and NOx in the process of livestock manure management [kg ($NH_3$-N+$NO_X$-N)] |
| $EF$ | : Emission factor [kg-$N_2O$-N/kg ($NH_3$-N+$NO_X$-N)] |

- ***Emission Factors***

0.010 [kg-$N_2O$-N/kg-$NH_3$-N & $NO_X$-N deposited] (default value, *2006 IPCC Guidelines*, Vol.4, Page 10.24, Table11.3).

- ***Activity Data***

For cattle, swine, and poultry (hen and broiler), as described in the following equation, amount of nitrogen that volatilized as ammonia and nitrogen oxides from livestock manure management ($N_{Volatilizaiton\text{-}MMS}$) is calculated using the nitrogen amount included in each manure management system ($N_{Bi}$) which calculated in the above 5.3.1., and volatilization rate as $NH_3$ and NOx from manure in each livestock barn ($Frac_{GASM1i}$) and in each process of treatment ($Frac_{GASM2i}$). The volatilization rate as $NH_3$ and NOx from manure are estimated from data described in Hojito et al., (2003) (See Table 5-38). For “Purification”, it is considered that there are not volatilized in treatment process. Indirect $N_2O$ emissions form grazing animal are reported in 3.D.b.1.

$$N_{Volatilization\text{-}MMS} = \sum\{ N_{Bi} \times (Frac_{GASM1i} + Frac_{GASM2i}) \}$$

| | |
|---|---|
| $N_{Volatilization\text{-}MMS}$ | : Nitrogen amount volatilized as $NH_3$ and NOx in the process of livestock manure management [kg ($NH_3$-N+$NO_X$-N)] |
| $N_{Bi}$ | : Nitrogen amount in livestock manure for management system *i* [kg-N] |
| $Frac_{GASM1i}$ | : Volatilization rate as $NH_3$ and $NO_X$ in livestock barn for management system *i* [kg-$NH_3$-N + $NO_X$-N/kg-N] |
| $Frac_{GASM2i}$ | : Volatilization rate as $NH_3$ and $NO_X$ in process of treatment for management system *i* [kg- |

$NH_3$-N + $NO_X$-N/kg-N]

Table 5-38 Volatilization rate as $NH_3$ and NOx from manure (in livestock barn and in process of treatment)

| Livestock species | Treatment | | Volatilization rate in livestock barn ($Frac_{GASM1}$) | Volatilization rate in process of treatment ($Frac_{GASM2}$) |
|---|---|---|---|---|
| Dairy cattle | Feces | Other than Composting | 10.3% | 13.7% |
| | | Composting | 10.3% | 1.9% |
| | Urine | Other than Purification | 10.3% | 11.0% |
| | | Purification | 10.3% | 0% |
| | Mixed | Other than Purification, Pit storage, Methane fermentation | 4.5% | 13.7% |
| | | Purification | 10.3% | 0% |
| | | Pit storage, Methane fermentation | 10.3% | 10.8% |
| Non-dairy cattle | Feces | Other than Composting | 6.38% | 13.7% |
| | | Composting | 6.38% | 1.9% |
| | Urine | Other than Purification | 6.38% | 11% |
| | | Purification | 6.38% | 0% |
| | Mixed | Other than Purification, Pit storage, Methane fermentation | 6.38% | 13.7% |
| | | Purification | 6.38% | 0% |
| | | Pit storage, Methane fermentation | 6.38% | 10.8% |
| Swine | Feces | All management | 14.7% | 19.7% |
| | Urine | Other than Purification | 14.7% | 27.0% |
| | | Purification | 14.7% | 0% |
| | Mixed | Other than Purification, Pit storage, Methane fermentation | 15.8% | 24.2% |
| | | Purification | 14.7% | 0% |
| | | Pit storage, Methane fermentation | 14.7% | 25.0% |
| Hen and Broiler | Feces | All management | 8.4% | 51.5% |

Reference: Hojito et al., (2003)

For buffalo, rabbit, and mink, nitrogen amount volatilized as $NH_3$ and NOx from manure were estimated by multiplying total nitrogen amount of manure of each livestock by default volatilization rate described in the *2006 IPCC Guidelines* (Other-Solid storage: 12%).

Table 5-39 Nitrogen amount volatilized as $NH_3$ and NOx in the process of livestock manure management [kt ($NH_3$-N+$NO_X$-N)]

| Livestock Species | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | 26.6 | 26.1 | 24.6 | 23.4 | 21.0 | 20.5 | 20.5 | 20.2 | 19.7 | 19.4 | 19.5 | 19.1 | 19.1 | 19.1 |
| Non-dairy cattle | 22.3 | 23.0 | 23.0 | 22.5 | 23.5 | 22.5 | 22.2 | 21.5 | 20.9 | 20.3 | 20.3 | 20.4 | 20.5 | 20.3 |
| Swine | 54.7 | 47.5 | 44.7 | 38.3 | 35.9 | 36.2 | 36.2 | 36.0 | 34.8 | 34.0 | 33.4 | 33.3 | 34.7 | 34.5 |
| Poultry (Hen, Broiler) | 187.6 | 177.5 | 157.2 | 136.3 | 121.8 | 118.1 | 113.8 | 111.2 | 111.5 | 112.1 | 113.0 | 114.5 | 117.0 | 118.5 |
| Other livestocks (Buffalo, Mink, Rabbit) | 0.10 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Total | 291.3 | 274.0 | 249.6 | 220.5 | 202.4 | 197.3 | 192.8 | 189.0 | 186.9 | 185.8 | 186.2 | 187.4 | 191.3 | 192.4 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

Uncertainty (-106% to +447%) described in “Agricultural Soils (Atmospheric Deposition)” below was applied.

- ***Time-series Consistency***

For emission factors, consistent values (default values) were used in all time-series. For activity data, constant value for volatilized factor and constant estimation method for manure amount calculated in 5.3.1. were used.

#### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

#### *e) Category-specific Recalculations*

Since the calculation methods of nitrogen content in excretion for non-dairy cattle and swine have been revised, the emissions for non-dairy cattle and swine for the whole time-series were recalculated. See Chapter 10 for impact on trend.

#### *f) Category-specific Planned Improvements*

Refer to the section" 5.3.1. Cattle, Swine and Poultry (Hen and Broiler)".

### 5.3.4.2. Nitrogen Leaching and Run-off (3.B.5.-)

In Japan, under the "*Act on the Appropriate Treatment and Promotion of Utilization of Livestock Manure*", taking some measures to prevent from flowing wastewater in manure management, such as introducing concrete-clad floor, or using waterproof sheet, is required; so, the possibility of nitrogen leaching and run-off to subsurface water is very low. Therefore, this source is reported as "NO".

## 5.4. Rice Cultivation (3.C.)

$CH_4$ is generated under anaerobic conditions by microbes' activity. Therefore, paddy fields provide favorable conditions for $CH_4$ generation. In Japan, all paddy fields are irrigated, and intermittently and continuously flooded paddy fields are targeted in this category. In Japan, rice cultivation is practiced mainly on intermittently flooded paddy field.

$CH_4$ emissions from rice cultivation in FY2018 are 13,561 kt-$CO_2$ eq., comprising 1.1% of total emissions (excluding LULUCF). The value represents an increase by 6.2% from FY1990. Main driver of the emission increase from FY1990 is an increase of amount of organic matter application.

Table 5-40 $CH_4$ emissions from rice cultivation

| Gas | Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 3.C.1.- Continuously flooded | kt-$CH_4$ | 69.8 | 77.9 | 72.0 | 78.2 | 78.2 | 83.8 | 83.7 | 82.6 | 83.3 | 82.7 | 79.4 | 78.6 | 77.6 | 75.5 |
| | 3.C.1.- Intermittently flooded | | 441.1 | 466.3 | 437.9 | 459.6 | 476.3 | 517.8 | 503.5 | 490.4 | 499.3 | 494.8 | 476.9 | 477.6 | 467.5 | 467.0 |
| | Total | kt-$CH_4$ | 510.8 | 544.2 | 510.0 | 537.8 | 554.5 | 601.6 | 587.2 | 573.0 | 582.6 | 577.5 | 556.3 | 556.3 | 545.1 | 542.4 |
| | | kt-$CO_2$eq | 12,771 | 13,605 | 12,749 | 13,445 | 13,863 | 15,041 | 14,680 | 14,325 | 14,565 | 14,437 | 13,908 | 13,907 | 13,627 | 13,561 |

### 5.4.1. Irrigated (Intermittently Flooded (Single Aeration) and Continuously Flooded) (3.C.1.)

#### *a) Category Description*

This section provides the estimation methods for $CH_4$ emissions from intermittently flooded and continuously flooded rice cultivation.

- ***Water management regime in Japanese paddy fields***

The general practice of mid-season drainage and subsequent intermittent flooding by paddy farmers in Japan is different in nature from the intermittently flooded paddy field (multi aeration) concept in the *2006 IPCC Guidelines*. Therefore, Japan reports its practice as "Intermittent flooding (Single aeration)"

in the CRF. The diagram below presents the outline.

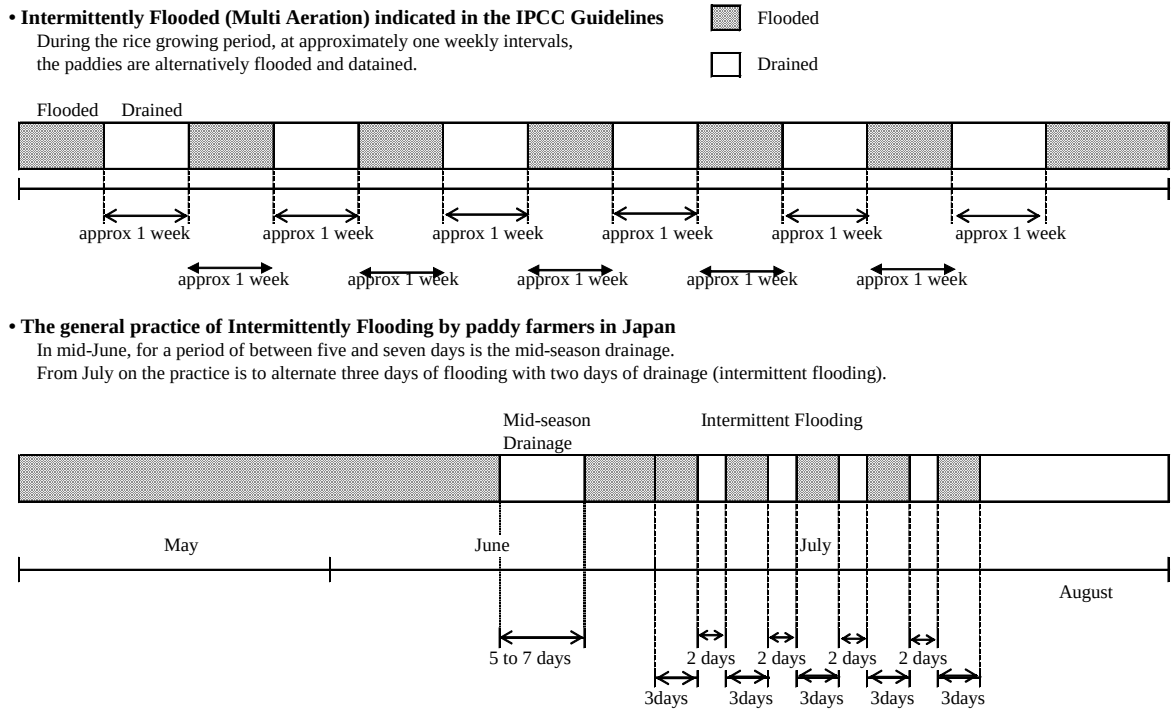


Figure 5-4 Comparison of water management regime in Japan and intermittent flooding (multi aeration) indicated in the *2006 IPCC Guidelines*

### *b) Methodological Issues*

- ***Estimation Method***

Based on the calculation method in the *2006 IPCC Guidelines*, the emissions were estimated using emission factors established by the calculation using DeNitrification-DeComposition-Rice model (DNDC-Rice model), which is the mathematical model to estimate change of $CH_4$ emissions with methods of organic matter application and/or water regime on paddy field, and the following formula determined by its model. The improved model, the DNDC-Rice model is based on the DNDC model and has developed in Japan so as to estimate $CH_4$ emissions from rice paddy field in Japan. Figure 5-5 is a conceptual scheme of the DNDC-Rice model.

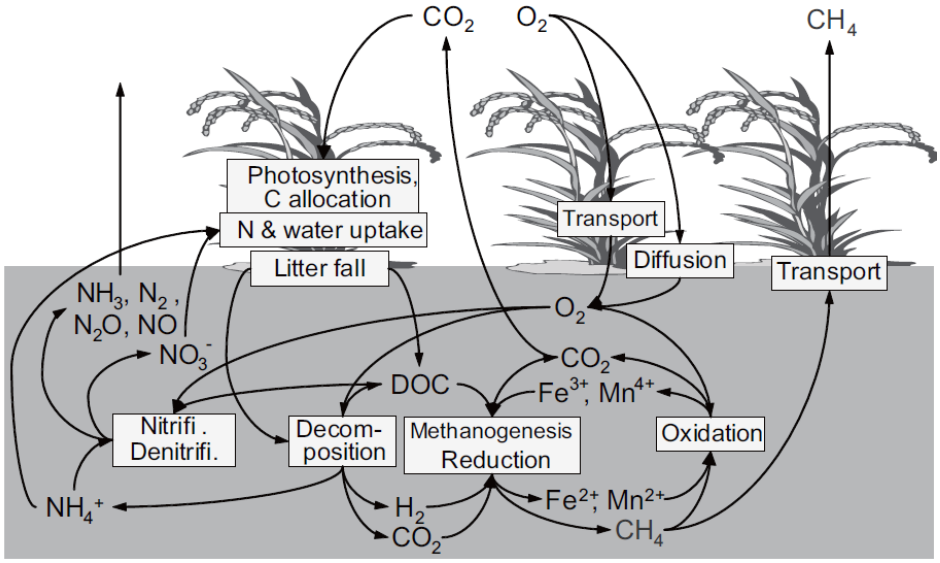


Figure 5-5 Conceptual scheme of the DNDC-Rice model

Reference: Fumoto et al. (2010)

Tier3 method (DNDC-Rice model) was used to establish emission factor, and modified Tier2 method was used to estimate emissions.

Estimation method used in this section was developed through discussion in the Committee for Greenhouse Gas Emissions Estimation Methods on the basis of a paper of Katayanagi et al. (2016), Katayanagi et al. (2017) and relevant paper.

$$E = \sum_{i,j,k,l} \{(A_i \times f_{Di,j} \times f_{Wi,k} \times f_{Ol}) \times EF_{i,j,k,l}\} \times 16 / 12$$

$$EF = aX + b$$

| | |
|---|---|
| $E$ | : $CH_4$ Emissions from paddy field [$kgCH_4$/year] |
| $i$ | : Region (7 regions in Japan) |
| $j$ | : Type of drainage (Poorly drained, one day drained, 4 hours drained) |
| $k$ | : Type of water regime (Intermittently flooded, continuously flooded) |
| $l$ | : Type of organic matter application (rice straw, compost, non-amendment) |
| $A$ | : Crop area of rice paddy field by region [ha] |
| $f_D$ | : Proportion of drainage |
| $fw$ | : Proportion of water regime |
| $f_O$ | : Proportion by type of organic matter application |
| $EF$ | : EFs by region, drainage, water regime, organic matter management method [$kgCH_4$-C/ha/year] |
| $X$ | : Amount of organic matter [t-C/ha/year] |
| $a$ | : Slope (estimated by regression formula with $CH_4$ emissions calculated by the DNDC-Rice model and amount of organic matter) |
| $b$ | : Intercept (estimated by regression formula with $CH_4$ emissions calculated by the DNDC-Rice model and amount of organic matter) |

- ***Emission Factors***

The DNDC-Rice model was used to calculate the emission factor.

EFs were established on the basis of the information on nationwide 986 points of paddy field. The input data are soil (soil organic carbon content, pH, clay content, dry density, etc.), field drainage (maximum

drainage rate), meteorological data (temperature, precipitation), and field management information (the day of transplantation, harvest date, plowing date, tillage method, fertilization date, fertilizer amount, organic matter application date, amount of organic matter application, organic C/N ratio, flooded date, drained date). The following are input data and references.

- Soil physical and chemical properties: data in 986 points described in the *Basic Survey of Soil Environment* (MAFF), which includes all data needed to be input in the DNDC-Rice model
- Field drainage: Maximum drainage rate of survey sites were set as 15 mm $day^{-1}$, 10 mm $day^{-1}$ and 5 mm $day^{-1}$ based on the data provided in "Flooded Situation" (4 hours drained, one day drained, poor drainage) in the *Fourth Basic Survey on Infrastructure Development of Land Use* (MAFF)
- Meteorological data: Daily lowest temperature, daily highest temperature, and precipitation of the nearest AMeDAS point from each survey site were used.
- Field management information: data set created by Hayano et al. (2013) which were divided the whole Japan to 136 regions in accordance to the primary subdivision area by Japan Meteorological Agency and included cultivated history on the basis of the data published by Japan Agricultural Cooperatives or similar organization in each region were used.
- Amount of organic matter application: By using the method described by Yagasaki and Shirato (2014), application amount of compost and crop residue (e.g. rice straw) plowed into soil by each prefecture in 1981 to 2010 were estimated. In other words, the average amount of crop residues plowed into soil such as rice straw were estimated by multiplying crop residue amount estimated from crop residue from prefecture harvest statistics of rice (and second crop such as wheat and fertilizer feed crops) by percentage plowed into the soil, then, by dividing the value by the rice cropping area. For amount of compost application, the average application amount by each year were estimated by the survey results of *Basic Survey of Soil Environment* (1990). and *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration* (2013).

Using the DNDC-Rice model and the above input data, $CH_4$ flux of each 986 points from 1981 to 2010 (30 years) were estimated by total 8 scenarios (water management 2 scenarios (intermittently flooded and continuously flooded) and organic matter applied 4 scenarios (straw and compost[1], rice straw only, compost only, non-organic matter). Taking into account statistical significant difference of their results, $CH_4$ flux were sorted out by seven regions, drainage (3 levels), water regime, and organic matter application, and estimated averages of each year by each classification. In addition, the regression equation (linear function) to predict $CH_4$ flux (mean values for each year of each category) were determined by amount of organic matter application. Intercept "b" of the regression equation were fixed to the $CH_4$ emissions flux estimated non-organic application scenario.

Total amount of organic matter application by prefecture which was estimated by the method described in Yagasaki and Shirato (2014) were aggregated to region level. In addition, to induce amount of organic matter application by region and application type ($X$) which are used in estimation for the inventory, their data of total amount of organic matter by region and proportion of organic matter management

1 The application scenario "straw and compost" was constructed in the model. However, since proportion of organic matter management to input both straw and compost in Japan ($f_O$) is not available, its scenario is not used for inventory emission estimation.

(Table 5-46) were used. The proportion of organic matter management is based on the survey result of *Basic Survey of Soil Environment*, *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*, *The Project of Basic Survey on Greenhouse Gas Emission Estimation from Agricultural Land Soil*, and *The Project of Basic Survey for Carbon Stock on Agricultural Land Soil*. Amount of organic matter application in each input segment by region and the emission factor of each segment calculated these input, and they are shown in Table 5-41, and Table 5-42 below, respectively.

Table 5-41 Amount of organic matter application by region and type (*X*) [t-C/ha]

| Item | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rice straw | Hokkaido | 1.68 | 2.16 | 2.39 | 2.74 | 2.31 | 2.74 | 2.68 | 2.50 | 2.50 | 2.56 | 2.57 | 2.52 | 2.56 | 2.28 |
| | Tohoku | 1.83 | 2.25 | 2.62 | 2.66 | 2.60 | 2.85 | 2.59 | 2.46 | 2.52 | 2.54 | 2.53 | 2.48 | 2.43 | 2.46 |
| | Hokuriku | 2.97 | 2.99 | 3.41 | 2.36 | 2.43 | 3.60 | 3.34 | 2.31 | 2.37 | 2.33 | 2.38 | 2.52 | 2.34 | 2.38 |
| | Kanto | 1.76 | 2.09 | 2.54 | 2.56 | 2.48 | 2.58 | 2.44 | 2.34 | 2.41 | 2.36 | 2.26 | 2.30 | 2.26 | 2.31 |
| | Tokai and Kinki | 2.29 | 2.65 | 2.87 | 2.97 | 2.83 | 3.06 | 2.83 | 2.75 | 2.84 | 2.70 | 2.82 | 2.87 | 2.80 | 2.79 |
| | Chugoku and Shikoku | 1.96 | 2.51 | 2.72 | 2.74 | 2.50 | 2.90 | 2.71 | 2.58 | 2.59 | 2.48 | 2.57 | 2.68 | 2.67 | 2.63 |
| | Kyusyu and Okinawa | 1.39 | 1.50 | 1.65 | 1.57 | 1.75 | 1.96 | 1.53 | 1.75 | 1.77 | 1.72 | 1.75 | 1.80 | 1.79 | 1.79 |
| Compost | Hokkaido | 1.24 | 0.61 | 0.68 | 1.79 | 2.32 | 2.22 | 2.61 | 2.49 | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 |
| | Tohoku | 1.24 | 0.61 | 0.67 | 1.78 | 2.30 | 2.18 | 2.52 | 2.41 | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 |
| | Hokuriku | 1.23 | 0.61 | 0.67 | 1.78 | 2.31 | 2.20 | 2.58 | 2.47 | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 |
| | Kanto | 1.38 | 0.74 | 0.73 | 2.14 | 2.73 | 2.57 | 2.99 | 2.85 | 2.50 | 2.49 | 2.49 | 2.49 | 2.49 | 2.50 |
| | Tokai and Kinki | 1.25 | 0.61 | 0.68 | 1.80 | 2.34 | 2.22 | 2.61 | 2.48 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 | 2.16 |
| | Chugoku and Shikoku | 1.33 | 0.67 | 0.71 | 1.94 | 2.49 | 2.37 | 2.77 | 2.65 | 2.31 | 2.31 | 2.33 | 2.33 | 2.34 | 2.35 |
| | Kyusyu and Okinawa | 1.60 | 0.95 | 0.85 | 2.82 | 3.82 | 3.58 | 4.33 | 4.11 | 3.67 | 3.70 | 3.73 | 3.77 | 3.75 | 3.79 |

Table 5-42 $CH_4$ emission factors in each segment [kg-$CH_4$-C/ha/year]

| Item | | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Poorly drained field, Continuously flooded | Rice straw | Hokkaido | 571 | 701 | 765 | 859 | 743 | 859 | 843 | 794 | 795 | 811 | 812 | 798 | 811 | 734 |
| | | Tohoku | 664 | 775 | 875 | 886 | 871 | 936 | 867 | 833 | 847 | 854 | 850 | 839 | 825 | 833 |
| | | Hokuriku | 805 | 810 | 909 | 664 | 679 | 953 | 892 | 653 | 666 | 655 | 668 | 701 | 660 | 668 |
| | | Kanto | 235 | 276 | 331 | 333 | 324 | 335 | 319 | 306 | 316 | 309 | 297 | 302 | 297 | 303 |
| | | Tokai and Kinki | 492 | 562 | 606 | 627 | 600 | 644 | 599 | 583 | 600 | 574 | 596 | 606 | 593 | 591 |
| | | Chugoku and Shikoku | 464 | 573 | 615 | 619 | 571 | 650 | 611 | 587 | 589 | 568 | 585 | 606 | 605 | 597 |
| | | Kyusyu and Okinawa | 185 | 198 | 216 | 206 | 229 | 254 | 202 | 228 | 231 | 224 | 228 | 235 | 234 | 234 |
| | Compost | Hokkaido | 452 | 279 | 298 | 600 | 746 | 717 | 823 | 792 | 698 | 698 | 698 | 698 | 698 | 698 |
| | | Tohoku | 505 | 337 | 355 | 651 | 790 | 757 | 848 | 820 | 748 | 748 | 748 | 748 | 748 | 748 |
| | | Hokuriku | 401 | 254 | 270 | 529 | 652 | 627 | 715 | 689 | 613 | 613 | 613 | 613 | 613 | 613 |
| | | Kanto | 188 | 109 | 108 | 282 | 355 | 335 | 387 | 370 | 326 | 325 | 325 | 325 | 325 | 326 |
| | | Tokai and Kinki | 284 | 157 | 170 | 394 | 500 | 478 | 554 | 530 | 466 | 466 | 466 | 466 | 466 | 466 |
| | | Chugoku and Shikoku | 341 | 210 | 218 | 460 | 570 | 546 | 624 | 600 | 534 | 534 | 537 | 538 | 539 | 541 |
| | | Kyusyu and Okinawa | 211 | 131 | 119 | 358 | 481 | 450 | 542 | 515 | 462 | 465 | 469 | 474 | 471 | 476 |
| | No-amendment | Hokkaido | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 |
| | | Tohoku | 175 | 175 | 175 | 175 | 175 | 175 | 175 | 175 | 175 | 175 | 175 | 175 | 175 | 175 |
| | | Hokuriku | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 |
| | | Kanto | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| | | Tokai and Kinki | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |
| | | Chugoku and Shikoku | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 |
| | | Kyusyu and Okinawa | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| Poorly drained field, Intermittently flooded | Rice straw | Hokkaido | 571 | 701 | 765 | 859 | 743 | 859 | 843 | 794 | 795 | 811 | 812 | 798 | 811 | 734 |
| | | Tohoku | 637 | 747 | 846 | 856 | 842 | 906 | 838 | 805 | 818 | 825 | 821 | 810 | 797 | 804 |
| | | Hokuriku | 605 | 609 | 691 | 488 | 501 | 727 | 677 | 479 | 490 | 481 | 492 | 519 | 485 | 492 |
| | | Kanto | 212 | 249 | 298 | 300 | 292 | 302 | 287 | 275 | 284 | 278 | 267 | 272 | 268 | 273 |
| | | Tokai and Kinki | 399 | 457 | 493 | 510 | 488 | 525 | 487 | 473 | 488 | 466 | 485 | 493 | 482 | 480 |
| | | Chugoku and Shikoku | 416 | 518 | 556 | 560 | 515 | 589 | 553 | 530 | 533 | 512 | 528 | 548 | 547 | 540 |
| | | Kyusyu and Okinawa | 162 | 173 | 188 | 180 | 199 | 220 | 176 | 198 | 201 | 195 | 198 | 204 | 203 | 203 |
| | Compost | Hokkaido | 452 | 279 | 298 | 600 | 746 | 717 | 823 | 792 | 698 | 698 | 698 | 698 | 698 | 698 |
| | | Tohoku | 480 | 314 | 332 | 624 | 762 | 730 | 819 | 792 | 720 | 720 | 720 | 720 | 720 | 720 |
| | | Hokuriku | 271 | 150 | 163 | 377 | 479 | 458 | 531 | 509 | 447 | 447 | 447 | 447 | 447 | 447 |
| | | Kanto | 170 | 99 | 98 | 254 | 319 | 301 | 348 | 333 | 293 | 293 | 292 | 293 | 293 | 293 |
| | | Tokai and Kinki | 227 | 122 | 133 | 318 | 406 | 387 | 450 | 430 | 377 | 377 | 377 | 377 | 377 | 377 |
| | | Chugoku and Shikoku | 302 | 180 | 187 | 412 | 514 | 492 | 565 | 543 | 481 | 481 | 484 | 484 | 486 | 487 |
| | | Kyusyu and Okinawa | 183 | 116 | 106 | 308 | 412 | 386 | 464 | 441 | 396 | 399 | 402 | 406 | 404 | 408 |
| | No-amendment | Hokkaido | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 |
| | | Tohoku | 153 | 153 | 153 | 153 | 153 | 153 | 153 | 153 | 153 | 153 | 153 | 153 | 153 | 153 |
| | | Hokuriku | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| | | Kanto | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | | Tokai and Kinki | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| | | Chugoku and Shikoku | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 57 |
| | | Kyusyu and Okinawa | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |

Table 5-42 $CH_4$ emission factors in each segment [$kgCH_4$-C/ha/year] (Continued)

| Item | | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| One day drained field, Continuously flooded | Rice straw | Hokkaido | 333 | 417 | 458 | 519 | 444 | 518 | 508 | 477 | 477 | 488 | 488 | 479 | 488 | 438 |
| | | Tohoku | 492 | 576 | 653 | 661 | 649 | 699 | 646 | 621 | 631 | 637 | 634 | 625 | 615 | 620 |
| | | Hokuriku | 608 | 612 | 692 | 493 | 506 | 728 | 678 | 484 | 495 | 486 | 497 | 523 | 490 | 497 |
| | | Kanto | 156 | 182 | 218 | 219 | 213 | 220 | 210 | 201 | 208 | 203 | 196 | 199 | 196 | 200 |
| | | Tokai and Kinki | 225 | 258 | 279 | 289 | 276 | 297 | 275 | 268 | 276 | 264 | 274 | 279 | 273 | 272 |
| | | Chugoku and Shikoku | 184 | 232 | 250 | 252 | 231 | 265 | 248 | 238 | 239 | 229 | 237 | 246 | 246 | 242 |
| | | Kyusyu and Okinawa | 155 | 166 | 180 | 172 | 191 | 212 | 169 | 190 | 193 | 187 | 191 | 196 | 195 | 195 |
| | Compost | Hokkaido | 256 | 145 | 157 | 352 | 446 | 427 | 495 | 475 | 415 | 415 | 415 | 415 | 415 | 415 |
| | | Tohoku | 371 | 242 | 256 | 482 | 588 | 563 | 632 | 611 | 556 | 556 | 556 | 556 | 556 | 556 |
| | | Hokuriku | 280 | 160 | 173 | 384 | 484 | 464 | 535 | 514 | 452 | 452 | 452 | 452 | 452 | 452 |
| | | Kanto | 126 | 75 | 75 | 186 | 233 | 220 | 253 | 242 | 214 | 214 | 213 | 214 | 214 | 214 |
| | | Tokai and Kinki | 125 | 65 | 71 | 178 | 229 | 218 | 254 | 243 | 212 | 212 | 212 | 212 | 212 | 212 |
| | | Chugoku and Shikoku | 131 | 74 | 77 | 183 | 230 | 220 | 254 | 244 | 215 | 215 | 216 | 216 | 217 | 218 |
| | | Kyusyu and Okinawa | 176 | 109 | 99 | 300 | 403 | 377 | 455 | 432 | 387 | 390 | 393 | 398 | 395 | 399 |
| | No-amendment | Hokkaido | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |
| | | Tohoku | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 | 119 |
| | | Hokuriku | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 |
| | | Kanto | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | | Tokai and Kinki | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| | | Chugoku and Shikoku | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | | Kyusyu and Okinawa | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| One day drained field, Intermittently flooded | Rice straw | Hokkaido | 229 | 289 | 318 | 360 | 307 | 360 | 353 | 331 | 331 | 339 | 339 | 333 | 339 | 303 |
| | | Tohoku | 349 | 412 | 469 | 475 | 467 | 504 | 465 | 445 | 453 | 457 | 455 | 448 | 441 | 445 |
| | | Hokuriku | 441 | 444 | 502 | 357 | 366 | 529 | 492 | 351 | 358 | 352 | 360 | 379 | 355 | 360 |
| | | Kanto | 115 | 134 | 160 | 161 | 156 | 162 | 154 | 148 | 153 | 149 | 144 | 146 | 144 | 147 |
| | | Tokai and Kinki | 101 | 116 | 126 | 130 | 124 | 134 | 124 | 121 | 124 | 119 | 123 | 126 | 123 | 122 |
| | | Chugoku and Shikoku | 98 | 125 | 135 | 136 | 124 | 144 | 134 | 128 | 129 | 124 | 128 | 133 | 132 | 131 |
| | | Kyusyu and Okinawa | 88 | 94 | 103 | 98 | 109 | 121 | 96 | 109 | 110 | 107 | 109 | 112 | 111 | 111 |
| | Compost | Hokkaido | 175 | 96 | 105 | 242 | 309 | 296 | 344 | 330 | 287 | 287 | 287 | 287 | 287 | 287 |
| | | Tohoku | 259 | 163 | 173 | 342 | 421 | 402 | 454 | 438 | 397 | 397 | 397 | 397 | 397 | 397 |
| | | Hokuriku | 201 | 114 | 124 | 277 | 350 | 335 | 388 | 372 | 327 | 327 | 327 | 327 | 327 | 327 |
| | | Kanto | 93 | 57 | 56 | 137 | 171 | 161 | 186 | 178 | 157 | 157 | 157 | 157 | 157 | 157 |
| | | Tokai and Kinki | 56 | 29 | 32 | 80 | 103 | 98 | 114 | 109 | 95 | 95 | 95 | 95 | 95 | 95 |
| | | Chugoku and Shikoku | 69 | 37 | 39 | 98 | 124 | 118 | 137 | 131 | 115 | 116 | 116 | 116 | 117 | 117 |
| | | Kyusyu and Okinawa | 100 | 62 | 56 | 171 | 230 | 215 | 260 | 247 | 221 | 223 | 225 | 227 | 225 | 228 |
| | No-amendment | Hokkaido | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| | | Tohoku | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 | 71 |
| | | Hokuriku | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 |
| | | Kanto | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| | | Tokai and Kinki | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | Chugoku and Shikoku | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | | Kyusyu and Okinawa | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| 4 hour drained field, Continuously flooded | Rice straw | Hokkaido | 300 | 376 | 413 | 468 | 400 | 468 | 459 | 430 | 430 | 440 | 441 | 433 | 440 | 395 |
| | | Tohoku | 451 | 532 | 605 | 612 | 601 | 649 | 598 | 574 | 584 | 589 | 586 | 578 | 568 | 574 |
| | | Hokuriku | 578 | 582 | 659 | 469 | 481 | 693 | 646 | 461 | 471 | 463 | 473 | 498 | 466 | 472 |
| | | Kanto | 208 | 242 | 288 | 289 | 282 | 291 | 277 | 267 | 275 | 269 | 259 | 263 | 259 | 264 |
| | | Tokai and Kinki | 240 | 275 | 296 | 307 | 293 | 316 | 293 | 285 | 294 | 281 | 292 | 297 | 290 | 289 |
| | | Chugoku and Shikoku | 250 | 313 | 337 | 339 | 312 | 357 | 335 | 321 | 322 | 310 | 319 | 332 | 331 | 327 |
| | | Kyusyu and Okinawa | 185 | 198 | 216 | 206 | 229 | 255 | 202 | 228 | 232 | 225 | 229 | 235 | 234 | 234 |
| | Compost | Hokkaido | 230 | 130 | 140 | 317 | 402 | 385 | 447 | 429 | 374 | 374 | 374 | 374 | 374 | 374 |
| | | Tohoku | 336 | 214 | 227 | 442 | 543 | 519 | 585 | 565 | 512 | 512 | 512 | 512 | 512 | 512 |
| | | Hokuriku | 266 | 152 | 165 | 365 | 460 | 441 | 509 | 489 | 430 | 430 | 430 | 430 | 430 | 430 |
| | | Kanto | 169 | 103 | 102 | 247 | 307 | 291 | 334 | 320 | 283 | 282 | 282 | 282 | 283 | 283 |
| | | Tokai and Kinki | 137 | 73 | 80 | 191 | 244 | 233 | 271 | 259 | 227 | 227 | 227 | 227 | 227 | 227 |
| | | Chugoku and Shikoku | 179 | 104 | 108 | 248 | 311 | 297 | 342 | 328 | 290 | 290 | 292 | 292 | 293 | 294 |
| | | Kyusyu and Okinawa | 211 | 130 | 118 | 360 | 484 | 454 | 547 | 519 | 465 | 469 | 473 | 478 | 475 | 480 |
| | No-amendment | Hokkaido | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| | | Tohoku | 97 | 97 | 97 | 97 | 97 | 97 | 97 | 97 | 97 | 97 | 97 | 97 | 97 | 97 |
| | | Hokuriku | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 |
| | | Kanto | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 |
| | | Tokai and Kinki | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| | | Chugoku and Shikoku | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 |
| | | Kyusyu and Okinawa | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |

Table 5-42 $CH_4$ emission factors in each segment [$kgCH_4$-C/ha/year] (Continued)

| Item | | | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 hour drained field, Intermittently flooded | Rice straw | Hokkaido | 166 | 210 | 231 | 263 | 224 | 263 | 257 | 241 | 241 | 247 | 247 | 242 | 247 | 221 |
| | | Tohoku | 316 | 374 | 427 | 432 | 424 | 458 | 422 | 404 | 412 | 415 | 413 | 407 | 400 | 404 |
| | | Hokuriku | 390 | 392 | 445 | 315 | 323 | 468 | 436 | 309 | 316 | 310 | 317 | 334 | 313 | 317 |
| | | Kanto | 143 | 167 | 199 | 200 | 195 | 201 | 192 | 184 | 190 | 186 | 179 | 182 | 179 | 182 |
| | | Tokai and Kinki | 135 | 154 | 167 | 173 | 165 | 178 | 165 | 160 | 165 | 158 | 164 | 167 | 163 | 163 |
| | | Chugoku and Shikoku | 173 | 217 | 233 | 235 | 216 | 248 | 232 | 222 | 223 | 214 | 221 | 230 | 229 | 226 |
| | | Kyusyu and Okinawa | 109 | 117 | 128 | 122 | 136 | 151 | 120 | 135 | 137 | 133 | 135 | 139 | 139 | 139 |
| | Compost | Hokkaido | 126 | 69 | 75 | 176 | 225 | 215 | 251 | 240 | 209 | 209 | 209 | 209 | 209 | 209 |
| | | Tohoku | 232 | 144 | 154 | 309 | 382 | 365 | 412 | 398 | 360 | 360 | 360 | 360 | 360 | 360 |
| | | Hokuriku | 175 | 97 | 106 | 243 | 309 | 295 | 342 | 328 | 288 | 288 | 288 | 288 | 288 | 288 |
| | | Kanto | 115 | 69 | 68 | 170 | 213 | 201 | 231 | 221 | 195 | 195 | 195 | 195 | 195 | 196 |
| | | Tokai and Kinki | 76 | 40 | 44 | 107 | 137 | 131 | 152 | 145 | 127 | 127 | 127 | 127 | 127 | 127 |
| | | Chugoku and Shikoku | 123 | 71 | 74 | 171 | 215 | 206 | 237 | 227 | 201 | 201 | 202 | 202 | 203 | 204 |
| | | Kyusyu and Okinawa | 125 | 76 | 69 | 214 | 288 | 270 | 325 | 309 | 276 | 279 | 281 | 284 | 282 | 285 |
| | No-amendment | Hokkaido | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| | | Tohoku | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 |
| | | Hokuriku | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| | | Kanto | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | | Tokai and Kinki | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| | | Chugoku and Shikoku | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | | Kyusyu and Okinawa | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |

- ***Activity Data***

For area of paddy rice field by region ($A$), data described in the *"Statistics of Cultivated and Planted Area"* by MAFF were used. For drainage ($f_D$), proportion of water regime ($f_w$), proportion of organic matter ($f_O$), survey data by MAFF etc. described in Table 5-43 to Table 5-46 were used respectively.

Table 5-43 Area of paddy fields by region ($A$) [kha]

| Region | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hokkaido | 146 | 163 | 135 | 119 | 115 | 115 | 114 | 113 | 113 | 112 | 111 | 108 | 107 | 106 |
| Tohoku | 525 | 539 | 456 | 444 | 421 | 429 | 406 | 414 | 419 | 419 | 415 | 414 | 413 | 412 |
| Hokuriku | 258 | 260 | 221 | 218 | 211 | 213 | 213 | 213 | 215 | 216 | 214 | 213 | 212 | 213 |
| Kanto | 386 | 390 | 336 | 331 | 320 | 322 | 323 | 324 | 324 | 323 | 322 | 321 | 318 | 316 |
| Tokai | 117 | 116 | 95 | 91 | 87 | 88 | 88 | 88 | 87 | 86 | 85 | 85 | 84 | 84 |
| Kinki | 145 | 148 | 122 | 117 | 111 | 111 | 111 | 111 | 111 | 110 | 108 | 107 | 106 | 106 |
| Chugoku and Shikoku | 236 | 232 | 187 | 182 | 176 | 178 | 176 | 175 | 175 | 173 | 170 | 167 | 165 | 162 |
| Kyusyu and Okinawa | 246 | 251 | 207 | 206 | 196 | 202 | 202 | 203 | 203 | 201 | 199 | 196 | 195 | 193 |
| Total | 2,058 | 2,098 | 1,758 | 1,708 | 1,637 | 1,657 | 1,632 | 1,641 | 1,647 | 1,639 | 1,623 | 1,611 | 1,600 | 1,592 |

Note: Upon the estimation, Tokai and Kinki regions are aggregated as one region
Reference: *Statistics of Cultivated and Planted Area* (MAFF)

Table 5-44 Proportion of drainage ($f_D$)

| Region | 4 hours drained | One day drained | Poorly drained |
|---|---|---|---|
| Hokkaido | 51% | 42% | 7% |
| Tohoku | 63% | 31% | 6% |
| Hokuriku | 69% | 26% | 4% |
| Kanto | 59% | 32% | 9% |
| Tokai and Kinki | 69% | 23% | 8% |
| Chugoku and Shikoku | 65% | 27% | 8% |
| Kyusyu and Okinawa | 74% | 21% | 5% |

Reference: *Forth basic survey on infrastructure development of land use*

Table 5-45 Proportion of water regime ($f_w$)

| Region | Continuously flooded | Intermittently flooded |
|---|---|---|
| Hokkaido | 48% | 52% |
| Tohoku | 5% | 95% |
| Hokuriku | 4% | 96% |
| Kanto | 14% | 86% |
| Tokai and Kinki | 11% | 89% |
| Chugoku and Shikoku | 8% | 92% |
| Kyusyu and Okinawa | 7% | 93% |

Reference: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*

Table 5-46 Proportion of organic matter management in Japan ($f_O$)

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Straw amendment | 60% | 60% | 60% | 60% | 61% | 57% | 62% | 65% | 64% | 64% | 61% | 61% | 61% | 61% |
| Various compost amendment | 20% | 20% | 20% | 20% | 23% | 26% | 22% | 23% | 27% | 27% | 27% | 27% | 27% | 27% |
| No-amendment | 20% | 20% | 20% | 20% | 16% | 17% | 16% | 12% | 9% | 9% | 12% | 12% | 12% | 12% |

Reference: 1990-2007: *Basic Survey of Soil Environment*
2008-2012: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*
2013-2014: *The Project of Basic Survey on Greenhouse Gas Emissions from Agricultural Land Soils*
After 2015: *The Project of Basic Survey for Carbon Stock on Agricultural Land Soil*

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the emission factors, uncertainty (6%) was calculated by the DNDC-Rice model. For the uncertainty of the activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied. As a result, the uncertainties of the emissions were determined to be 6%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

Through the verification for the data of amount of organic matter application reported in 2016 submission, it was recognized that the data of amount of organic matter for compost to be input in the DNDC-Rice model was estimated adding up overlap because the data for sum of straw and compost was input instead of the data for straw. Therefore, the data of amount of organic matter application was reported with revision in 2017 submission.

Comparison of $CH_4$ emissions calculated by the DNDC-Rice model and emissions of actually measured data in the field was discussed and reported in the paper by Minamikawa et al. (2014), Fumoto et al. (2010), and Katayanagi et al. (2016).

Figure 5-6 is comparison of annual methane emission between values observed and values simulated by the DNDC-Rice model described in Katayanagi et al. (2016). The Paper reports that simulated $CH_4$ emission was strongly and significantly correlated with the observations (r=0.861), reflecting the variations caused by differences among the sites and the treatments.

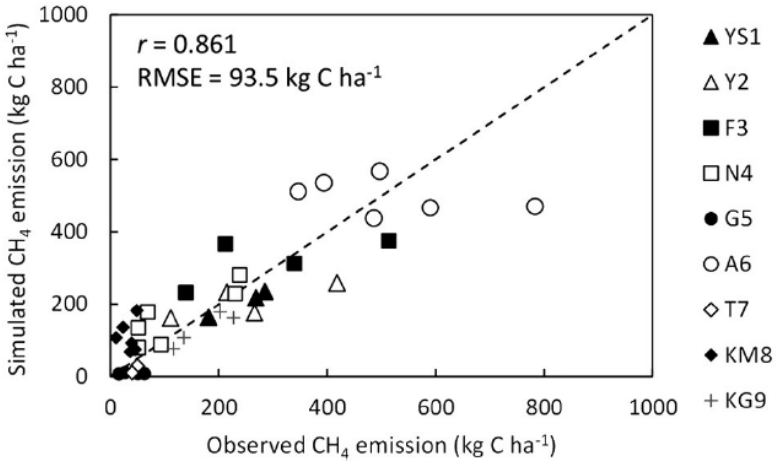


Figure 5-6 Comparison of annual methane emission between values obserbed and values simulated by the DNDC-Rice model

Reference: Quoted from Figure 3 in Katayanagi et al. (2016)

In addition, validation of application of the emission factors calculated by the DNDC-Rice model, into Japan's inventory has been conducted in Katayanagi et al. (2016) and also discussed in the Agriculture Breakout Group on the Committee of GHG Emission Estimation Methods.

***e) Category-specific Recalculations***

There have been no source-specific recalculations.

***f) Category-specific Planned Improvements***

In the future, if the research on the DNDC-Rice model progress and the model are improved and updated, application of the improved version will be considered.

### 5.4.2. Rainfed & Deep Water and Other (3.C.2., 3.C.3., 3.C.4.)

As indicated in the *World Rice Statistics 1993–94*, International Rice Research Institute (IRRI)(1995), rainfed and deep water paddy fields do not exist in Japan. Therefore, this category has been reported as "NO".

Just as indicated in IRRI (1995), a possible source of emissions for other paddy field is upland rice field, but since upland rice field are not flooded, like the soil of fields, they are aerobic. The bacteria that generate $CH_4$ are obligatory anaerobic bacterium, and unless the soil is maintained in an anaerobic state, $CH_4$ will not be emitted. As generation of $CH_4$ is not feasible, this category was reported as "NA".

## 5.5. Agricultural Soils (3.D.)

This section provides the estimation methods for $N_2O$ direct emissions from soils (by applied inorganic fertilizers, organic fertilizers, grazing livestock manure, crop residue, mineralization by soil carbon loss, and plowing of organic soil), and for $N_2O$ indirect emissions (by atmospheric deposition, and nitrogen leaching and run-off).

$N_2O$ emissions from agricultural soils in FY2018 are 5,412 kt-$CO_2$ eq., comprising 0.4% of total

emissions (excluding LULUCF). The value represents a reduction by 23.9% from FY1990. Main drivers of the emission reduction from FY1990 are decreases of nitrogen amount applied to soil of inorganic fertilizer, and organic fertilizer from livestock manure. The main reasons of their decrease of fertilizer are that the area of cropping has been decreasing (Table 5-53) and reducing the usage of fertilizer has been recommended to mitigate nitrogen pollution in groundwater in some areas.

Table 5-47 $N_2O$ emissions from agricultural soils

| Gas | Item | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_2O$ | 3.D.a. Direct emission | 1. Inorganic N fertilizers | kt-$N_2O$ | 6.2 | 5.3 | 5.0 | 4.8 | 3.6 | 4.2 | 4.0 | 4.1 | 4.2 | 4.1 | 3.9 | 3.9 | 3.9 | 3.9 |
| | | 2. Organic N fertilizers | | 5.3 | 5.0 | 4.8 | 4.2 | 4.1 | 4.2 | 4.2 | 4.1 | 4.1 | 4.2 | 4.5 | 4.4 | 4.6 | 4.6 |
| | | 3. Manure by grazing animal | | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | 4. Residues | | 2.4 | 2.3 | 2.5 | 2.3 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 |
| | | 5. Mineralization | | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| | | 6. Cultivation of organic soil | | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| | 3.D.b. Indirect emission | 1. Atmospheric deposition | | 2.7 | 2.5 | 2.3 | 2.1 | 1.9 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.1 | 2.0 | 2.1 | 2.1 |
| | | 2. N leaching and run-off | | 5.4 | 5.1 | 4.8 | 4.5 | 4.0 | 4.2 | 4.1 | 4.1 | 4.2 | 4.1 | 4.1 | 4.1 | 4.2 | 4.1 |
| | Total | | kt-$N_2O$ | 23.9 | 22.1 | 21.2 | 19.8 | 17.4 | 18.5 | 18.1 | 18.1 | 18.3 | 18.1 | 18.2 | 18.1 | 18.3 | 18.2 |
| | | | kt-$CO_2$eq | 7,115 | 6,580 | 6,327 | 5,894 | 5,175 | 5,506 | 5,391 | 5,397 | 5,448 | 5,388 | 5,426 | 5,390 | 5,440 | 5,412 |

### 5.5.1. Direct Soil Emissions (3.D.a.)

Application of inorganic fertilizers, organic fertilizers, and grazing livestock manure, or plowing of crop residues into soil generates ammonium ions in the soil. The soil emits $N_2O$ in the process of oxidizing the ammonium ions into nitrate-nitrogen under aerobic conditions. $N_2O$ is also emitted via denitrification of nitrate. In addition, $N_2O$ is generated by decomposition of organic matter in mineral soil and plowing of organic soil because of nitrification and denitrification of nitrogen.

#### 5.5.1.1. Inorganic N Fertilizers (3.D.a.1.)

##### *a) Category Description*

This section provides the estimation methods for $N_2O$ emissions by the application of inorganic synthetic fertilizers (synthetic fertilizers).

##### *b) Methodological Issues*

- ***Methodology for Estimating Emissions / Removals of GHGs***

$N_2O$ emissions were calculated by Tier2 method, using country-specific emission factors in accordance with decision tree of the *2006 IPCC Guidelines* (Vol. 4, p.11.9, Fig.11.2).

In addition, estimation method for $N_2O$ emission reduction from agricultural soil using synthetic fertilizer with nitrification inhibitor is also established.

$$E = \sum_{ij} (F_{SNij} \times EF_{1ij}) \times 44/28$$

| | |
|---|---|
| $E$ | : $N_2O$ emissions associated with the application of synthetic fertilizer in agricultural soil (crop field) [kg-$N_2O$] |
| $F_{SNij}$ | : Nitrogen amount of synthetic fertilizer $j$ applied to agricultural soil for crop type $i$ [kg-N] |
| $EF_{1ij}$ | : Emission factor of synthetic fertilizer $j$ for crop type $i$ [kg-$N_2O$-N/kg-N] |
| $i$ | : Crop type |
| $j$ | : Fertilizer type (with or without nitrification inhibitor) |

- ***Emission Factors***

Emission factors were established by analyzing measured data in Japan, based on the amount of

application of synthetic fertilizer and $N_2O$ emissions. Emission factors of the application of synthetic fertilizer with nitrification inhibitor were established by multiplying their country-specific emission factor by $N_2O$ reduction rate.

Comparing emission factors among various crops, it was identified that emission factor of tea was significantly higher and emission factor of rice was significantly lower than those of other crops. As there were not significant differences among the other crops, emission factors associated with the application of synthetic fertilizer in agricultural soil were defined three categories for rice, tea and other crops. Emission factor of Japan is lower than that of default value in the *2006 IPCC Guidelines*. It is the reason that the volcanic ash soil that is well-drained soil and widely distributed in Japan releases little $N_2O$ emissions. The emission factor of rice is adopted as a default value within the *2006 IPCC Guidelines* and its validity has been internationally confirmed.

$N_2O$ emission reduction rate using synthetic fertilizer with nitrification inhibitor was decided as 26%, the lower limit of $N_2O$ reduction rate using fertilizer with dicyandiamide (26-36%) described in Akiyama et al. (2010). Although dicyandiamide is dominantly added as nitrification inhibitor in Japan, other chemical materials as inhibitor are used in a few products. Therefore, the lower limit of the rate of dicyandiamide was used to avoid overestimation of emission reduction. In addition, since nitrification seldom occur on flooded situation in paddy rice field, synthetic fertilizer with nitrification inhibitor is never used. Therefore, EF with nitrification inhibitor for paddy rice was not developed.

Table 5-48 $N_2O$ emission factor for synthetic fertilizer to agricultural soil

| Crop type | Emission Factor without nitrogen inhibitor [kg-$N_2O$-N/kg-N] | Emission Factor with nitrogen inhibitor [kg-$N_2O$-N/kg-N] |
|---|---|---|
| Paddy rice | 0.31 % | - |
| Tea | 2.9 % | 2.1 % [ =2.9%×(1-0.26)] |
| Other crops | 0.62 % | 0.46 % [ =0.62%×(1-0.26)] |

Reference: Akiyama et al. 2006 a
Akiyama et al. 2006 b
Akiyama et al. 2010

- ***Activity Data***

Total nitrogen amount of synthetic fertilizer described in *Yearbook of Fertilizer Statistics (Pocket Edition* are used for estimation. To estimate amount of synthetic fertilizer applied to the agricultural soil, amount of synthetic fertilizer applied to forest are subtracted from this total amount (Table 5-49).

In addition, considering emission factors above, to estimate the amount of synthetic fertilizer applied by crop type, values corresponding to the amounts of nitrogen applied for each crop type are calculated by multiplying area of each crop field (Table 5-53) by the amounts of synthetic fertilizers applied per unit area for each crop type based on the results of studies (Tsuruta 2001) in Japan. Total synthetic fertilizer is apportioned to each crop type in accordance with the corresponding application amount for each crop type.

$$F_{SNi} = (F_T - F_{FRST}) \times \frac{(RA_i \times RF_i \times 10)}{\sum(RA_n \times RF_n \times 10)}$$

$F_{SNi}$ : Nitrogen amount of synthetic fertilizer applied to agricultural soil for crop type *i* [t-N]
$F_T$ : Total nitrogen amount of synthetic fertilizer [t-N]
$F_{FRST}$ : Nitrogen amount of synthetic fertilizer applied to forest [t-N]
$RA_i$ : Area of crop field for crop type *i* [ha]
$RF_i$ : Nitrogen amount of synthetic fertilizer per area of crop field for crop type *i* [kg-N/10a]

$RA_n$ : Area of crop field by each crop type [ha]

$RF_n$ : Nitrogen amount of synthetic fertilizer per area of crop field by each crop type [kg-N/10a]

The amounts of fertilizer applied by crop type are known because the amounts of synthetic and organic fertilizers applied for each crop type were determined by a farming study conducted in 2000 (Tsuruta 2001). Based on expert judgement, there is likely little year-on-year change in application amounts to crops except for paddy rice and tea, data on the amounts of synthetic fertilizer applied per unit area according to Tsuruta (2001) were applied uniformly for these crops in all the years.

Fertilizer application amounts for tea change from year to year because of the influence of the transition of recommended rate of fertilizer application by local governments and other factors. The amounts of nitrogen applied to tea fields (the total amount of nitrogen from synthetic and organic fertilizer) in 1993, 1998, and 2002 investigated and summarized by Nonaka (2005) and the ratio of synthetic fertilizer and organic fertilizer applied to tea according to Tsuruta (2001) were used to estimate the amounts of synthetic and organic fertilizer applied in 1993, 1998 and 2002. Time-series data were prepared by interpolating calculated values by estimated fertilizer amount data of three years into from 1993 to 2002 and deferring the 1993 data for previous years and the 2002 data for subsequent years (see Table 5-52).

For paddy rice, the data of synthetic fertilizer application amount for unit area for each year in *Yearbook of Fertilizer Statistics* was used. The values of paddy rice were substituted for upland rice.

Shipping amount of synthetic fertilizer with nitrification inhibitor which is included in “N amount of synthetic N fertilizer applied (agricultural soil)" is from surveyed data by MAFF since 1996, and 13% which is an average nitrogen content in production from major manufacturers was applied for emission estimation. In addition, since synthetic fertilizer with nitrification inhibitor was not used for paddy rice nor feed crops, they were excluded from estimation.

Table 5-49 Nitrogen amount of synthetic fertilizer applied to soil [t-N]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total N amount of synthetic N fertilizer | 611,955 | 527,517 | 487,406 | 471,190 | 350,135 | 409,590 | 387,201 | 396,783 | 409,918 | 394,629 | 372,339 | 374,879 | 374,879 | 374,879 |
| N amounut of synthetic N fertilizer applied (forest soil) | 288 | 248 | 229 | 222 | 165 | 193 | 182 | 187 | 193 | 186 | 175 | 176 | 176 | 176 |
| N amounut of synthetic N fertilizer applied (agricultural soil) | 611,667 | 527,269 | 487,177 | 470,968 | 349,970 | 409,397 | 387,019 | 396,596 | 409,725 | 394,443 | 372,164 | 374,703 | 374,703 | 374,703 |

Note: This amount includes synthetic fertilizer with nitrification inhibitor.
Reference: Total N amount: *Yearbook of Fertilizer Statistics (Pocket Edition)*
N amount to forest soil: Estimated on the basis of Forestry Agency Survey

Table 5-50 Nitrogen amount of synthetic fertilizer with nitrification inhibitor [t-N]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N amount of synthetic N fertilizer with nitrification inhibitor | NO | NO | 4,030 | 4,290 | 5,980 | 4,940 | 5,850 | 5,070 | 7,800 | 4,550 | 5,070 | 5,330 | 5,070 | 5,590 |

Reference: Estimated from MAFF data and nitrogen contents (13%)

Table 5-51 Amount of synthetic fertilizers application per area by each type of crop (other than rice and tea)

| Crop type | Amount of application [kg-N/10a] |
|---|---|
| Vegetables | 21.27 |
| Fruit | 14.70 |
| Potatoes | 12.70 |
| Pulse | 3.10 |
| Feed crops | 10.00 |
| Sweet potato | 6.20 |
| Wheat | 10.00 |
| Coarse cereal (including Buckwheat) | 4.12 |
| Mulberries | 16.20 |
| Industrial crops | 22.90 |
| Tobacco | 15.40 |

Reference: Tsuruta (2001)

Table 5-52 Amount of synthetic fertilizers application per area (rice and tea) [kg-N/10a]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amount of synthetic N fertilizers application per area (rice) | 9.65 | 8.71 | 7.34 | 6.62 | 5.80 | 5.95 | 5.93 | 6.04 | 6.10 | 5.97 | 5.85 | 5.85 | 5.85 | 5.85 |
| Amount of synthetic N fertilizers application per area (tea) | 57.23 | 54.88 | 48.06 | 44.76 | 44.76 | 44.76 | 44.76 | 44.76 | 44.76 | 44.76 | 44.76 | 44.76 | 44.76 | 44.76 |

Reference: Rice: *Yearbook of Fertilizer Statistics (Pocket Edition)*, Tea: Nonaka (2005) and Tsuruta (2001)

Table 5-53 Area of cropping by each type of crop [kha]

| Crop type | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vegetables | 620.1 | 564.4 | 524.9 | 476.3 | 468.7 | 465.4 | 460.4 | 457.9 | 453.4 | 452.1 | 448.9 | 444.1 | 441.7 | 437.3 |
| Paddy rice (for grain) | 2,055.0 | 2,106.0 | 1,763.0 | 1,702.0 | 1,621.0 | 1,625.0 | 1,574.0 | 1,579.0 | 1,597.0 | 1,573.0 | 1,505.0 | 1,478.0 | 1,465.0 | 1,470.0 |
| Fruit | 346.3 | 314.9 | 286.2 | 265.4 | 250.7 | 246.9 | 243.5 | 240.3 | 237.0 | 233.8 | 230.2 | 226.7 | 222.9 | 218.8 |
| Tea | 58.5 | 53.7 | 50.4 | 48.7 | 47.3 | 46.8 | 46.2 | 45.9 | 45.4 | 44.8 | 44.0 | 43.1 | 42.4 | 41.5 |
| Potatoes | 115.8 | 104.4 | 94.6 | 86.9 | 83.1 | 82.5 | 81.0 | 81.2 | 79.7 | 78.3 | 77.4 | 77.2 | 77.2 | 76.5 |
| Pulse | 256.6 | 155.5 | 191.8 | 193.9 | 197.5 | 189.0 | 186.2 | 180.2 | 178.5 | 181.0 | 187.6 | 187.7 | 187.9 | 185.4 |
| Feed crops | 1,096.0 | 1,013.0 | 1,026.0 | 1,030.0 | 1,008.0 | 1,012.0 | 1,030.0 | 1,029.0 | 1,012.0 | 1,019.0 | 1,072.0 | 1,082.0 | 1,084.9 | 1,068.6 |
| Sweet potato | 60.6 | 49.4 | 43.4 | 40.8 | 40.5 | 39.7 | 38.9 | 38.8 | 38.6 | 38.0 | 36.6 | 36.0 | 35.6 | 35.7 |
| Wheat | 366.4 | 210.2 | 236.6 | 268.3 | 266.2 | 265.7 | 271.7 | 269.5 | 269.5 | 272.7 | 274.4 | 275.9 | 273.7 | 272.9 |
| Coarse cereal (incl. buckwheat) | 29.6 | 23.4 | 38.4 | 45.9 | 47.5 | 49.7 | 58.1 | 62.6 | 62.9 | 61.4 | 59.7 | 62.2 | 64.5 | 65.5 |
| Mulberries | 59.5 | 26.3 | 5.9 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Industrial crops | 142.9 | 124.5 | 116.3 | 110.3 | 106.4 | 104.8 | 101.9 | 100.2 | 98.5 | 97.8 | 98.8 | 99.3 | 100.3 | 98.2 |
| Tobacco | 30.0 | 26.4 | 24.0 | 19.1 | 15.8 | 15.0 | 13.0 | 9.0 | 8.9 | 8.6 | 8.3 | 8.0 | 7.6 | 7.1 |
| Upland rice | 18.9 | 11.6 | 7.1 | 4.5 | 3.0 | 2.9 | 2.4 | 2.1 | 1.7 | 1.4 | 1.2 | 0.9 | 0.8 | 0.8 |

Reference: Potatoes: *Vegetable Production and Shipment Statistics*, Tobacco: Survey of Japan Tobacco Inc., Mulberries: MAFF Survey, Other crops: *Statistics of Cultivated and Planted Area* (Note: "Industrial crops" is subtracted the area of "Tabacco" from estimated value from total area of tea, rapa, sugar beet and sugarcane. The values of "Vegetable" before 2017 excluded the value of "Potatoes". The values of "Vegetable", "Fruit", "Pulse", "Feed crops" and "Coarse cereal" in 2017 are estimated by using the last five years average proportion of sum of planted areas for object crops in each crop group to the statistic because of the abolition of statistical survey for planted area of these crop groups.)

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the emission factors, uncertainty (31%) described in the reference of EFs, Akiyama et al. (2006), was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 31%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*.

The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1. Comparison with Japan's EF and the default EF in the IPCC Guidelines is described in the section 'Emissions factors' above.

***e) Category-specific Recalculations***

Statistic data of synthetic fertilizer without nitrification inhibitor after 2015 and the data of synthetic fertilizer with nitrification inhibitor after 2016 were revised. Therefore, emissions after 2015 were recalculated. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

There are no improvement plans.

### 5.5.1.2. Organic Fertilizer (3.D.a.2.)

***a) Category Description***

This section provides the estimation methods for $N_2O$ emissions by application of organic fertilizer (livestock and other composting and barnyard manure).

***b) Methodological Issues***

- ***Estimation Method***

Emissions of $N_2O$ have been calculated by Tier2 method in accordance with decision tree of the *2006 IPCC Guidelines* (Vol.4, p.11.9, Fig.11.2).

$$E = \sum_i (N_{ONi} \times EF_{1i}) \times 44/28$$

| | |
|---|---|
| $E$ | : $N_2O$ emissions from the application of organic fertilizers to agricultural soils [kg-$N_2O$] |
| $N_{ONi}$ | : Nitrogen amount of organic fertilizer applied to agricultural soil for crop type *i* [kg-N] |
| $EF_{1i}$ | : Emission factor of organic fertilizer for crop type *i* [kg-$N_2O$-N/kg-N] |
| $i$ | : Type of crop |

- ***Emission Factors***

Emission factors for $N_2O$ associated with the application of Inorganic N Fertilizers and Organic Fertilizers were defined as the same value, because there was no significant difference between emission factors of synthetic fertilizers and organic fertilizers.

- ***Activity Data***

For activity data (total amount of nitrogen contained in the organic fertilizers), the following nitrogen was calculated on the basis of formula described in the *2006 IPCC Guidelines* (Vol.4, p11.12, Equation 11.3).

$$N_{ON} = N_{AM} + N_{SEW} + N_{FU} + N_{COMPsub} + N_{OOA}$$

| | |
|---|---|
| $N_{ON}$ | : Nitrogen amount in organic fertilizers applied to soil |
| $N_{AM}$ | : Nitrogen amount in livestock manure applied to soil |
| $N_{SEW}$ | : Nitrogen amount in sewage sludge applied to soil |

$N_{FU}$ : Nitrogen amount in human waste applied to soil

$N_{COMPsub}$ : Nitrogen amount in composting sub-material applied to soil (rice straw, rice husk, wheat straw )

$N_{OOA}$ : Nitrogen amount in other organic fertilizers applied to soil (fish residue, soybean oil residue, canola oil residue, etc.)

- ***Nitrogen amount in livestock manure applied to soil ($N_{AM}$)***

Amount of nitrogen in livestock manure applied to agricultural soil ($N_{AM}$) was calculated by subtracting the amount of nitrogen included in grazing cattle manure ($N_{PRP}$), nitrogen in livestock manure volatilized as $N_2O$ (excluding grazing cattle) ($N_{N2O}$), nitrogen in manure volatilized as $NH_3$ and $NO_X$ (excluding grazing cattle) ($N_{NH3+NOx}$), nitrogen eliminated by "incineration" and "purification" ($N_{inc+pur}$), and nitrogen in manure disposed directly as waste ($N_{disposal}$) from the total nitrogen in livestock manure ($N_{Total\text{-}AW}$).

$$N_{AM} = N_{Total\text{-}AW} - N_{PRP} - N_{N_2O} - N_{NH_3+NOx} - N_{inc+pur} - N_{disposal}$$

$N_{AM}$ : Nitrogen amount in livestock manure applied to soil [kg-N]

$N_{Total\text{-}AW}$ : Total amount of nitrogen excreted by livestock [kg-N]

$N_{PRP}$ : Amount of nitrogen included in grazing cattle manure [kg-N]

$N_{N_2O}$ : Nitrogen in livestock manure volatilized as $N_2O$ (excluding grazing cattle) [kg-N]

$N_{NH_3+NOx}$ : Nitrogen in manure volatilized as $NH_3$ and $NO_X$ (excluding grazing cattle) [kg-$NH_3$-N + $NO_X$-N]

$N_{inc+pur}$ : Nitrogen eliminated by "incineration" and "purification [kg-N]

$N_{disposal}$ : Amount of nitrogen in manure disposed directly as waste [kg-N]

For the amount of nitrogen included in grazing livestock manure ($N_{PRP}$), nitrogen in livestock manure volatilized as $N_2O$ (excluding grazing livestock) ($N_{N2O}$) and nitrogen eliminated by "Incineration" and "Purification ($N_{inc+pur}$), the amount calculated in 3.B. Manure management were used.

Nitrogen in manure disposed directly as waste ($N_{disposal}$) includes manure sent to landfill after treatment ("Treated disposal") and manure sent directly to landfill without treatment ("Direct final disposal"). The amount of treated disposal manure is negligible and its treatment method is unknown. Therefore, treated disposal manure was included in the calculation of the direct final disposal manure.

The amount of nitrogen in manure disposed directly as waste ($N_{disposal}$) was calculated as equation below.

*Nitrogen content in livestock manure disposed in the direct final disposal ($N_{disposal}$)*
= Total amount of direct final disposal and treated final disposal × Average nitrogen contents in manure

For the total amounts of direct final disposal and treated disposal, data shown in the *Report of the Research on the State of Wide-range Movement and the Cyclical Use of Wastes* (MOE) were used. Average nitrogen contents in manure were calculated from total nitrogen amount in manure and total manure amount.

The livestock manure that was not applied to agricultural soils but disposed directly was included in the estimation of "7.2.1. Emissions from Managed Landfill Sites (5.A.1.)"

Table 5-54 Nitrogen amount in livestock manure applied to agricultural soil ($N_{AM}$) [t-N]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total nitrogen amount in animal manure ($N_{Total-AW}$) | 786,060 | 743,633 | 692,290 | 634,484 | 603,321 | 589,142 | 580,013 | 569,103 | 558,658 | 551,719 | 551,507 | 552,595 | 563,117 | 564,245 |
| Nigrtogen amount in manure for grazing animal ($N_{PRP}$) | 12,987 | 12,836 | 11,935 | 11,162 | 11,072 | 10,709 | 10,721 | 10,505 | 10,390 | 9,996 | 10,278 | 10,237 | 10,399 | 10,568 |
| Amount of $N_2O$-N released from manure (excluing Incineration and Purification) ($N_{N2O}$) | 4,460 | 4,363 | 4,318 | 4,690 | 5,080 | 4,943 | 4,898 | 4,798 | 4,679 | 4,593 | 4,591 | 4,577 | 4,639 | 4,629 |
| Amount of $NH_3$-N and NOx-N released from manure (excluding garazing animal) ($N_{NH3}$+$N_{Nox}$) | 270,977 | 256,432 | 232,562 | 199,757 | 179,093 | 174,361 | 170,407 | 166,455 | 164,621 | 163,662 | 164,003 | 165,046 | 168,511 | 169,377 |
| Nitrogen eliminated by Incineration and purification ($N_{inc+pur}$) | 77,554 | 67,389 | 66,526 | 78,933 | 90,246 | 90,096 | 88,956 | 88,922 | 86,773 | 85,687 | 84,707 | 84,961 | 87,580 | 87,746 |
| Nitrogen amount in manure disposed directly as waste ($N_{disposal}$) | 317 | 301 | 272 | 248 | 315 | 235 | 239 | 278 | 285 | 293 | 280 | 288 | 280 | 280 |
| Nitrogen amount in livestock manure applied to agricultural soil ($N_{AM}$) | 419,764 | 402,311 | 376,677 | 339,692 | 317,514 | 308,799 | 304,792 | 298,144 | 291,909 | 287,489 | 287,648 | 287,486 | 291,708 | 291,645 |

- ***Nitrogen amount in sewage sludge applied to soil ($N_{SEW}$)***

Nitrogen amount in sewage sludge applied to soil ($N_{SEW}$) was calculated by multiplying amount of sludge described in the *Yearbook of Fertilizer Statistics (Pocket Edition)* by nitrogen contents established using data provided by Japan Sewage Works Association.

- ***Nitrogen amount in human wastes applied to soil ($N_{FU}$ )***

Nitrogen amount of human waste ($N_{FU}$) was calculated from the amount of human waste-derived nitrogen calculated with the data of *Waste Treatment in Japan*.

- ***Nitrogen amount in composting sub-material applied to soil ($N_{COMPsub}$)***

For composting sub-material, data of "composting" and "barn bedding" of rice straw, rice chaff and wheat straw calculated from each prefecture data were used. For nitrogen content rate of rice straw, rice chaff and wheat straw, values described in 5.5.1.4. “Crop Residue” below were used (Table 5-62).

- ***Nitrogen amount in other organic fertilizers applied to soil ($N_{OOA}$)***

Nitrogen amount in other organic fertilizers (fish residue, soybean oil residue, canola oil residue, etc.) applied to soil ($N_{OOA}$) was calculated by multiplying amount of other organic fertilizer described in the *Yearbook of Fertilizer Statistics (Pocket Edition)* by nitrogen contents established using data provided in the *Yearbook of Fertilizer Statistics (Pocket Edition)*.

Table 5-55 Amount of sludge and other organic fertilizer [kt]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Animal derived Fertilizers | 384.1 | 389.4 | 341.0 | 262.7 | 271.2 | 268.3 | 259.8 | 302.6 | 298.3 | 268.2 | 300.6 | 310.0 | 285.4 | 285.4 |
| Fish residue | 111.5 | 88.6 | 89.0 | 73.9 | 70.0 | 62.2 | 52.1 | 55.4 | 60.0 | 51.7 | 52.9 | 54.7 | 53.3 | 53.3 |
| Bone meal | 113.1 | 134.2 | 112.8 | 11.4 | 21.3 | 16.7 | 17.6 | 19.4 | 16.2 | 18.5 | 20.0 | 22.3 | 20.0 | 20.0 |
| Other animal derived | 159.5 | 166.6 | 139.2 | 177.5 | 179.9 | 189.4 | 190.1 | 227.7 | 222.1 | 198.1 | 227.7 | 233.0 | 212.1 | 212.1 |
| Plant derived fertilizers | 635.9 | 725.7 | 982.4 | 494.8 | 643.2 | 1,064.3 | 1,190.9 | 1,079.2 | 1,203.7 | 1,455.4 | 1,852.7 | 1,810.9 | 2,012.0 | 2,012.0 |
| Soybean oil residue | 3.5 | 4.7 | 28.9 | 1.1 | 36.1 | 209.5 | 138.5 | 134.4 | 167.7 | 265.0 | 477.0 | 494.5 | 491.3 | 491.3 |
| Canola oil residue | 451.0 | 437.2 | 620.7 | 241.0 | 228.0 | 221.4 | 396.3 | 347.9 | 288.4 | 399.5 | 474.8 | 486.8 | 449.3 | 449.3 |
| Other plant derived | 181.4 | 283.8 | 332.8 | 252.7 | 379.1 | 633.5 | 656.1 | 596.9 | 747.6 | 790.9 | 900.9 | 829.6 | 1,071.4 | 1,071.4 |
| Sludge | 787.3 | 935.2 | 817.7 | 1,287.4 | 1,295.0 | 1,395.6 | 1,361.5 | 1,329.3 | 1,355.5 | 1,292.9 | 1,395.7 | 1,351.7 | 1,377.8 | 1,377.8 |

Reference: *Yearbook of Fertilizer Statistics (Pocket Edition)*

Table 5-56 Nitrogen content rate of each organic fertilizer

| Organic fertilizer | Nitrogen content |
|---|---|
| Fish residue | 8.0% |
| Bone meal | 4.1% |
| Other animal matters | 7.5% |
| Soybean oil residue | 7.5% |
| Canola oil residue | 5.1% |
| Other vegetable matter | 4.6% |
| Sludge | 2.7% |

Reference: Other than sludge: *Yearbook of Fertilizer Statistics (Pocket Edition)*
Sludge: Established from Japan Sewage Works Association data

Table 5-57 Nitrogen amount in organic fertilizers applied to agricultural soil [t-N]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From livestock manure ($N_{AM}$) | 419,764 | 402,311 | 376,677 | 339,692 | 317,514 | 308,799 | 304,792 | 298,144 | 291,909 | 287,489 | 287,648 | 287,486 | 291,708 | 291,645 |
| From sewage sludge ($N_{SEW}$) | 21,257 | 25,250 | 22,078 | 34,760 | 34,965 | 37,682 | 36,759 | 35,892 | 36,599 | 34,907 | 37,685 | 36,497 | 37,202 | 37,202 |
| From human waste ($N_{FU}$) | 10,394 | 4,747 | 2,116 | 874 | 457 | 427 | 369 | 351 | 286 | 273 | 231 | 204 | 223 | 260 |
| From composting sub-material ($N_{COMPsub}$) | 18,316 | 15,514 | 11,485 | 11,217 | 9,270 | 8,864 | 8,443 | 8,803 | 8,879 | 7,700 | 6,816 | 6,774 | 6,480 | 6,494 |
| From other organic fertilizers ($N_{OOA}$) | 57,128 | 60,790 | 71,314 | 43,685 | 51,743 | 76,006 | 79,927 | 77,593 | 83,796 | 96,378 | 123,560 | 122,844 | 130,034 | 130,034 |
| Total (Nitrogen amount applied to agricultural soil as organic N fertilizer) ($N_{ON}$) | 526,859 | 508,611 | 483,670 | 430,229 | 413,949 | 431,779 | 430,289 | 420,784 | 421,469 | 426,747 | 455,940 | 453,804 | 465,647 | 465,635 |

➢ ***Estimation for nitrogen amount of organic fertilizer applied to agricultural soil for crop type i***

Nitrogen amount of organic fertilizer applied to agricultural soil for crop type *i* is calculated the total nitrogen amount in organic fertilizers applied to agricultural soil above ($N_{ON}$) by multiplying the proportion of nitrogen amount to be applied to crop type *i* for the total nitrogen ($N_{ON}$) (proportion of fertilizer application). The proportion of fertilizer application was calculated by dividing the product of nitrogen amount of organic fertilizer application per unit area of crop field for crop type *i* and the cultivation area for crop type *i* by the grand total of all products for all crop types.

$$N_{ONi} = N_{ON} \times \frac{(RA_i \times RF_i / 10)}{\sum (RA_n \times RF_n / 10)}$$

$N_{ONi}$ : Nitrogen amount of organic fertilizer applied to agricultural soil for crop type *i* [t-N]
$N_{ON}$ : Total nitrogen amount in organic fertilizers applied to agricultural soil [t-N]
$RA_i$ : Area of crop field for crop type *i* [ha]
$RF_i$ : Nitrogen amount of organic fertilizer per area of crop field for crop type *i* [kg-N/10a]
$RA_n$ : Area of crop field by each crop type [ha]
$RF_n$ : Nitrogen amount of organic fertilizer per area of crop field by each crop type [kg-N/10a]

For nitrogen amount in organic fertilizer applied per unit area for tea, as same as the synthetic fertilizers, the amounts of nitrogen applied to tea fields (the total of synthetic and organic) in 1993, 1998, and 2002 investigated and summarized by Nonaka (2005) and the ratio of synthetic fertilizer and organic fertilizer applied to tea according to Tsuruta (2001) were used to estimate the amounts of organic fertilizer applied and time-series data were prepared (see Table 5-52). Organic fertilizer application amount per unit area by each crop type except tea is based on the data on the survey in 2000 as same as synthetic fertilizer. The value of upland rice was substituted by the value of paddy rice. Cultivated area by each crop type is same as synthetic fertilizers.

Table 5-58 Amount of nitrogen as organic fertilizers application per area for tea [kg-N/10a]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amount of organic fertilizers application per area (tea) | 20.77 | 19.92 | 17.44 | 16.24 | 16.24 | 16.24 | 16.24 | 16.24 | 16.24 | 16.24 | 16.24 | 16.24 | 16.24 | 16.24 |

Reference: Nonaka (2005), Tsuruta (2001)

Table 5-59 Amount of nitrogen as organic fertilizers application per area by each type of crop (except tea)

| Crop type | Amount of application [kg-N/10a] |
|---|---|
| Vegetables | 23.62 |
| Paddy rice | 3.2 |
| Fruit | 10.90 |
| Potatoes | 7.94 |
| Pulse | 6.24 |
| Feed crops | 10.00 |
| Sweet potato | 8.85 |
| Wheat | 5.70 |
| Coarse cereal (including Buckwheat) | 1.81 |
| Mulberries | 0.00 |
| Industrial crops | 3.96 |
| Tobacco | 11.41 |

Reference: Tsuruta (2001)

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the emission factors, uncertainty (31%) described in the reference of EFs, Akiyama et al. (2006), was applied. For activity data for livestock manure, 9% for population of broiler given in the *Livestock Statistics* was applied as substitution. For activity data for others, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 32%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Statistic data of organic fertilizer after 2015 were revised. The calculation method of nitrogen content in excretion for non-dairy cattle and swine have been revised. Therefore, the emissions for the whole time-series were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

The same emission factor has been used for inorganic and organic fertilizers. Thus, the possibility to establish separate emission factors for these two types of fertilizer is under consideration.

## 5.5.1.3. Urine and dung deposited by grazing animals (3.D.a.3.)

### *a) Category Description*

This section provides the estimation methods for $N_2O$ emissions from urine and dung deposited by

grazing animals.

***b) Methodological Issues***

The method for calculating $CH_4$ and $N_2O$ emissions from urine and dung deposited by grazing animals is described in 5.3.1 "Livestock Waste Management: Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.)" and 5.3.2. "Buffalo, Sheep, Goats, Horses, Rabbit and Mink (3.B.2., 3.B.4.)".

### 5.5.1.4. Crop Residues (3.D.a.4.)

***a) Category Description***

This section provides the estimation methods for $N_2O$ emissions by crop residue plowed into soil.

***b) Methodological Issues***

- ***Estimation Method***

Basically, the $N_2O$ emissions were calculated by using the *2006 IPCC Guidelines*. For Emission factors, default EF described in the *2006 IPCC Guidelines* were used. However, activity data for some crops (rice, tea, vegetables, sugarcane and sugar beet) were estimated by country-specific method which is considered to be capable for estimating emissions more accurately than the method provided in the *2006 IPCC Guidelines*.

$$E = EF \times A \times 44 / 28$$

| | |
|---|---|
| $E$ | : $N_2O$ emissions for crop residue [kg-$N_2O$] |
| $EF$ | : $N_2O$ EF for crop residue [kg-$N_2O$-N/kg-N] |
| $A$ | : Nitrogen amount plowed into soils as crop residue [kg-N] |

- ***Emission Factors***

0.01 [kg-$N_2O$-N/kg-N] (Default, *2006 IPCC Guidelines*)

- ***Activity Data***

➢ ***Rice***

For the amount of rice crop residue of above-ground biomass plowed into soil, the data for rice straw and rice chaff calculated from each prefecture data was used. The nitrogen content of this crop was calculated by multiplying the aforementioned data by nitrogen content in crop residue (kg-N/t) calculated from Date (1988). In addition, below-ground were calculated from production, dry matter fraction of harvested product, ratio of below-ground residues to production, N content of below-ground residues. For the ratio of below-ground residues to production ($Frac_{BGR\text{-}P}$), 27% indicated by Ogawa K. et al. (1988) was used. For dry matter fraction of harvested product (*DRY*), 0.89 of default value indicated in the *2006 IPCC Guidelines* was used.

$$A_{Rice} = Residue \times N_{AG} + P \times DRY \times Frac_{BGR\text{-}P} \times N_{BG}$$

| | |
|---|---|
| $A_{Rice}$ | : Nitrogen amount plowed into soils as crop residue [t-N] (Rice) |
| $Residue$ | : Amount plowed into soils as crop residue (rice straw and chaff) [t] |
| $N_{AG}$ | : N contents of above-ground residues [kg-N/kg] |
| $P$ | : Production amount of rice [t] |
| $DRY$ | : Dry matter fraction of harvested product |

$Frac_{BGR-P}$ : Ratio of below-ground residues to production of crop T [%]
$N_{BG}$ : N contents of below-ground residues [kg-N/kg]

- ***Tea***

For tea, "Leaf fall" and "Autumn pruning" were targeted as the residues which return into soils annually. In addition, as residues return into soil once in several years, "Medium pruning", which prunes the part of 30-50 cm from the ground and carried out once in about five years, was targeted. For the "Medium pruning", it assumed that it carried out by one fifth in every year in all area of tea field, and all of tea field will be renewal in five years. The residues' nitrogen contents were calculated by multiplying by nitrogen contents per unit area of "Leaf fall", "Autumn pruning" and "Medium pruning" by crop field areas. The crop field areas used for this were the data indicated in the *Statistics of Cultivated and Planted Area* by MAFF.

$$A_{Tea} = (A_{AP} + A_{LF} + A_{MP}/5) \times 10 \times Area$$

$A_{Tea}$ : Nitrogen amount plowed into soils as crop residue [kg-N] (Tea)
$A_{AP}$ : Nitrogen amount included in residue by autumn pruning [kg-N/10a]
$A_{LF}$ : Nitrogen amount included in residue by leaf fall [kg-N/10a]
$A_{MP}$ : Nitrogen amount included in the residue by medium pruning [kg-N/10a]
$Area$ : Cultivated area of tea [ha]

Table 5-60 Amount of nitrogen content included in tea residue of branch pruning

| Kind of branch pruning | | Amount of Nitrogen content [kg-N/10a] | Reference |
|---|---|---|---|
| Autumn pruning | Annual | 7.7 | Hoshina et al.(1982), Kinoshita et al. (2005), Tachibana et al. (1996) |
| Medium pruning | Once in five years | 19.4 | Ohta et al. (1996) |
| Leaf fall | Annual | 11.5 | Hoshina et al.(1982) |

- ***Vegetables, sugarcane and sugar beet***

The amount of nitrogen in each crop residue plowed into soil were calculated by multiplying nitrogen content in residue per crop production calculated from Matsumoto (2000) by annual crop production (by *Statistics of Cultivated and Planted Area* or *Vegetable Production and Shipment Statistics*) by the fraction of above-ground residue removed and fraction burnt on field (after consideration of Combustion Factor).

For the amount of nitrogen in crop residue plowed into soil, the data of the *Document of Kagoshima prefectural Institute for Agricultural Development* was used for sugarcane, and the data of *Hokkaido Fertiliser Recommendations 2010* was used for sugar beets, potato, Japanese radish and onion, and the data of Owa (1996) was used for Chinese cabbage and lettuce.

When any crop has no available data with respect to nitrogen content included in crop residue per crop production, the value for a similar type of crop was used. The same values were adopted for all fiscal years.

$$A_{Vegetable} = P \times (1 - Frac_{Remove} - Frac_{burnt} \times CF) \times N_R$$

$A_{Vegetable}$ : Nitrogen amount plowed into soils as crop residue (Vegetables, Sugarcane, Sugarbeet) [t-N]
$P$ : Production amount [t]
$Frac_{Remove}$ : Fraction of above-ground residue removed [%]

$Frac_{burnt}$ : Fraction burnt on field [%]
$CF$ : Combustion factor
$N_R$ : Nitrogen contents in crop residue [kg-N/kg]

Table 5-61 Fraction of above-ground residue removed ($Frac_{Remove}$), Fraction burnt on field ($Frac_{burnt}$), Combustion factor ($CF$), and Ratio of below-ground residues to above-ground biomass ($R_{BG\text{-}BIO}$)) for main crops

| Crop type | Fraction of above-ground residue removed ($Frac_{Remove}$) | Fraction burnt on field ($Frac_{burnt}$) | Combustion factor ($CF$) | Raito of above-ground residues ($R_{BG\text{-}BIO}$) |
|---|---|---|---|---|
| Vegetables | 47% | 7% | 0.80 [4)] | - |
| Sugarbeet | 47% [1)] | 7% [1)] | 0.80 [4)] | - |
| Sugarcane | 47% [1)] | 7% [1)] | 0.80 [4)] | - |
| Green manure crops | 0% [2)] | 0% [2)] | - | Non-legume hay:0.80<br>Sorghum: 0.24 [9)] |
| Feed crops | 100% [3)] | 0% [3)] | - | |
| Wheat, barley, rye and oats | See Table 5-63 | See Table 5-63 | 0.90 [5)] | Wheat: 0.24<br>Barley: 0.22<br>Rye: 0.25 [10)]<br>Oats: 0.25 |
| Pulse | 13% | 12% | 0.80 [4)] | 0.19 [6)] |
| Maize, tubers and roots, other crops | 47% [1)] | 7% [1)] | 0.80 [4)] | Maize: 0.22<br>Tubers and roots: 0.20 [7)]<br>Other crops: 0.22 [8)] |

Reference:
*$Frac_{Remove(T)}$, $Frac_{burnt(T)}$: Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*
*CF, $R_{BG\text{-}BIO(T)}$: 2006 IPCC Guidelines*
Note:
1): Value of vegetables, 2): all residue are plowed into soil, 3): all above-ground biomass removed as for feed, 4): Value of maize and/or sugarcane、5): Value of wheat, 6): Value of Soybean, 7): Value of potato, 8): Value of grains, 9): Average value between maize and oats, 10): Substituted by oats

Table 5-62 N contents of above- and below-ground residues ($N_{AG}$, $N_{BG}$) for main crops

| Crop type | N contents of above-ground residues ($N_{AG}$) | N contents of below-ground residues ($N_{BG}$) | Note |
|---|---|---|---|
| Rice (above ground) | Straw: 0.541% [a)]<br>Chaff: 0.423% [a)] | - | Wet weight |
| Rice (below ground) | - | 0.9% [z), 3)] | Dry weight |
| Vegetables | Japanese radish: 0.093% [b),c)]<br>Chinese cabbage: 0.071% [c)]<br>Cabbage: 0.183% [e)]<br>Lettuce: 0.164% [c)]<br>Onion: 0.019% [b),c)] | | Wet weight |
| Sugar beet | 0.095% [b),c)] | | |
| Sugarcane | 0.548% [d)] | | Dry weight |
| Green manure crops and Feed crops | Non-legume hay: 1.5% [z)]<br>Sorghum: 0.7% [z)] | Non-legume hay:1.2% [z)]<br>Sorghum: 0.6% [z)] | |
| Wheat | 0.43% [e)] | 0.9% [z)] | |
| Barley | Two-row: 2.14% [e)]<br>Six-row: 0.31% [e)] | 1.4% [z)] | |
| Rye | 0.50% [z)] | 1.1% [z)] | |
| Oats | 0.70% [z)] | 0.8% [z)] | |
| Maize | 1.64% [e)] | 0.7% [z)] | |
| Soybean | 0.65% [e)] | 0.8% [z)] | |
| Adzuki beans | 0.84% [e)] | 1.0% [z), 1)] | |
| Potatoes | 2.42% [e)] | 1.4% [z), 2)] | |

Reference:
a): Date (1988)
b): Hokkaido Government, Department of Agriculture, (2010)
c): Owa (1996)
d): Document of Kagoshima prefectural Institute for Agricultural Development
e): Matsumoto (2000)
z): *2006 IPCC Guidelines*

Note:
1): Substituted by dry bean, 2): Substituted by potato, 3): Substituted by wheat

- ***Feed and green manure crops, wheat, barley, orts, rye, maize, pulse, tubers and roots (e.g. potato, sweet potato), and other crops (e.g. buckwheat, tobacco)***

Activity data were calculated by the method shown in the following equation in accordance with the *2006 IPCC Guidelines*. For parameters, values in Table 5-61 and Table 5-62 were used. The proportion removed from field and burned in field for wheat, barley, rye and oats were determined on the basis of data of crop area by treating method for wheat straw surveyed by MAFF as shown in the Table 5-60. Since the survey data are not available in and before FY2006, the values for FY2007 were applied to these years. Fraction renewed of field ($Frac_{Renew}$) was determined for feed crops as 3% by expert judgment, taking into account variable survey results. For other crops, it was calculated as 100% renewed.

$$A = \sum_T \left\{ \begin{array}{c} \left(Area_{(T)} - Areaburnt_{(T)} \times CF\right) \times Frac_{Renew(T)} \times \\ \left[AG_{DM(T)} \times N_{AG(T)} \times \left(1 - Frac_{Remove(T)}\right) + \left(AG_{DM(T)} \times 1000 + Crop_{(T)}\right) \times R_{BG-BIO(T)} \times N_{BG(T)}\right] \end{array} \right\}$$

$$Area_{burnt(T)} = Area_{(T)} \times Frac_{burnt(T)}$$

| | |
|---|---|
| $A$ | : Nitrogen amount plowed into soils as crop residue [t-N] |
| $Area_{(T)}$ | : Crop area of crop T [ha] |
| $Area_{burnt(T)}$ | : Crop area burnt of crop T [ha] |
| $CF$ | : Combustion factor |
| $Frac_{Renew(T)}$ | : Fraction renewed of field of crop T [%] |
| $AG_{DM(T)}$ | : Dry matter of above-ground residues of crop T [Mg/ha] |
| $N_{AG(T)}$ | : N contents of above-ground residues of crop T [%] |
| $Frac_{Remove(T)}$ | : Fraction removed from field of crop T [%] |
| $Crop_{(T)}$ | : Dry matter in production of crop T [kg/ha] |
| $R_{BG-BIO(T)}$ | : Ratio of below-ground residues to above-ground biomass of crop T |
| $N_{BG(T)}$ | : N contents of below-ground residues of crop T [%] |
| $Frac_{burnt(T)}$ | : Fraction burnt on field of crop T [%] |

Table 5-63 Proportion removed from field and burned in field for wheat, barley, rye and oats [%]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Proportion removed from field | 32.1 | 32.1 | 32.1 | 32.1 | 35.9 | 37.8 | 39.8 | 40.2 | 41.0 | 41.0 | 37.9 | 40.2 | 38.5 | 39.5 |
| Proportion burned in field | 13.5 | 13.5 | 13.5 | 13.5 | 11.6 | 10.6 | 9.5 | 9.2 | 8.8 | 8.3 | 8.0 | 7.7 | 7.7 | 6.9 |

Note: Calculated from each prefecture data

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For uncertainty of the emission factor, default values (-70% to +200%) described in the *2006 IPCC Guidelines* were applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -70% to +200%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*.

The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

At the Break Out Group on Agriculture of the Committee for GHG Emissions Estimation Method in 2012, nitrogen content for rice were checked in detail. As a result, the group decided to use data by Date (1988), which were separated into rice straw and chaff and were considered as the most appropriate to represent Japan's actual circumstances because the data are intermediate among the various regional data in Japan.

***e) Category-specific Recalculations***

Since the data for rice straw and rice chaff plowed into soil in FY2017 were updated, the emissions in FY2017 were recalculated. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

Discussion whether it will be possible to establish country-specific emission factors for Japan has been conducted.

### 5.5.1.5. Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter (3.D.a.5.)

***a) Category Description***

This section estimates $N_2O$ emissions by nitrogen mineralization in loss of carbon oxidized by organic matter in mineral soil.

***b) Methodological Issues***

- ***Estimation Method***

When using the estimation method in the *2006 IPCC Guidelines*, amount of carbon loss in organic matter in mineral soil, which is a part of activity data, cannot be figured out in Japan. Therefore, it was calculated by country-specific method by using the cultivation area of a mineral soil, and the $N_2O$ emission per area (background $N_2O$ emission of agricultural land).

$$E = EF \times A \times 44 / 28$$

| | |
|---|---|
| $E$ | : $N_2O$ emissions by mineralization of nitrogen in mineral soils [kg-$N_2O$] |
| $EF$ | : $N_2O$ emission factor by mineralization of nitrogen in mineral soils per ha [kg-$N_2O$-N/ha] |
| $A$ | : Area of plowed mineral soil [ha] |

- ***Emission Factors***

$N_2O$ emission factor of background in agricultural soils in Japan (0.65 kg$N_2O$-N/ha) indicated by Akiyama et al. (2006), which is the scientific paper used in "5.5.1.1. Inorganic N Fertilizers (3.D.a.1.)", was used as basis of EF, and $N_2O$ emissions by atmospheric deposition and crop residue were subtracted from the background EF.

Nitrogen amount deposited as $NH_3$+NOx on agricultural soils in Japan is decided by expert judgment on the basis of domestic case studies as 10kgN/ha. For nitrogen amount plowed into soils as crop residue per area, 32kgN/ha calculated in "5.5.1.4. Crop Residues (3.D.a.4.)" above are used. 0.10kg$N_2O$-N/ha + 0.32kg$N_2O$-N/ha (emission factors are 1% of atmospheric deposition amount and 1% of crop residue)

which were emitted from its deposition and crop residue plowed into soil were subtracted as double counting from background EF. Finally, 0.23 (=0.65 -0.10 -0.32) kg$N_2O$-N/ha was used as the corrected emission factor.

- ***Activity Data***

The area of plowed mineral soil was established by subtracting the area of organic soils (peat soil and muck soil) in paddy fields and common upland fields in Japan from the cultivated areas of paddy fields and common upland fields, obtained from the *Statistics of Cultivated and Planted Area* (MAFF). Lands of mineral soil converted to paddy field and upland field are estimated in LULUCF sector. For detail, see estimation method described in LULUCF sector (6.6.1 b) 2) “Activity Data” below).

Table 5-64 Intended areas of mineral soil in Agriculture sector [kha]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intended paddy field | 2,612 | 2,549 | 2,469 | 2,386 | 2,334 | 2,325 | 2,303 | 2,295 | 2,288 | 2,279 | 2,268 | 2,252 | 2,236 | 2,219 |
| Intended upland field | 1,162 | 1,117 | 1,095 | 1,112 | 1,127 | 1,131 | 1,128 | 1,129 | 1,126 | 1,122 | 1,117 | 1,115 | 1,107 | 1,101 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For the emission factors, uncertainty (31%) described in the reference of EFs, Akiyama et al. (2006), was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 31%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since the estimation method for mineral soil area associated with land use conversion in LULUCF sector was changed, the emissions for whole time-series were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

It is planned to discuss the subtraction method for double count of $N_2O$ emissions from the EF of Akiyama et al. (2006)

## 5.5.1.6. Plowing of Organic Soil (3.D.a.6.)

### *a) Category Description*

In Japan, organic soil mainly occurs in Hokkaido. In Japanese GHG inventory, two categories of soil type, “muck soil” and “peat soil”, are treated as organic soils. In Japan, the creation of farmland on organic soils was mostly completed by the 1970s, and in general farmers till land that has had soil dressing.

### *b) Methodological Issues*

- ***Estimation Method***

Emissions of $N_2O$ from the plowing of organic soil were calculated by multiplying the area of the plowed organic soil of paddy field, upland field, and grassland by the emission factor in accordance with the *2006 IPCC Guidelines*.

$$E = EF \times A \times 44 / 28$$

| | |
|---|---|
| $E$ | : $N_2O$ emission associated with the plowing of organic soil [kg-$N_2O$] |
| $EF$ | : $N_2O$ emission factor for plowing of organic soil [kg-$N_2O$-N/ha] |
| $A$ | : Area of plowed organic soil [ha] |

- ***Emission Factors***

For paddy cultivation in organic soils, it is known that $N_2O$ emission in paddy field is lower than the one in upland field. In Japan, Nagata (2006) observed $N_2O$ emissions for paddy field of organic soil in Hokkaido, but the observations included emissions from applied nitrogen. Therefore, country-specific emission factor is determined to be 0.30 [kg-$N_2O$-N/ha/year] by deducting emission for applied fertilizer (estimated from country-specific emission factor of fertilizers (0.31% [kg-$N_2O$-N/kg-N]) indicated in Table 5-48 above). For the upland field of organic soil, some observation results exist (Nagata 2006, Nagata 2009), but there is not much difference from the default of temperate region (8 [kg-$N_2O$-N/ha/year]) indicated in *2006 IPCC Guidelines*. Therefore, default value is used for upland field. For grassland, same default value (8 [kg-$N_2O$-N/ha/year]) is used.

- ***Activity Data***

The area of organic soil was calculated for every year by adding the area of organic soil of rice fields, upland fields and pasture lands converted from other land-use to the organic soil area of rice fields, upland fields and pasture lands in 1992 and 2001 which were calculated areas of organic soils on the information, and by subtracting area of organic soil of rice fields, upland fields and pasture lands converted from agricultural land from the summation above.

Plowed area of organic soil includes all areas of organic soil for rice field and upland field and the renewed pasture lands, while organic soils for orchard, grazed meadow and wild land are not included. This is because orchard, grazed meadow and wild land are not plowed. (see 6.7.1. Grassland remaining Grassland)

The renewal of grassland is the maintenance work with re-sowing and re-plowing which is done once in several years. Annual plowed grassland area of organic soil is calculated by multiplying the annual renewal ratios by organic soil areas of grassland. For annual renewal ratio of grassland, a report of a study result by Hatano (2017) was utilized. The result by Hatano mentioned annual renewal ratios of grassland for categorized two areas, “Hokkaido” and “other areas” from 2006 to 2015. Averaged annual renewal ratios from 2006 to 2010 for each area (Hokkaido : 3.0%, other area : 1.3% ) were substituted for the ratios before 2006 and after 2016.

Table 5-65 Annual renewal ratio of grassland

| | Before 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | After 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hokkaido | 3.0% | 2.5% | 2.8% | 3.0% | 3.7% | 2.9% | 3.5% | 3.6% | 3.3% | 3.9% | 4.1% | 3.0% |
| Other area | 1.3% | 1.0% | 1.2% | 1.0% | 1.4% | 2.1% | 3.8% | 15.7% | 9.6% | 5.2% | 3.5% | 1.3% |

Reference: Hatano (2017)

Table 5-66 Intended areas of organic soil in the agriculture sector [kha]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intended paddy field | 161.9 | 161.3 | 160.6 | 159.9 | 159.7 | 159.6 | 159.5 | 159.7 | 160.0 | 160.2 | 160.2 | 160.2 | 160.4 | 160.7 |
| Intended upland field | 24.7 | 24.4 | 24.2 | 24.0 | 24.0 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 24.0 | 24.2 |
| Intended grassland (Hokkaido) | 1.2 | 1.2 | 1.2 | 1.2 | 1.5 | 1.2 | 1.4 | 1.5 | 1.3 | 1.6 | 1.7 | 1.2 | 1.2 | 1.2 |
| Intended grassland (other area) | 0.005 | 0.004 | 0.004 | 0.004 | 0.004 | 0.006 | 0.010 | 0.043 | 0.026 | 0.014 | 0.009 | 0.004 | 0.003 | 0.003 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For uncertainty of the emission factor, default values (-75% to +200%) described in the *2006 IPCC Guidelines* were applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -75% to +200%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

The country-specific emission factor, 0.30 [kg-$N_2O$-N/ha/yr], from paddy fields with organic soil is set based on the actual measurement values of $N_2O$ emissions from the paddy fields with peat soil in Hokkaido (Nagata et al. 2006). $N_2O$ emissions from the paddy fields with peat soil were measured on 8 observation points and the range of emission measurement values were -0.28 to 1.27 [kg$N_2O$-N/ha/yr]. For setting the CSEF, emissions from fertilization were deducted because fertilizers were applied on those observation points. Emission estimation values of $N_2O$ from fertilization to the paddy fields were in the range between 0.11 to 0.29 [kg$N_2O$-N/ha/yr]. The $N_2O$ emission factor from the paddy fields with peat soil, therefore, is calculated as 0.30 [kg-$N_2O$-N/ha/yr].

Moreover, Nagata conducted measurements for $N_2O$ emissions at upland fields with peat soil. Measurement from upland fields was conducted on 9 observation points and the emission measurement values were in the range between 2.87 to 13.60 [kg$N_2O$-N/ha/yr]. $N_2O$ emissions from fertilization to the upland fields were in the range between 0.17 to 2.38 [kg$N_2O$-N/ha/yr]. The emission factor from the upland field with peat soil was 7.42 [kg-$N_2O$-N/ha/yr] after subtracting estimated emission by fertilization from measurement emission value. This value is close to the default emission factor 8 [kg-$N_2O$-N/ha/yr] (*2006 IPCC Guideline*, Vol.4, page 11.11, Table 11.1). The result by Nagata (2006) disclosed $N_2O$ emissions were clearly different between the irrigated paddy field and the upland field on organic soil.

### *e) Category-specific Recalculations*

Since the estimation method for organic soil area associated with land use conversion in LULUCF sector was changed, the emission from all years were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvement plans.

### 5.5.2. Indirect Emissions (3.D.b.)

Nitrogen compounds such as ammonia, that volatilize and are released into the atmosphere from synthetic fertilizers applied to agricultural soils, organic fertilizers applied to agricultural soils and the grazing livestock manure applied to soil are deposited on soil as the results of various actions, including turbulent diffusion, molecular diffusion, effect of electrostatic forces, chemical reactions, plant respiration, and being washed out of the air by rain. In this section, the amount of $N_2O$ generated by microbe activity on the deposited nitrogen compounds was calculated.

$N_2O$ is generated by the action of microbes on nitrogen that leaches or runs off as nitrate from synthetic fertilizers, organic fertilizers, etc.

#### 5.5.2.1. Atmospheric Deposition (3.D.b.1.)

***a) Category Description***

This section provides the estimation methods for $N_2O$ indirect emissions caused by atmospheric deposition of nitrogen compounds volatilized as $NH_3$ and NOx from synthetic fertilizers applied to soil, organic fertilizers applied to soil, and the grazing livestock manure applied to soil.

***b) Methodological Issues***

- ***Estimation Method***

$N_2O$ emissions have been calculated in accordance with decision tree of the *2006 IPCC Guidelines* (Vol. 4, Page 11.20, Fig11.3).

$$E = EF \times A \times 44 / 28$$

| | |
|---|---|
| $E$ | : $N_2O$ emissions from atmospheric deposition [kg-$N_2O$] |
| $EF$ | : $N_2O$ Emission factor for atmospheric deposition [kg-$N_2O$-N/ kg-$NH_3$-N+$NO_X$-N volatilized] |
| $A$ | : Total nitrogen amount volatilized as $NH_3$ and NOx from synthetic fertilizers, organic fertilizers, and grazing livestock manure [kg-$NH_3$-N+$NO_x$-N] |

- ***Emission Factors***

0.01 [kg-$N_2O$-N/kg-$NH_3$-N & $NO_X$-N volatilized] (default value, *2006 IPCC Guidelines*, Vol.4 Table11.3).

- ***Activity Data***

As described in the following equation, the activity data are composed of the “nitrogen amount volatilized as $NH_3$ and NOx from inorganic fertilizers applied to soil, organic fertilizers applied to soil, and the grazing livestock manure applied to soil. The “nitrogen amount volatilized $NH_3$ and NOx in process of livestock manure management” are reported in 3.B.5.

$$A = N_{FERT} \times Frac_{GASF} + N_{ON} \times Frac_{GASM3} + N_{PRP} \times Frac_{GASM4}$$

| | |
|---|---|
| $A$ | : Total N amount volatilized as $NH_3$ and NOx from synthetic fertilizers, organic fertilizers, and grazing livestock manure [kg-$NH_3$-N+$NO_x$-N] |
| $N_{FERT}$ | : N amount for inorganic fertilizers applied to agricultural soil [kg-N] |
| $Frac_{GASF}$ | : Percentage of volatilization as $NH_3$ and NOx from inorganic fertilizers applied to agricultural soil [(kg-$NH_3$-N + $NO_X$-N)/kg-N] |

$N_{ON}$ : N amount for organic fertilizers applied to agricultural soil [kg-N]

$Frac_{GASM3}$ : Percentage of volatilization as $NH_3$ and NOx from nitrogen contained in livestock manure and human waste applied to agricultural soils [(kg-$NH_3$-N + $NO_X$-N)/kg-N]

$N_{PRP}$ : N amount in grazing livestock manure [kg-N]

$Frac_{GASM4}$ : Fraction of volatilization as $NH_3$ and NOx from livestock manure during treatment [(kg-$NH_3$-N + $NO_X$-N)/kg-N]

- ***N amount volatilized as $NH_3$ and NOx from inorganic fertilizers applied to soil ($N_{FERT} \times Frac_{GASF}$)***

"N amount of synthetic fertilizer applied to agricultural soil (in Table 5-49)" calculated in the Inorganic N Fertilizers (3.D.a.1.) was used for the amount of fertilized nitrogen ($N_{FERT}$), and the default value, indicated in Table 5-67, given in the *2006 IPCC Guidelines* was used for the percentage of volatilization ($Frac_{GASF}$).

Table 5-67 Proportion of nitrogen volatilized from synthetic fertilizers and organic fertilizers as ammonia or nitrogen oxides

| | Value | Unit |
|---|---|---|
| $Frac_{GASF}$ | 0.10 | kg-$NH_3$-N + $NO_X$-N/kg of synthetic fertilizer nitrogen applied |
| $Frac_{GASM}$ | 0.20 | kg-$NH_3$-N + $NO_X$-N/kg of nitrogen excreted by livestock |

Reference: *2006 IPCC Guidelines* Vol. 4, Table 11.3

- ***N amount volatilized as $NH_3$ and NOx from organic fertilizers applied to agricultural soil ($N_{ON} \times Frac_{GASM3}$)***

For nitrogen amount in organic fertilizers applied to agricultural soil ($N_{ON}$), the data described in the "Organic N Fertilizers (3.D.a.2.)" were used. For proportion of nitrogen volatilized as $NH_3$ and NOx ($Frac_{GASM3}$), default value ($Frac_{GASM}$ = 0.20) of the *2006 IPCC Guidelines* indicated in Table 5-67 above was used.

- ***N amount volatilized as $NH_3$ and NOx from grazing livestock manure ($N_{PRP} \times Frac_{GASM4}$)***

For the nitrogen amount in grazing livestock manure ($N_{PRP}$), the calculated data in 3.B. were used. For proportion of nitrogen volatilized as $NH_3$ and NOx ($Frac_{GASM4}$), default value ($Frac_{GASM}$ = 0.20) of the *2006 IPCC Guidelines* indicated in Table 5-67 was used.

Table 5-68 Amount of nitrogen that volatilizes as ammonia and nitrogen oxides from synthetic fertilizers, livestock manure, and human waste [t ($NH_3$-N+NOx-N)]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From inorganic N fertilizers applied to soil ($N_{FERT} \times Frac_{GASF}$) | 61,167 | 52,727 | 48,718 | 47,097 | 34,997 | 40,940 | 38,702 | 39,660 | 40,973 | 39,444 | 37,216 | 37,470 | 37,470 | 37,470 |
| From organaic N fertilizers ($N_{ON} \times Frac_{GASM3}$) | 105,372 | 101,722 | 96,734 | 86,046 | 82,790 | 86,356 | 86,058 | 84,157 | 84,294 | 85,349 | 91,188 | 90,761 | 93,129 | 93,127 |
| From grazing livestock manure ($N_{PRP} \times Frac_{GASM4}$) | 2,597 | 2,567 | 2,387 | 2,232 | 2,214 | 2,142 | 2,144 | 2,101 | 2,078 | 1,999 | 2,056 | 2,047 | 2,080 | 2,114 |
| Total (nitrogen amount volatilized as ammonia and nitrogen oxides (A) | 169,136 | 157,016 | 147,839 | 135,375 | 120,001 | 129,437 | 126,904 | 125,917 | 127,344 | 126,793 | 130,460 | 130,278 | 132,679 | 132,711 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For uncertainty of the emission factor, uncertainty (-106% to +447%) was calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 9% for population of broiler given in the *Livestock Statistics* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -106% to +447%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

Statistic data of synthetic fertilizer without nitrification inhibitor after 2015 and the data of synthetic fertilizer with nitrification inhibitor after 2016 were revised. Therefore, emission after 2015 were recalculated. Since the calculation method of amount of excretion and nitrogen content in excretion for non-dairy cattle and swine have been revised, the emissions for the whole time-series were recalculated. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

Discussion for the establishment of country-specific emission factors and the ratios of volatile nitrogen compounds has been conducted.

### 5.5.2.2. Nitrogen Leaching and Run-off (3.D.b.2.)

***a) Category Description***

This section provides the estimation methods for $N_2O$ emissions from Nitrogen Leaching and Run-off.

***b) Methodological Issues***

- ***Estimation Method***

$N_2O$ emissions were calculated according to the decision tree in the *2006 IPCC Guidelines* (Vol. 4, Page 11.20, Fig11.3), by multiplying default emission factors by the amount of nitrogen that leached and run-off.

$$E = EF \times A \times 44 / 28$$

| | |
|---|---|
| $E$ | : $N_2O$ emissions from N leaching and run-off [kg-$N_2O$] |
| $EF$ | : $N_2O$ Emission factor for N leaching and run-off [kg-$N_2O$-N/kg-N] |
| $A$ | : Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [kg-N] |

- ***Emission Factors***

0.0075 [kg-$N_2O$-N/kg-N] (default value, *2006 IPCC Guidelines*).

- ***Activity Data***

As described the formula below, activity data was composed of each nitrogen amount of leaching and run-off by synthetic fertilizers, organic fertilizers, grazing livestock manure, crop residue, and carbon loss by mineralization. Each AD was calculated by multiplying the default value of proportion of leaching and run-off given in the *2006 IPCC Guidelines* (0.30 [kg-N/kg-N]) by the amount of nitrogen calculated in 3.D.a.1. to 3.D.a.5. above.

$$A = (N_{FERT} + N_{ON} + N_{PRP} + N_{CR} + N_{SOM}) \times Frac_{LEACH}$$

| | |
|---|---|
| $A$ | : Total nitrogen amount for N leaching and run-off from inorganic fertilizers, organic fertilizers, etc. [kg-N] |
| $N_{FERT}$ | : Nitrogen amount in inorganic fertilizers applied to agricultural soil [kg-N] |
| $N_{ON}$ | : Nitrogen amount in organic fertilizers applied to agricultural soil [kg-N] |
| $N_{PRP}$ | : Nitrogen amount in grazing livestock manure [kg-N] |
| $N_{CR}$ | : Nitrogen amount in crop residue plowed into soil [kg-N] |
| $N_{SOM}$ | : Nitrogen amount in mineralization in loss of carbon oxidized by organic matter in mineral soil [kg-N] |
| $Frac_{LEACH}$ | : Fraction of nitrogen leaching and run-off in each activity [kg-N/kg-N] (=0.30) (default value in the *2006 IPCC Guidelines* (Vol.4 Table 11.3)) |

Table 5-69 Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [t ($NH_3$-N+$NO_X$-N)]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From inorganic N fertilizers applied to soil ($N_{FERT}$×$Frac_{LEACH}$) | 183,500 | 158,181 | 146,153 | 141,291 | 104,991 | 122,819 | 116,106 | 118,979 | 122,918 | 118,333 | 111,649 | 112,411 | 112,411 | 112,411 |
| From organaic N fertilizers ($N_{ON}$×$Frac_{LEACH}$) | 158,058 | 152,583 | 145,101 | 129,069 | 124,185 | 129,534 | 129,087 | 126,235 | 126,441 | 128,024 | 136,782 | 136,141 | 139,694 | 139,690 |
| From grazing livestock manure ($N_{PRP}$×$Frac_{LEACH}$) | 3,896 | 3,851 | 3,580 | 3,349 | 3,322 | 3,213 | 3,216 | 3,152 | 3,117 | 2,999 | 3,083 | 3,071 | 3,120 | 3,170 |
| From crop residue ($N_{CR}$×$Frac_{LEACH}$) | 45,299 | 44,780 | 47,719 | 43,955 | 38,834 | 37,750 | 37,521 | 38,290 | 38,276 | 37,328 | 36,916 | 35,332 | 35,157 | 34,147 |
| From mineralization ($N_{SOM}$×$Frac_{LEACH}$) | 71,071 | 69,161 | 67,136 | 65,482 | 64,499 | 64,332 | 63,814 | 63,644 | 63,455 | 63,219 | 62,910 | 62,531 | 62,083 | 61,644 |
| Total (nitrogen amount by leachingand run-off) (A) | 461,824 | 428,556 | 409,689 | 383,144 | 335,831 | 357,648 | 349,744 | 350,299 | 354,206 | 349,903 | 351,340 | 349,486 | 352,464 | 351,063 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For uncertainty of the emission factor, uncertainty (-115% to +287%) was calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 9% was applied as same as "Atmospheric Deposition" above. As a result, the uncertainties of the emissions were determined to be -115% to +287%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Statistic data of synthetic fertilizer without nitrification inhibitor after 2015 and the data of synthetic fertilizer with nitrification inhibitor after 2016 were revised. Therefore, emission after 2015 were recalculated. Since the calculation method of nitrogen content in excretion for non-dairy cattle and swine have been revised, the emissions for the whole time-series were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

Discussion for the establishment of country-specific emission factors and the fraction of nitrogen

leaching and run-off has been conducted.

## 5.6. Prescribed Burning of Savannas (3.E.)

This source is given in the *2006 IPCC Guidelines* as "being for the purpose of managing pastureland in sub-tropical zones". There is no equivalent activity in Japan, and this source has been reported as "NO".

## 5.7. Field Burning of Agricultural Residues (3.F.)

### *a) Category Description*

Incomplete burning of crop residues in field releases $CH_4$ and $N_2O$ into the atmosphere. $CH_4$ and $N_2O$ emissions from this source are calculated and reported in this category.

$CH_4$ and $N_2O$ emissions from Field Burning of Agricultural Residues in FY2018 are 63 kt-$CO_2$ eq. and 20 kt-$CO_2$ eq., comprising 0.005% and 0.002% of total emissions (excluding LULUCF), respectively. The value represents a reduction by 50.1% and 50.1% for $CH_4$ and $N_2O$ from FY1990, respectively.

Table 5-70 $CH_4$ and $N_2O$ emissions from field burning of agriculture residues

| Gas | Item | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 3.F.1. Cereals | Wheet | kt-$CH_4$ | 0.38 | 0.22 | 0.27 | 0.31 | 0.26 | 0.24 | 0.22 | 0.21 | 0.20 | 0.19 | 0.18 | 0.18 | 0.18 | 0.16 |
| | | Barley | | 0.15 | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 | 0.06 | 0.06 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | | Maize | | 0.08 | 0.07 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.04 | 0.05 |
| | | Rice | | 1.96 | 2.05 | 1.38 | 1.03 | 0.71 | 0.70 | 0.70 | 0.66 | 0.75 | 0.68 | 0.56 | 0.57 | 0.47 | 0.47 |
| | | Other cereals | | 0.06 | 0.05 | 0.08 | 0.09 | 0.09 | 0.09 | 0.11 | 0.12 | 0.12 | 0.12 | 0.11 | 0.12 | 0.12 | 0.13 |
| | 3.F.2. Pulses | Soybeans | | 0.47 | 0.22 | 0.40 | 0.43 | 0.47 | 0.45 | 0.44 | 0.42 | 0.42 | 0.43 | 0.46 | 0.49 | 0.49 | 0.47 |
| | | Other pulses | | 0.35 | 0.27 | 0.22 | 0.19 | 0.16 | 0.16 | 0.16 | 0.15 | 0.16 | 0.16 | 0.14 | 0.12 | 0.12 | 0.12 |
| | 3.F.3. Tubers and roots | Potatoes | | 0.23 | 0.20 | 0.18 | 0.17 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| | | Sugarbeet | | 0.14 | 0.14 | 0.14 | 0.13 | 0.13 | 0.12 | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 | 0.12 | 0.11 | 0.11 |
| | | Other tubers and roots | | 0.20 | 0.17 | 0.15 | 0.13 | 0.13 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 |
| | 3.F.4. | Sugarcane | | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | 3.F.5. Other | Vegetables | | 0.95 | 0.87 | 0.81 | 0.74 | 0.72 | 0.72 | 0.71 | 0.71 | 0.70 | 0.69 | 0.69 | 0.69 | 0.68 | 0.68 |
| | | Other crops | | 0.08 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | Total | | kt-$CH_4$ | 5.1 | 4.4 | 3.8 | 3.4 | 3.0 | 2.9 | 2.9 | 2.8 | 2.9 | 2.8 | 2.7 | 2.7 | 2.6 | 2.5 |
| | | | kt-$CO_2$eq | 127 | 111 | 96 | 86 | 76 | 74 | 73 | 71 | 72 | 70 | 67 | 67 | 64 | 63 |
| $N_2O$ | 3.F.1. Cereals | Wheet | kt-$N_2O$ | 0.010 | 0.006 | 0.007 | 0.008 | 0.007 | 0.006 | 0.006 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.004 |
| | | Barley | | 0.004 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | | Maize | | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | | Rice | | 0.051 | 0.053 | 0.036 | 0.027 | 0.018 | 0.018 | 0.018 | 0.017 | 0.019 | 0.018 | 0.015 | 0.015 | 0.012 | 0.012 |
| | | Other cereals | | 0.002 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| | 3.F.2. Pulses | Soybeans | | 0.012 | 0.006 | 0.010 | 0.011 | 0.012 | 0.012 | 0.011 | 0.011 | 0.011 | 0.011 | 0.012 | 0.013 | 0.013 | 0.012 |
| | | Other pulses | | 0.009 | 0.007 | 0.006 | 0.005 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.003 | 0.003 | 0.003 |
| | 3.F.3. Tubers and roots | Potatoes | | 0.006 | 0.005 | 0.005 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| | | Sugarbeet | | 0.004 | 0.004 | 0.004 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| | | Other tubers and roots | | 0.005 | 0.004 | 0.004 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| | 3.F.4. | Sugarcane | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | 3.F.5. Other | Vegetables | | 0.025 | 0.023 | 0.021 | 0.019 | 0.019 | 0.019 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 |
| | | Other crops | | 0.0020 | 0.0017 | 0.0014 | 0.0011 | 0.0009 | 0.0009 | 0.0008 | 0.0006 | 0.0006 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| | Total | | kt-$N_2O$ | 0.13 | 0.12 | 0.10 | 0.09 | 0.08 | 0.08 | 0.08 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| | | | kt-$CO_2$eq | 39 | 34 | 30 | 26 | 23 | 23 | 22 | 22 | 22 | 22 | 21 | 21 | 20 | 20 |
| Total of all gases | | | kt-$CO_2$eq | 166 | 145 | 126 | 112 | 99 | 96 | 95 | 93 | 94 | 92 | 88 | 88 | 84 | 83 |

### *b) Methodological Issues*

- ***Estimation Method***

$CH_4$ and $N_2O$ emissions were calculated by using the method indicated in the *2006 IPCC Guidelines.*

$$E = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

$E$ : $CH_4$ and $N_2O$ emissions from field burning of agriculture residues [t-$CH_4$ or t-$N_2O$]

$A$ : Area burnt [ha]

$M_B$ : Mass of fuel available for combustion [t/ha]

$C_f$ : Combustion factor

$G_{ef}$ : Emission factor [g-$CH_4$/kg or g-$N_2O$/kg]

- ***Emission Factors***

$CH_4$: 2.7 [g-$CH_4$/kg (dry matter)] (default value in the *2006 IPCC Guidelines*)

$N_2O$: 0.07 [g-$N_2O$/kg (dry matter)] (default value in the *2006 IPCC Guidelines*)

- ***Activity Data***

Parameters used in estimation are indicated in the Table 5-71 below. For proportion of burned residue and combustion factor, same values to estimate $N_2O$ emissions for crop residue were used. For rice, since data of the amount of burning rice straw and rice chaff on crop field (Table 5-72) is available, mass of fuel available for combustion ($M_B$) was not multiplied in estimation.

The proportion burned in field for wheat, barley, rye and oats were determined on the basis of data of crop area by treating method for wheat straw calculated from each prefecture data as shown in Table 5-63 above.

Table 5-71 Proportion of burned residue on agricultural field, $M_B \times C_f$ and Combustion factor

| Crop | Proportion of burned residue | $M_B \times C_f$ | Combustion Factor ($C_f$) |
|---|---|---|---|
| Rice | --- | --- | 0.80 |
| Pulse | 12% 1) | 10 3) | --- |
| Vegetable, Sugarbeet, Maize, Tuber crops (e.g. potato), Buckwheat, Canola seed, Konjac, Rush grass, Tabaco | 7% 2) | 10 3) | --- |
| Sugarcane | 7% 2) | 6.5 | --- |
| Wheat, Barley, Ray, Oats | See Table 5-63 | 4 4) | --- |

Reference: Proportion burned: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*
$M_B \times C_f$: *2006 IPCC Guidelines*
Note: 1): value of pulse, 2): value of vegetable, 3): value of maize, 4): value of wheat

For rice, amount of burning rice straw and rice chaff on crop field is surveyed by MAFF (Table 5-72). The amounts of burning residue of other crops were estimated by area data described in the *Crop Statistics* or the *Vegetable Production and Shipment Statistics*.

Table 5-72 Amount of burning rice straw and rice chaff on crop field [kt]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rice straw | 438.2 | 536.9 | 429.1 | 276.6 | 163.5 | 149.3 | 187.0 | 149.4 | 183.4 | 161.7 | 144.2 | 152.8 | 129.3 | 129.3 |
| Rice chaff | 581.3 | 528.3 | 291.3 | 260.3 | 206.0 | 212.9 | 179.2 | 195.6 | 206.6 | 193.9 | 147.5 | 142.6 | 114.2 | 114.2 |
| Total | 1,019.5 | 1,065.2 | 720.4 | 536.9 | 369.4 | 362.2 | 366.2 | 345.0 | 390.0 | 355.6 | 291.7 | 295.4 | 243.5 | 243.5 |

Reference: Calculated from each prefecture data

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

For uncertainty of the emission factor, uncertainties ($CH_4$: 296%, $N_2O$: 300%) were calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 296% for $CH_4$ and 300% for $N_2O$.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since the data for rice straw and rice chaff plowed into soil in FY2017 was updated, the emission in FY2017 was recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvement plans.

## 5.8. Liming (3.G.)

### *a) Source/Sink Category Description*

$CO_2$ are released into the air by application of limestone ($CaCO_3$) fertilizer and/or dolomite ($CaMg(CO_3)_2$) fertilizer via hydrogen carbonate ions ($HCO_3^-$) which is released in soil water. This category deals with $CO_2$ emissions from their agricultural lime application.

$CO_2$ emissions from this category in FY2018 were 294 kt-$CO_2$, comprising 0.02 % of total emissions (excluding LULUCF). The value represents a decrease by 46.7% from FY1990.

Table 5-73 $CO_2$ emissions from agricultural lime application

| Gas | Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 3.G.-Limestone | kt-$CO_2$ | 550 | 303 | 332 | 231 | 270 | 242 | 246 | 369 | 379 | 362 | 258 | 252 | 293 | 293 |
| | 3.G.-Dolomite | | 0.3 | 0.5 | 0.5 | 0.6 | 0.6 | 1.0 | 1.1 | 0.6 | 1.1 | 1.0 | 0.8 | 0.8 | 0.9 | 0.9 |
| | Total | kt-$CO_2$ | 550 | 304 | 333 | 231 | 270 | 243 | 247 | 370 | 380 | 363 | 259 | 253 | 294 | 294 |

### *b) Methodological Issues*

- ***Estimation Method***

The Tier 1 method is used in accordance with the decision tree described in the *2006 IPCC Guidelines* (Vol.4, 11.27, Figure11.4).

$$E = (M_{Limestone} \times EF_{Limestone} + M_{Dolomite} \times EF_{Dolomite}) \times 44/12$$

| | |
|---|---|
| $E$ | : Annual $CO_2$ emissions from agricultural lime application [t-$CO_2$/yr] |
| $M_{Limestone}$ | : Annual amount of calcic limestone [t/yr] |
| $M_{Dolomite}$ | : Annual amount of dolomite [t/yr] |
| $EF_{Limestone}$ | : Emission factor of calcic limestone [t-C/t] |
| $EF_{Dolomite}$ | : Emission factor of dolomite [t-C/t] |

- ***Emission Factors***

Limestone ($CaCO_3$): 0.12 [t-C/t] (default value, *2006 IPCC Guidelines*).

Dolomite (CaMg(CO3)2): 0.13 [t-C/t] (default value, *2006 IPCC Guidelines*).

- ***Activity Data***

➢ ***Annual amount of limestone and dolomite applied to cropland***

These data were calculated by adding up lime production and import quantities as listed in *the Yearbook*

*of Fertilizer Statistics* published by the Association of Agriculture and Forestry Statistics. Based on expert judgment, all of the "Calcium carbonate fertilizer" and 70% of each of "Fossil seashell fertilizer", "Crushed limestone" and "Seashell fertilizer" listed in the Yearbook were classified as calcic limestone ($CaCO_3$), and all of the "Magnesium carbonate fertilizer" and 74% of "Mixed magnesium fertilizer" as dolomite ($CaMg(CO_3)_2$).

Table 5-74 Amount of limestone and dolomite applied to agricultural soils [kt]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Applied Limestone | 1,250 | 689 | 755 | 524 | 613 | 550 | 558 | 839 | 860 | 822 | 586 | 573 | 665 | 665 |
| Applied Dolomite | 0.7 | 1.1 | 1.1 | 1.4 | 1.2 | 2.0 | 2.4 | 1.3 | 2.2 | 2.0 | 1.7 | 1.7 | 2.0 | 2.0 |

Reference: Estimated from the data described in *Yearbook of Fertilizer Statistics*

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

For uncertainty of the emission factor, default values (50%) described in the *2006 IPCC Guidelines* was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 50%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

### *d) Source-/Sink-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Statistic data of limestone and dolomite after 2015 were revised. Emission after 2015 were recalculated. See Chapter 10 for impact on trend.

### *f) Source-/Sink-specific Planned Improvements*

There are no improvement plans.

## 5.9. Urea application (3.H.)

### *a) Source/Sink Category Description*

$CO_2$ are released into the air by application of urea ($(NH_3)_2CO$) fertilizer via hydrogen carbonate ions ($HCO_3^-$) which is released in soil water. This category deals with estimation and reporting for this $CO_2$ emissions. Since estimation of urea production in Japan in Industrial Processes sector includes $CO_2$ emission in use phase, this category estimates $CO_2$ emissions from use phase of imported urea fertilizer.

$CO_2$ emissions from this category in FY2018 were 193 kt-$CO_2$, comprising 0.02 % of national total emissions (excluding LULUCF). The value represents an increase by 229 % from FY1990.

Table 5-75 $CO_2$ emissions from urea fertilizer

| Gas | Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 3.H. Urea fertilization | kt-$CO_2$ | 59 | 56 | 110 | 179 | 120 | 160 | 168 | 150 | 198 | 189 | 201 | 193 | 193 | 193 |

### b) Methodological Issues

- **Estimation Method**

The Tier 1 method is used in accordance with the decision tree described in the *2006 IPCC Guidelines* (Vol.4, p.11.33, Fig.11.5).

$$E = (M \times EF) \times 44/12$$

| | |
|---|---|
| $E$ | : Annual $CO_2$ emissions from urea fertilizer [t-$CO_2$/yr] |
| $M$ | : Annual amount of imported urea fertilizer [t/yr] |
| $EF$ | : Emission factor of urea fertilizer [t-C/t] |

- **Emission Factors**

0.20 [t-C/t] (default value, *2006 IPCC Guidelines*).

- **Activity Data**

These data were calculated by deducting "amount of domestic urea production for fertilizer" from "total demand of urea fertilizer" described in *the Yearbook of Fertilizer Statistics (Pocket Edition)* published by the Association of Agriculture and Forestry Statistics.

Table 5-76 Amount of imported urea fertilizer [kt]

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amount of imported urea fertilizer | 80 | 76 | 149 | 244 | 164 | 218 | 229 | 205 | 270 | 258 | 274 | 263 | 263 | 263 |

Reference: Estimated from the data described in *Yearbook of Fertilizer Statistics (Pocket Edition)*

### c) Uncertainties and Time-series Consistency

- **Uncertainties**

For uncertainty of the emission factor, default value (50%) described in the *2006 IPCC Guidelines* was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 50%.

- **Time-series Consistency**

Emissions are estimated by using consistent estimation methods and data sources.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) Category-specific Recalculations

Statistic data of urea after 2015 was revised. Emission after 2015 were recalculated. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

There are no improvement plans.

## 5.10. Other carbon-containing fertilizers (3.I.)

Since there are no other sources to be reported in this category, this category is reported as “NO”.

## 5.11. Other (3.J.)

Since there are no other sources as “Other”, this category is reported as “NO”.

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# Chapter 6. Land Use, Land-Use Change and Forestry (CRF sector 4)

## 6.1. Overview of Sector

The land use, land-use change, and forestry (LULUCF) sector deals with greenhouse gas (GHG) emissions and removals resulting from land use such as forestry activities and its land-use change. Japan classifies its national land into six categories—forest land, cropland, grassland, wetlands, settlements, and other land—and subdivides each of them into two subcategories on the basis of the occurrences of land conversion in a certain period, in accordance with the *2006 IPCC Guidelines*; a default value of 20 years is applied as the threshold to distinguish the occurrences of land conversion. GHG emissions and removals in this sector consist of carbon stock changes in five carbon pools (aboveground biomass, belowground biomass, dead wood, litter, and soil), carbon stock changes in harvested wood products (HWP) in forest land, direct $N_2O$ emissions from N fertilization in forest land, $CH_4$ and $N_2O$ emissions from drainage of organic soils, $N_2O$ emissions from nitrogen mineralization resulting from land use changes in mineral soils or changes of its management, indirect $N_2O$ emissions from managed soils, and non-$CO_2$ emissions from biomass burning. Tiers of methodology used in this sector are shown in Table 6-1. In this chapter, above- and below- ground biomass are collectively referred as “living biomass”, and dead wood and litter are also referred as “dead organic matter”.

Japan’s total land area as of FY2018 is about 37.8 million ha, which represents an increase by 0.06% over the FY1990 value. The increase results from reclamation by drainage and soil filling of sea areas[1]. The dominant land use type is forest land, which covers about 24.91 million ha, followed by cropland, which covers about 4.24 million ha. In addition, grassland, wetlands, settlements, and other land cover about 0.95 million ha, 1.35 million ha, 3.87 million ha, and 2.47 million ha, respectively. In the estimation and reporting in LULUCF sector, only land territory is included and sea area for which the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (hereafter *Wetlands Guidelines*) provides some methodologies is excluded.

Japan’s national land is an archipelago consisting of Hokkaido, Honshu, Shikoku, Kyushu and other islands, and lies off the east coast of the Eurasian Continent. The archipelago is formed into a crescent shape extending from northeast to southwest. Its northernmost point is located at about 45 degrees north latitude, and its southernmost point is located at about 20 degrees north latitude. Most of Japan’s national land is located in a temperate, humid climate zone. Some islands in the southern part of Japan belong to a subtropical climate zone, and the northern part of Japan is located in a cool-temperate climate zone. The average annual temperature and precipitation in Tokyo, the capital city of Japan located in the temperate, humid climate zone, are 15.4 degrees Celsius and 1,528.8mm; those in Sapporo, Hokkaido prefecture, located in the cool-temperate climate zone, are 8.9 degrees Celsius and 1,106.5 mm; and those in Naha, Okinawa prefecture, located in the subtropical climate zone, are 23.1 degrees Celsius and 2,040.8 mm, respectively.[2]

The LULUCF sector contains both sources and sinks; in Japan, it has been a net sink continuously since

[1] *Statistical reports on the land area by prefectures and municipalities in Japan* (the Geospatial Information Authority of Japan: GSI) <http://www.gsi.go.jp/kokusaikoryu/kokusaikoryu-e30092.html>

[2] The average annual temperatures and precipitation are the average of the years between FY1981 and 2010. See National Astronomical Observatory (2019) pp.184-185 and pp.196-197. With respect to the degrees of latitude, see *Degrees of Latitudes and Longitudes of Japan’s Northernmost, Southernmost, Easternmost and Westernmost Points* (GSI) <http://www.gsi.go.jp/KOKUJYOHO/center.htm>.

FY1990. Net removals in FY2018 were 57,390 kt-$CO_2$ eq; this accounts for 4.6% of the total national emissions (excluding LULUCF). The net removals in FY2018 also represent a decrease of 7.8% below the FY1990 value and a decrease of 2.0% below the FY2017 value. Net removals in Japan had increased until FY2003, but have been decreasing continuously since 2003. The key drivers for the rise in removals since FY1990 until FY2003 were increase of removals in forest land and decrease of emissions resulting from land use changes due to the decrease of areas of land conversion. The subsequent decreasing trends were due to decrease of removals in forest land. See descriptions in each category for further information on reasons of trends.

Table 6-1 Methodological tiers used in the LULUCF sector

| GREENHOUSE GAS SOURCE AND SINK | $CO_2$ | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| A. Forest land | T1,T2,T3 | CS,D | T1 | D | T1,T2 | CS,D |
| B. Cropland | T1,T2,T3 | CS,D | T1 | D | T1,CS | CS,D |
| C. Grassland | T1,T2,T3 | CS,D | T1 | D | T1,CS | CS |
| D. Wetlands | T1,T2 | CS,D | NO,NA,NE | NA | NO,NA,NE | NA |
| E. Settlements | T1,T2 | CS,D | T1 | CS,D | T1 | CS,D |
| F. Other land | T2 | CS,D | NO | NO | T1 | D |
| G. Harvested wood products | T2,T3 | CS,D | | | | |

Note: D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country-specific method or emission factor

## 6.2. Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories

In accordance with the *2006 IPCC Guidelines*, all lands in Japan are classified into 6 land-use categories. In Japan, as shown in Table 6-2, lands are allocated in each land-use categories on the basis of the definitions in existing statistics. Area of each land-use category is identified by using value indicated in land classification in existing statistics. Lands which are not be classified into the above five land use categories is defined as “Other Land”, of which the area is determined by deducting the total area of five land use categories from total national land. As for forest land, cropland and grassland, country-specific subcategories are determined (forest land: forests with standing trees (intensively managed forests / semi-natural forests) / forests with less standing trees / bamboo; cropland: rice fields / upland fields / orchards / cultivation abandoned agricultural land; grassland: pasture land / grazed meadow land/ wild land). In addition, the definition of country-specific subcategory for forest land, which was established by Japan, is shown in Table 6-3.

Table 6-2 Criteria for land-use category allocation and reference of data and information to determine area

| IPCC Land use category | Criteria for land-use category allocation | Reference of data and information to determine area |
|---|---|---|
| Forest land | Forests under Forest Law Article 5 and 7.2. | Forests with standing trees (intensively managed forests, semi-natural forests), forests with less standing trees and bamboo in the forests which are included in the regional forests plan according to the *Forestry Status Survey* [-2004] and the *National Forest Resources Database* (NFRDB) [2005-] (Forestry Agency).[3] |
| Cropland | Rice fields, upland fields, orchards and cultivation abandoned agricultural land | Rice fields, upland fields and orchard according to *Statistics of Cultivated and Planted Area* by the MAFF. Cultivation abandoned agricultural land according to *World Census of Agriculture and Forestry* (MAFF). |
| Grassland | Pasture land, grazed meadow land, and wild land[4]. (excluding pasture land and grazed meadow land) | Pasture land according to *Statistics of Cultivated and Planted Area* (MAFF), grazed meadow land (excluding when it is included in forest land) according to *World Census of Agriculture and Forestry* (MAFF), and wild land according to *Land Use Status Survey* (MLIT). |
| Wetlands | Lands covered with water (such as dams), rivers, and waterways. | Lands covered with water, rivers, and waterways according to *Land Use Status Survey, Survey of Forestry regions* (MLIT). Among them, the lands that are subject to revegetation activities (e.g. green areas along rivers and erosion control sites, a part of urban parks) are allocated to settlements. |
| Settlements | Urban areas that do not constitute forest land, cropland, grassland or wetlands. Urban green areas are all wooded and planted areas that do not constitute forest land. | Settlements are roads, residential land, school reservations, park and green areas, road sites, environmental facility sites, golf courses, ski courses and other recreation sites identified in *Land Use Status Survey* and other surveys by the MLIT. The included figures for urban green areas are taken from the surveys on urban green facilities conducted by the MLIT. (Details are shown in Table 11-11). |
| Other land | Any land that does not belong to the above land-use categories. | Determined by subtracting the total area belonging to the above five land-use categories from the total area of national land according to *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan* by the Geospatial Information Authority of Japan. |

MAFF: Ministry of Agriculture, Forestry and Fisheries; MLIT: Ministry of Land, Infrastructure, Transport and Tourism

Table 6-3 Definitions of forest subcategories

| Forest subcategories | | Definitions |
|---|---|---|
| Forest with standing trees | | Forest that does not fall under "forest with less standing trees" and has a tree crown cover of standing trees 30% or higher (including young stands with the degree of stocking[5] of 3 or higher even though the tree crown cover is less than 30%). Even if the tree crown cover of standing trees is less than 30%, forest in which the sum of the crown covers of both standing trees and bamboo is 30% or higher, while dominated by standing trees, is also included |
| | Intensively managed forest | Forest land that is subject to artificial regeneration such as tree planting and seeding, and in which no less than 50% of the volume (or the number) of standing trees are of tree species subject to artificial regeneration. |
| | Semi-natural forest | Forest with standing trees which is not classified as intensively managed forests |
| Forest with less standing trees | | Forest in which the sum of the tree crown covers of both standing trees and bamboo is less than 30 percent. |
| Bamboo | | Forest, other than “forest with standing trees”, in which a tree crown cover of bamboo (excluding bamboo grasses) is 30% or higher. Even if the tree crown cover of bamboo is less than 30%, forest in which the sum of the crown covers of both standing trees and bamboo is 30% or higher with bamboo being dominated is also included. |

Reference: Forestry Agency of Japan, *Forest Status Survey* (March, 2007) (partially modified)

In accordance with the *2006 IPCC Guidelines*, each land use category is further classified into “Land remaining Land” and “Land converted to Land” depending on its history of land-use conversion; each

[3] The *Forestry Status Survey* and the *National Forest Resources Database* (NFRDB) use the same definitions and survey methods for forests, and these two data bases have time-series consistency.

[4] Its present status is mainly wild grassland (including perennial pasture land, degenerated pasture land, and areas abandoned after cultivation and becoming wild).

[5] The degree of stocking is the ratio of actual volume to the expected volume of the forest stand, multiplied by 10.

area is calculated by estimation based on existing statistics. Among them, the areas of land converted to forest land are estimated based on data of afforestation and reforestation under Article 3, paragraph 3, of the Kyoto Protocol, which are determined by utilizing orthophotos taken at the end of 1989 and recent satellite images, in addition to existing statistics. The areas of forest land converted to other land-use categories are estimated based on data of deforestation determined in the same way as afforestation and reforestation, in addition to data of the *World Census of Agriculture and Forestry* and the Forestry Agency's records. For detailed information on the methods of determining the areas of afforestation, reforestation and deforestation, see section 11.4.2.3. in Chapter 11. In addition, Land-use categories that cannot be directly determined from existing statistics are determined by applying estimation measures such as allocation of areas of land conversion by means of the ratio of actual land areas for each land-use category.

## 6.3. Approaches for estimating land areas and land-use database used for the inventory preparation

### 6.3.1. Survey methods and due dates of major land area statistics

Table 6-4 shows the survey methods and due dates of major land area statistics.

Table 6-4 Survey methods and due dates of major land area statistics

| Name of the statistics / census | | Survey method | Survey due date | Frequency | Presiding ministry |
|---|---|---|---|---|---|
| Forest Status Survey | | Complete count survey | March, 31st | Approximately 5 years (Before 2004) | MAFF (Forestry Agency) |
| National Forest Resources Database | | Complete count survey | April, 1st | Every year (Since 2005) | MAFF (Forestry Agency) |
| Statistics of Cultivated and Planted Area (Survey of cropland area) | [Cropland area] | Ground measurement survey (sample) | July, 15th | Every year | MAFF |
| | [Expansion area and converted area of cropland] | Tabular survey (using documents from relevant agencies and aerial photographs, etc.) | July, 15th in the previous year until July, 14th | | |
| World Census of Agriculture and Forestry | | Complete count survey | [by 2000] August, 1st [from 2005] February, 1st | [by 2000] Every 10 years, [from 2005] every 5 years | MAFF |
| Land Use Status Survey | | Complete count Survey | --- | Every year | MLIT |
| Statistical Reports on the Land Area by Prefectures and Municipalities in Japan | | Complete count Survey | October, 1st | Every year | GSI |

Note: Details for urban green facilities are shown in Table 11-11.

### 6.3.2. Land area estimation methods

Some land areas cannot be directly determined from existing statistics; therefore, they are estimated using the following methods:

- Interpolation
- Allocation of areas of land conversion by means of the ratio of actual land areas for each land-use category
- Allocation of areas of land conversion by means of the ratio of converted land areas for a certain

year

Please refer to each related section for more detailed explanations about estimation method in individual area.

- ***Interpolation***

➢ ***Method***

The areas of forest land before 2004 were surveyed at an interval of approximately five years, and it is difficult to know the actual areas of forest land beside these years. Therefore, they were estimated by interpolation by means of linear expressions based on the areas in the surveyed years.

➢ ***Land-use category***

4.A.2. Land converted to Forest land (FY1991- 1994, 1996- 2001 and 2003- 2004).

- ***Allocation of areas of land conversion by means of the ratio of actual land areas for each land-use category***

➢ ***Method***

In Japan, it is difficult to obtain the areas of upland field converted to forest land, orchard converted to forest land and pasture land converted to forest land directly from existing statistics, since those are collectively reported as arable land. Therefore, these land areas were estimated by multiplying the arable land converted to forest land by the ratios of actual land areas for each of the land-use categories (upland field, orchards and pasture land).

➢ ***Land-use category***

4.A.2. Land (Cropland and Grassland) converted to Forest land
4.B.2. Land (Forest land, Grassland, Wetlands and Other land) converted to Cropland
4.C.2. Land (Forest land, Cropland, Wetlands and Other land) converted to Grassland
4.E.2. Land (Cropland and Grassland) converted to Settlements
4.F.2. Land (Cropland and Grassland) converted to Other land

- ***Allocation of areas of land conversion by means of the ratio of converted land area for a certain year***

➢ ***Method***

In Japan, it is difficult to directly obtain annual land areas of cropland, grassland, settlements and other land converted to wetlands, respectively. Therefore, with the assumption that the annual land ratios of cropland, grassland, settlements and other land converted to wetlands to land converted to wetlands in FY1998 is constant, the ratio are multiplied by the areas of land converted to wetlands in each year to obtain the area of respective land use category converted to wetlands.

➢ ***Land use category***

4.D.2. Land (Cropland, Grassland, Settlements and Other land) converted to Wetlands

### 6.3.3. Land-use transition matrix

Land use transition matrix to determine land use conversion has been produced annually since FY1990 until now, for six land use categories whose areas are identified in accordance with the description in section 6.2 and in the beginning part of section 6.3. Land use conversion made in FY1990 and in FY2018 are shown in the following Table 6-5 and Table 6-6 individually. In addition, land use matrix

produced by accumulating land conversion between each land use category, from FY1990 to FY2018, is shown in Table 6-7. In Japan, all lands are managed lands and lands without management do not exist; therefore, the columns for lands without management are shaded in gray.

Table 6-5 Land-use transition matrix for Japan in FY1990 (unit: kha)

| Before Conversion \ After Conversion | Forest land | Cropland | Grassland | Wetlands | Settlements | Other land | Total |
|---|---|---|---|---|---|---|---|
| Forest Land | 24,945.4 | 5.41 | 0.76 | 0.31 | 14.94 | 3.70 | 24,970.5 |
| Cropland | 2.71 | 4,806.9 | 0.90 | 0.02 | 21.35 | 2.16 | 4,834.1 |
| Grassland | 0.67 | 0.004 | 1,029.8 | 0.007 | 3.19 | 0.36 | 1,034.0 |
| Wetlands | NO | 0.34 | 0.12 | 1,308.4 | IE | IE | 1,308.9 |
| Settlements | 0.75 | IE | NO | 0.002 | 3,169.5 | IE | 3,170.3 |
| Other land | 0.75 | 0.21 | 0.01 | 0.09 | IE | 2,455.0 | 2,456.0 |
| Total | 24,950.3 | 4,812.9 | 1,031.6 | 1,308.8 | 3,209.0 | 2,461.2 | 37,773.7 |

Table 6-6 Land-use transition matrix for Japan in FY2018 (unit: kha)

| Before Conversion \ After Conversion | Forest land | Cropland | Grassland | Wetlands | Settlements | Other land | Total |
|---|---|---|---|---|---|---|---|
| Forest Land | 24,914.8 | 0.16 | 0.37 | 0.07 | 5.10 | 0.51 | 24,921.0 |
| Cropland | NO | 4,236.0 | 0.39 | 0.01 | 11.64 | 0.78 | 4,248.8 |
| Grassland | 0.08 | 0.005 | 946.6 | 0.001 | 1.83 | 0.14 | 948.7 |
| Wetlands | NO | NO | NO | 1,348.1 | IE | IE | 1,348.1 |
| Settlements | 0.01 | IE | NO | 0.0003 | 3,851.4 | IE | 3,851.4 |
| Other land | NO | 7.51 | 1.20 | 0.02 | IE | 2,470.6 | 2,479.3 |
| Total | 24,914.9 | 4,243.7 | 948.6 | 1,348.2 | 3,870.0 | 2,472.0 | 37,797.4 |

Table 6-7 Land-use transition matrix for FY1990-FY2018 (unit: kha)

| 1990 \ 2018 | Forest Land (managed) | Forest Land (unmanaged) | Cropland | Grassland (managed) | Grassland (unmanaged) | Wetlands (managed) | Wetlands (unmanaged) | Settlements | Other land | Total unmanaged land | Initial area |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Forest Land (managed) | 24,808.3 | | 27.7 | 14.7 | | 16.0 | | 212.4 | 52.3 | | 25,131.3 |
| Forest Land (unmanaged) | | | | | | | | | | | |
| Cropland | 35.1 | | 4,175.7 | 23.1 | | 1.3 | | 381.4 | 64.5 | | 4,681.0 |
| Grassland (managed) | 12.7 | | 1.1 | 907.7 | | 0.3 | | 58.8 | 8.9 | | 989.3 |
| Grassland (unmanaged) | | | | | | | | | | | |
| Wetlands (managed) | 0.1 | | 1.1 | 0.4 | | 1,326.1 | | IE | IE | | 1,327.7 |
| Wetlands (unmanaged) | | | | | | | | | | | |
| Settlements | 31.0 | | IE | NO | | 0.1 | | 3,217.5 | IE | | 3,248.5 |
| Other land | 27.8 | | 38.2 | 2.8 | | 4.4 | | IE | 2,346.4 | | 2,419.5 |
| Total unmanaged land | | | | | | | | | | | |
| Final area | 24,914.9 | | 4,243.7 | 948.6 | | 1,348.2 | | 3,870.0 | 2,472.0 | | 37,797.4 |
| Net change | -216.4 | | -437.4 | -40.7 | | 20.5 | | 621.5 | 52.5 | | 0.0 |

Note: The areas described as “IE” are included in “Other lands remaining the same land-use category” which could be used for adjustment with total area of national land.

## 6.4. Parameters for estimating carbon stock changes from land use conversions

Prior to the sections describing detailed methods for each land-use category, basic parameters used for estimating carbon stock changes due to land use conversions are shown here (Table 6-8a to Table 6-11) to prevent the reiteration of indicating these parameters in each subsequent section. The method of establishing some parameters, calculation method, and ground for establishing them are shown in "Note". Please refer to each section specified in Note. In case that notation "-" is used in table instead of describing numbers and description is separately made, please also refer to "Note" since the case may be under examination.

As for parameter whose value is indicated as "0", there are following three cases: in accordance with the *2006 IPCC guidelines*, default value, "0", is applied; carbon stock changes but no calculation methodology exists; it is assumed "0" under the assumption that there is no change. For details, please refer to "Note".

Table 6-8a Living biomass stocks for each land-use category before and immediately after conversion

| Land use category | | | Biomass stock or Carbon stock | Note |
|---|---|---|---|---|
| Before conversion | Forest land | | 100.4 [t-d.m./ha] (FY2018) | Calculated by utilizing the values of biomass stocks in land of deforestation under Article 3, paragraph 3, of the Kyoto Protocol, which are provided from the NFRDB. In addition, the values before FY2007 are substituted by the average value between FY2008 and FY2012. (See Table 6-12 for reference values) |
| | Cropland | Cropland (Average) | 1.7 [t-C/ha] | Weighted average carbon content of crop residues plowed into rice and upland fields from FY 1990 to FY2017, calculated by crop cultivation area for each type of crop |
| | | Rice field | 2.0 [t-C/ha] | Average carbon content of crop residues plowed into rice fields from FY1990 to FY2017 |
| | | Upland field | 1.3 [t-C/ha] | Weighted average carbon content of crop residues plowed into upland fields from FY1990 to FY2017, calculated by crop cultivation area for each type of crop |
| | | Orchard | IE | Included in cropland remaining cropland. |
| | Grassland | | 13.50 [t-d.m./ha] | Default value (Table 6.4: "warm temperate wet", Volume 4 of the *2006 IPCC Guidelines*) |
| | Wetlands, settlements and other land | | 0 | Biomass stocks are assumed to be "0". |
| Immediately after conversion | All land uses | | 0 | Biomass stocks are assumed to be "0". |

Table 6-8b Living biomass growth increments for each land-use category after conversion

| Land use category | | | Biomass growth increment | Note |
|---|---|---|---|---|
| After conversion | Forest land | | 3.0 [t-C./ha/yr] | Removals in this land are directly estimated based on the implied removal factor of AR activity under the Kyoto Protocol. The average value between FY2008 and FY2010 are applied to all reporting years. |
| | Cropland | Cropland (Average) | 1.7 [t-C/ha/yr] | Assumed that carbon stock after conversion reaches the value in Table 6-8a in one year |
| | | Rice field | 2.0 [t-C/ha/yr] | Assumed that carbon stock after conversion reaches the value in Table 6-8a in one year |
| | | Upland field | 1.3 [t-C/ha/yr] | Assumed that carbon stock after conversion reaches the value in Table 6-8a in one year |
| | | Orchard | IE | Included in cropland remaining cropland. |
| | Grassland | | 2.70 [t-d.m./ha] | Default value (Table 6.4: One fifth of the value 13.5 at "warm temperate wet", the *2006 IPCC Guidelines*) |
| | Settlements | | - | See section 6.9.2.b)1) |
| | Wetlands and other land | | 0 | Biomass growth increment are assumed to be "0". |

Table 6-9 Carbon stocks of dead wood for each land-use category before and after conversion

| Land-use Category | | Carbon Stock | Note |
|---|---|---|---|
| Before Conversion | Forest land | 14.65[t-C/ha] (FY2018) | Calculated from carbon stocks in dead wood in all forests. In addition, the values before 2004 are substituted by the value of FY2005.(See Table 6-12 for reference values) |
| | Cropland, grassland, wetlands, settlements, other land | 0 | Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier.1) |
| Immediately after conversion | All land uses | 0 | Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier.1) Carbon stocks immediately after conversion are assumed to be "0". |
| After conversion | Forest land | 13.01 [t-C/ha] | Average carbon stocks per unit area in 20-year-old forests obtained by the CENTURY-jfos model |
| | Cropland, grassland, wetlands, other land | 0 | Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier.1) |
| | Settlements | 0 | Default value (Section 8.3.2 in Volume 4 of the *2006 IPCC Guidelines*, Tier 1) |

Table 6-10 Carbon stocks of litter for each land-use category before and after conversion

| Land-use Category | | Carbon Stock | Note |
|---|---|---|---|
| Before Conversion | Forest land | 7.31 [t-C/ha] (FY2018) | Calculated from carbon stocks in litter in all forests. In addition, the values before 2004 are substituted by the value of FY2005. (See Table 6-12 for eference values) |
| | Cropland, grassland, wetlands, settlements, other land | 0 | Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier.1) |
| Immediately after conversion | All land-uses | 0 | Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier.1) Carbon stocks immediately after conversion are assumed to be "0". |
| After conversion | Forest land | 5.637 [t-C/ha] | Average carbon stocks per unit area in 20-year-old forests obtained by the CENTURY-jfos model |
| | Cropland, grassland, wetlands, other land | 0 | Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier.1) |
| | Settlements | - | See section 6.9.2.b)2) |

Table 6-11 Carbon stocks of soil for each land-use category before and after conversion (in mineral soils)

| Land-use Category | | | Carbon Stock | Note |
|---|---|---|---|---|
| Before conversion | Forest land | | 85.42 [t-C/ha] (FY2018) | Value of soil carbon stocks at 0-30 cm depth one year before the inventory year. National average value calculated by the CENTURY-jfos model. In addition, the value in FY2005 is applied to the years before 2004. (See Table 6-12 for reference values) |
| | Cropland | Rice field | 71.38 [t-C/ha] | Value of soil carbon stocks at 0-30 cm depth. Data provided from Dr. Makoto Nakai, National Institute for Agro-Environmental Sciences (Unpublished) * These carbon stocks were not applied to "cropland converted to grassland" and "grassland converted to cropland". |
| | | Upland field | 86.97 [t-C/ha] | |
| | | Orchard | 77.46 [t-C/ha] | |
| | | Cropland (average) | 76.46[t-C/ha] | |
| | Grassland | | 134.91 [t-C/ha] | |
| | Wetlands | | 88.00 [t-C/ha] | Default value (*2006 IPCC Guidelines* Table 2.3, Wetland soils/ Warm temperate). |
| | Settlements | | - | Under investigation |
| | Other land | | - | This value is determined depending on land conversion status. |
| After conversion | Forest land | | 82.907 [t-C/ha] | Value of soil carbon stocks at 0-30 cm depth. Average carbon stocks per unit area in 20-year-old forests obtained by the CENTURY-jfos model. |
| | Cropland | | IE | Included in cropland remaining cropland. |
| | Grassland | | IE | Included in grassland remaining grassland. |
| | Wetlands | | - | Under investigation |
| | Settlements | | - | These values are determined depending on land conversion status. |
| | Other land | | - | |

Note: All carbon stocks in mineral soils before conversion to forest land are regarded as 80 t-C/ha due to expert judgment.

Table 6-12 Carbon stock changes in five carbon pools in forest land before conversion

| Land use category | | Carbon pools | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Before conversion | Forest land | Biomass stock | [t-d.m./ha] | 113.4 | 113.4 | 113.4 | 113.4 | 108.3 | 99.8 | 100.6 | 123.2 | 98.5 | 99.1 | 99.5 | 99.9 | 100.3 | 100.4 |
| | | Dead wood | [t-C/ha] | 15.08 | 15.08 | 15.08 | 15.08 | 14.99 | 14.97 | 14.95 | 14.93 | 14.86 | 14.82 | 14.77 | 14.77 | 14.70 | 14.65 |
| | | Litter | [t-C/ha] | 7.24 | 7.24 | 7.24 | 7.24 | 7.27 | 7.28 | 7.28 | 7.29 | 7.29 | 7.29 | 7.30 | 7.33 | 7.31 | 7.31 |
| | | Soil | [t-C/ha] | 85.07 | 85.07 | 85.07 | 85.07 | 85.12 | 85.17 | 85.20 | 85.30 | 85.31 | 85.34 | 85.36 | 85.69 | 85.48 | 85.42 |

## 6.5. Forest land (4.A.)

Forests absorb $CO_2$ from the atmosphere by photosynthesis, fix carbon as organic substances, and store these substances for a given period. In contrast, forests emit $CO_2$ due to the effects of events such as logging and natural disturbances.

All forests in Japan are managed forests, and they consist of intensively managed forests, semi-natural forests, bamboo, and forests with less standing trees. Japan's forest land area in FY2018 was about 24.91 million ha; about 65.9% of the total national land area. The net removal in this category in FY2018 was 59,027 kt-$CO_2$ (excluding 2.64 kt-$CO_2$ eq. of $CH_4$ and $N_2O$ emissions resulting from biomass burning, 0.78 kt-$CO_2$ eq. of $N_2O$ emission resulting from N fertilization in forest land, and 157.84 kt-$CO_2$ eq. of $N_2O$ emission from nitrogen mineralization resulting from change of land use or management of mineral soils). This represents a decrease of 25.3% below the FY1990 value, and a decrease of 3.0% below the 2017 value. This declining trend in removals in recent years is due to the maturity of Japanese forests. In this section, forest land is divided into two subcategories: "Forest land remaining Forest land (4.A.1.)" and "Land converted to Forest land (4.A.2.)", and they are described separately in the

following subsections.

Table 6-13 Emissions and removals in forest land resulting from carbon stock changes

| Gas | Category | Carbon pool | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 4.A. Forest land | Total | kt-$CO_2$ | -79,061 | -87,606 | -90,637 | -92,662 | -75,867 | -76,371 | -78,110 | -77,676 | -69,991 | -68,279 | -63,108 | -58,562 | -60,849 | -59,027 |
| | | Living Biomass | kt-$CO_2$ | -73,002 | -79,826 | -83,660 | -87,551 | -72,712 | -73,886 | -76,214 | -76,242 | -68,872 | -67,330 | -62,244 | -57,735 | -59,983 | -58,135 |
| | | Dead Wood | kt-$CO_2$ | -2,860 | -3,803 | -2,837 | -1,082 | 414 | 914 | 1,342 | 1,655 | 1,830 | 1,873 | 1,854 | 1,787 | 1,665 | 1,546 |
| | | Litter | kt-$CO_2$ | -2,697 | -2,352 | -1,774 | -1,078 | -669 | -571 | -499 | -451 | -413 | -384 | -371 | -355 | -350 | -330 |
| | | Mineral soil | kt-$CO_2$ | -503 | -1,625 | -2,367 | -2,950 | -2,900 | -2,829 | -2,739 | -2,638 | -2,536 | -2,437 | -2,347 | -2,259 | -2,182 | -2,108 |
| | | Organic soil | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 4.A.1. Forest land remaining Forest land | Total | kt-$CO_2$ | -72,386 | -84,289 | -88,229 | -90,819 | -74,489 | -75,018 | -76,790 | -76,388 | -68,740 | -67,086 | -61,979 | -57,494 | -59,843 | -58,093 |
| | | Living Biomass | kt-$CO_2$ | -68,098 | -77,389 | -81,891 | -86,197 | -71,706 | -72,898 | -75,251 | -75,303 | -67,954 | -66,455 | -61,416 | -56,952 | -59,243 | -57,448 |
| | | Dead Wood | kt-$CO_2$ | -1,791 | -3,272 | -2,451 | -787 | 638 | 1,135 | 1,557 | 1,865 | 2,031 | 2,065 | 2,036 | 1,960 | 1,826 | 1,695 |
| | | Litter | kt-$CO_2$ | -2,233 | -2,122 | -1,607 | -950 | -572 | -475 | -405 | -360 | -326 | -301 | -292 | -280 | -280 | -265 |
| | | Mineral soil | kt-$CO_2$ | -264 | -1,506 | -2,281 | -2,884 | -2,850 | -2,779 | -2,691 | -2,591 | -2,491 | -2,395 | -2,306 | -2,221 | -2,146 | -2,075 |
| | | Organic soil | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 4.A.2. Land converted to Forest land | Total | kt-$CO_2$ | -6,675 | -3,317 | -2,408 | -1,843 | -1,378 | -1,353 | -1,320 | -1,288 | -1,251 | -1,193 | -1,129 | -1,068 | -1,006 | -934 |
| | | Living Biomass | kt-$CO_2$ | -4,904 | -2,437 | -1,768 | -1,354 | -1,006 | -988 | -963 | -939 | -918 | -875 | -828 | -783 | -740 | -687 |
| | | Dead Wood | kt-$CO_2$ | -1,069 | -531 | -386 | -295 | -224 | -221 | -215 | -210 | -201 | -192 | -182 | -172 | -161 | -149 |
| | | Litter | kt-$CO_2$ | -463 | -230 | -167 | -128 | -97 | -96 | -93 | -91 | -87 | -83 | -79 | -75 | -70 | -65 |
| | | Mineral soil | kt-$CO_2$ | -239 | -119 | -86 | -66 | -50 | -49 | -48 | -47 | -45 | -43 | -41 | -38 | -36 | -33 |
| | | Organic soil | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

## 6.5.1. Forest land remaining Forest land (4.A.1.)

### *a) Category Description*

This subcategory deals with carbon stock changes in forest land remaining forest land, which has remained forested without conversion for the past 20 years as of FY2018. The net removal in this subcategory in FY2018 was 58,093 kt-$CO_2$ (excluding GHG emissions other than carbon stock changes). This represents a decrease of 19.7% below the FY1990 value and a decrease of 2.9% below the FY2017 value. Net removals in forest land remaining forest land have been decreasing continuously since 2003. Nonetheless, removals per year fluctuate because annual quantity of harvesting domestic timber is changed depending on increase and decrease of demand on the domestic timber due to economic trends. This long-term declining trend in removals is due to the maturity of Japanese forests, especially in “intensively managed forests”. This is because the growth rate of forest over 50 years old in the major planted trees decreases gradually in Japan. In addition, intensively managed forest are maturing year by year in Japan, and these forests over 51 years old occupied 50% of the total forest area in FY2017 (Forestry Agency, 2018; Figure 6-1); this is due to the large-scale plantation after the 1960s. These older trees planted in 1960s have a major influence on Japan’s carbon stock change. These large-scale trees planted in 1960s have been contributed into carbon removals until they mature, and as results, the gains exceed the losses from logging and this category is consistently categorized as “absorbed”.

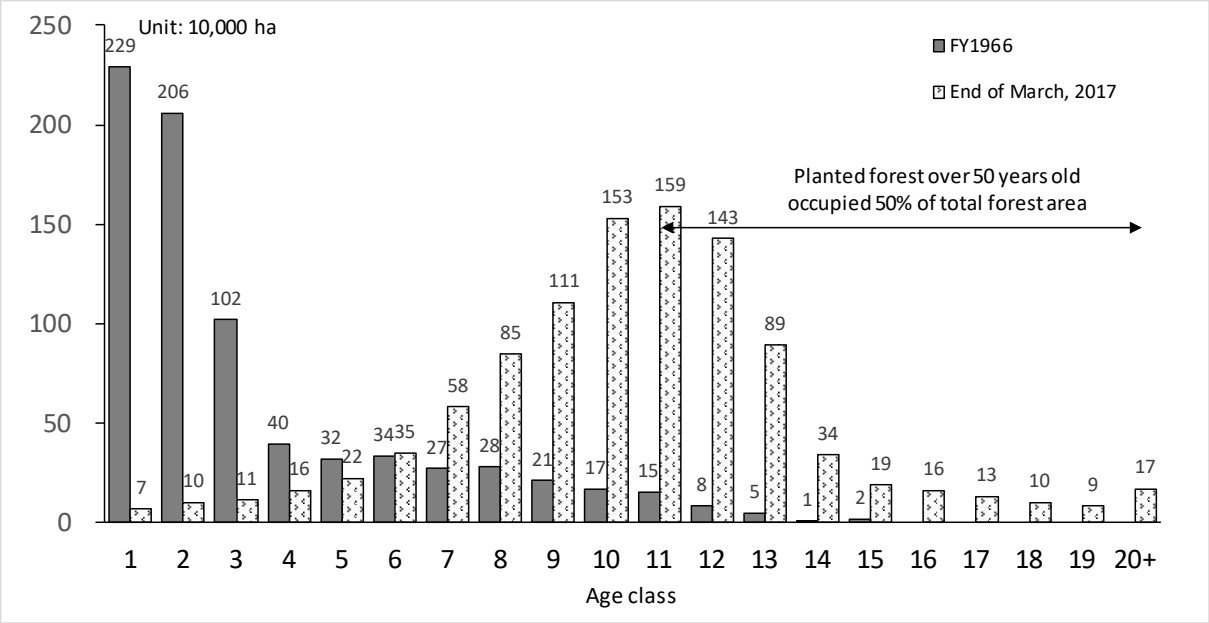


Figure 6-1 Changing forest age class configuration of planted forests

Sources: State of Forest Resources (March 31, 2017) (Forestry Agency); Forest Resources of Japan (April 1968) (Forestry Agency)

Note: Age-classes are divided by 5 year-period steps. "Age-class 1" includes the 1st to 5th year after plantation with the year of plantation counted as the 1st year.

Five carbon pools in bamboo in forest land remaining forest land are all reported as "NA" because annual growth and death of bamboo trunk in established bamboo are equivalent. Bamboo does not have a vascular cambium. Therefore, it reaches the limit of growth in the first year of the emergence and then do not exhibit secondary growth.

It is said that annual growth and death of bamboo trunk are almost equivalent in bamboo forests which reach the constant density in general. FAO conducted a survey (2007) on bamboo resources in 1990, 2000, and 2005 in several Asian and African countries. They reported that the carbon stock changes per unit area for five years (2000-2005) in each country had remained the same. The result of the survey supported the assumption that annual growth and death of bamboo trunk are almost equivalent.

With respect to forests with less standing trees, carbon stock changes in living biomass are estimated, and those in dead organic matter and mineral soils are reported as "NA" because gains and losses of carbon stocks in the dead organic matter and mineral soils are equivalent on a long-term basis (FRA,2010).

The carbon stock changes in dead organic matter in forest land remaining forest land were net removals during 1990–2008 and net emissions since 2009. The change in the trend is due to the age classes of the intensively managed forests where thinning and harvesting are cyclic, causing annual variations in the contributions to the dead wood pool. Concretely speaking, tree thinning in forests planted in 1960s was implemented in 1990s, and transition of carbon stocks from living biomass to dead organic matter was promoted. However, quantity of tree thinning decreased afterwards; hence, the carbon stock gains transmitted to dead organic matter were decreased, and carbon stock losses due to decomposition of the transmitted dead organic matter were increased. The carbon stock losses in the dead organic matter

exceed the carbon stock gains in the pool in 2009. As a result, the carbon stock changes were net removal from 1990 to 2008, and net emissions since 2009.

### *b) Methodological Issues*

#### *1) Carbon stock changes in Living Biomass in "Forest land remaining Forest land"*

- ***Estimation Method***

In accordance with the decision tree provided in the *2006 IPCC Guidelines*, carbon stock changes in living biomass in all forest land are estimated by the Tier 2 stock difference method using the country specific values of the amount of biomass accumulation. In this method, the carbon stock change in the living biomass pool is estimated by calculating the difference between the absolute amounts of carbon stocks in the pool at two points of time[6].

$$\Delta C_{LB} = \sum_k \{(C_{t2} - C_{t1})/(t_2 - t_1)\}_k$$

| | |
|---|---|
| $\Delta C_{LB}$ | : Annual change in carbon stocks in living biomass [t-C/yr] |
| $t_1$, $t_2$ | : Time points of carbon stock measurement |
| $C_{t1}$ | : Total carbon stock in biomass calculated at time $t_1$ [t-C] |
| $C_{t2}$ | : Total carbon stock in biomass calculated at time $t_2$ [t-C] |
| $k$ | : Type of forest management |

The carbon stocks in living biomass are calculated by multiplying the stand volume of each tree species by wood density, the biomass expansion factor, the root-to-shoot ratio and the carbon fraction of dry matter. These parameters except the carbon fraction are determined for each tree species.

$$\mathrm{C} = \sum_j \{V_j \times D_j \times BEF_j \times (1 + R_j) \times CF\}$$

| | |
|---|---|
| $C$ | : Carbon stock in living biomass [t-C] |
| $V$ | : Merchantable volume [$m^3$] |
| $D$ | : Wood density [t-d.m./$m^3$] |
| $BEF$ | : Biomass expansion factor for conversion of merchantable volume |
| $R$ | : Root-to-shoot ratio |
| $CF$ | : Carbon fraction of dry matter [ t-C/t-d.m.] |
| $j$ | : Tree species |

Since Japan calculates the carbon stock change of living biomass in the total forest land in this manner, the carbon stock change of living biomass in forest land remaining forest land is obtained by subtracting the carbon stock change in land converted to forest land from the total change. For the method of estimating carbon stock change in land converted to forest land, see section 6.5.2.b)1).

[6] Japan, as described below, estimates carbon stocks in living biomass using data from the National Forest Resources Database which is developed based on Forest Register's data from prefectures or Regional Forest Offices of National Forests. When they update Forest Registers' data, the prefectures and Regional Forest Offices revise basic information like tree species or areas to represent the correct status of forest. There are circumstances in which prefectures or Regional Forest Offices revise Forest Registers' data like tree species or areas when they update them so that the correct status of forests can be reflected. In this circumstance, modification of carbon stock changes in living biomass is implemented in order to obtain correct carbon stock change values. Without the modification, difference between carbon stock without revision at time point $t_1$ and carbon stock with revision at time point $t_2$ under the stock change method would not reflect the correct carbon stock changes.

- ***Parameters***

➢ ***Volume***

The Forestry Agency has developed the NFRDB in order to estimate GHG emissions/removals from forests. The data in the NFRDB are based on the information on areas, tree species and forest ages from the "Forest Registers" prepared by prefectures or Regional Forest Offices.

Merchantable volumes are estimated by multiplying the areas for each tree species and forest age in the NFRDB by merchantable volumes per area for each tree species and forest age in yield tables. Source of data for the volumes per area are shown in Table 6-14 below. With respect to estimating the volumes of Japanese cedar, Hinoki cypress and Japanese larch in private forests, which are major tree species of intensively managed forests in Japan, the volumes per area reported in new yield tables, reflecting the latest survey results, are applied.

$$V = \sum_{m,j} \left( A_{m,j} \times v \right)$$

$V$ : Merchantable volume [$m^3$]
$A$ : Area [ha]
$v$ : Merchantable volume per area [$m^3$/ha]
$m$ : Age class or forest age
$j$ : Tree species

Table 6-14 Yield tables used to estimate merchantable volume

<table>
<tr><th colspan="3" rowspan="2">Tree species</th><th colspan="2">Yield tables</th></tr>
<tr><th>Private Forest</th><th>National Forest</th></tr>
<tr><td rowspan="3">Intensively managed forests</td><td rowspan="2">Conifer</td><td>Japanese cedar, Hinoki cypress, Japanese larch</td><td>New yield tables</td><td rowspan="3">Yield tables developed by Regional Forest Offices</td></tr>
<tr><td>Other conifer</td><td rowspan="3">Yield tables developed by prefectures</td></tr>
<tr><td colspan="2">Broad leaf</td></tr>
<tr><td colspan="3">Semi-natural forests</td></tr>
</table>

- ***Forest Registers and yield tables developed by prefectures or Regional Forest Offices***

When forest plans are established for private and national forests (all forest lands are divided into 158 planning areas, and forest plans are established each year for 1/5 [about 30] of them), field surveys are implemented in these forests to develop a Forest Register which includes data on area, forest age, volume by tree species and so on. When forest plans are established (private forests: by each prefecture, national forests: by Regional Forest Offices of National Forests), the Forest Registers are updated to reflect the change in volume due to growth, cutting and disturbances. In general, the volume data described in the Forest Registers are estimated based on land area data and yield tables, which provide stand growth in the case that typical forest practices are implemented for each region, tree species and site class (yield tables show the relationship between forest age or age class and volume per area).

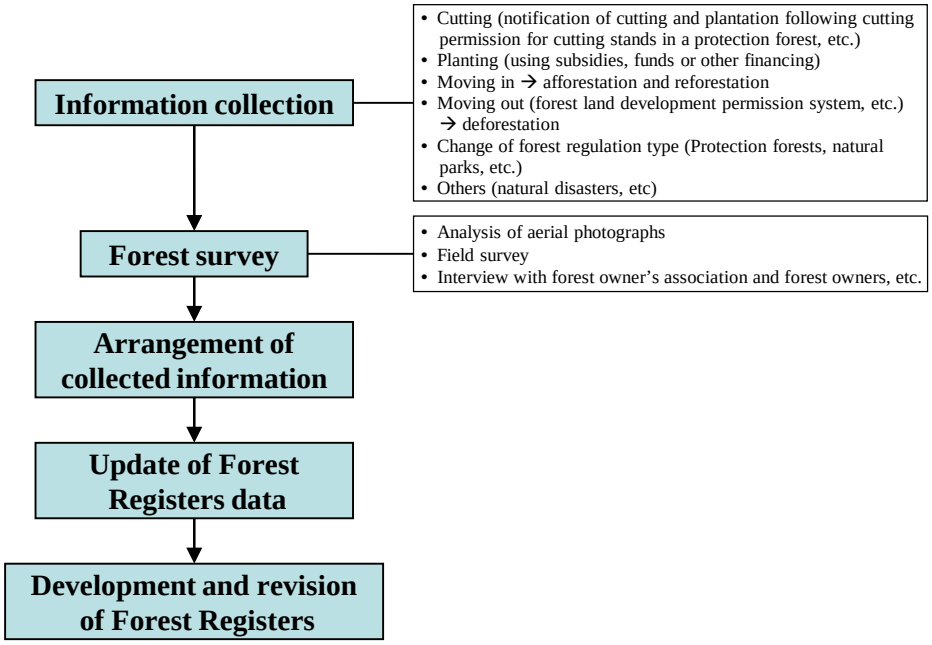


Figure 6-2 Procedures for developing Forest Registers

- ***New yield tables (Japanese cedar, Hinoki cypress, Japanese larch)***

In 2006, the Forestry and Forest Products Research Institute developed new yield tables for Japanese cedar, Hinoki cypress and Japanese larch based on the results of a field survey over the country. The area of these three tree species covers 82% of intensively managed forests in private forests.

The new yield tables for Japanese cedar were established for 7 regions, those for Hinoki cypress for 4 regions and those for Japanese larch for 2 regions.

➢ ***Biomass expansion factor and Root-to-shoot ratio***

The biomass expansion factors (BEF) and root-to-shoot ratios (R) were set based on the results of a biomass survey on dominant tree species, and existing research reports which were implemented by the Forestry and Forest Products Research Institute (Table 6-15).

BEFs were calculated for two age classes (20 years and below / 21 years and above) and for each tree species, because it was identified that BEFs differed between young forests and mature forests. On the other hand, R values were established only for tree species, because the root-to-shoot ratio was not correlated with forest age.

➢ ***Wood density***

Wood density (D) data were set based on the results of biomass survey on dominant tree species and existing research reports which were implemented by the Forestry and Forest Products Research Institute (Table 6-15). These D values were established only for tree species, because wood density was not correlated with forest age.

➢ ***Carbon fraction of dry matter***

The country specific value set based on Japan's research result was adopted as the carbon fraction (CF) of dry matter (Table 6-15).

Table 6-15 Biomass expansion factor, root-to-shoot ratio, wood density for tree species and carbon fraction

| | | BEF [-] | | R | D | CF | Note |
|---|---|---|---|---|---|---|---|
| | | ≦20 | ＞20 | [-] | [t-d.m./m$^3$] | [t-C./t-d.m] | |
| Conifer trees | Japanese cedar | 1.57 | 1.23 | 0.25 | 0.314 | 0.51 | |
| | Hinoki cypress | 1.55 | 1.24 | 0.26 | 0.407 | | |
| | Sawara cypress | 1.55 | 1.24 | 0.26 | 0.287 | | |
| | Japanese red pine | 1.63 | 1.23 | 0.26 | 0.451 | | |
| | Japanese black pine | 1.39 | 1.36 | 0.34 | 0.464 | | |
| | Hiba arborvitae | 2.38 | 1.41 | 0.20 | 0.412 | | |
| | Japanese larch | 1.50 | 1.15 | 0.29 | 0.404 | | |
| | Momi fir | 1.40 | 1.40 | 0.40 | 0.423 | | |
| | Sakhaline fir | 1.88 | 1.38 | 0.21 | 0.318 | | |
| | Japanese hemlock | 1.40 | 1.40 | 0.40 | 0.464 | | |
| | Yezo spruce | 2.18 | 1.48 | 0.23 | 0.357 | | |
| | Sakhaline spruce | 2.17 | 1.67 | 0.21 | 0.362 | | |
| | Japanese umbrella pine | 1.39 | 1.23 | 0.20 | 0.455 | | |
| | Japanese yew | 1.39 | 1.23 | 0.20 | 0.454 | | |
| | Ginkgo | 1.50 | 1.15 | 0.20 | 0.450 | | |
| | Exotic conifer trees | 1.41 | 1.41 | 0.17 | 0.320 | | |
| | Other conifer trees | 2.55 | 1.32 | 0.34 | 0.352 | | Applied to Hokkaido, Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima, Tochigi, Gunma, Saitama, Niigata, Toyama, Yamanashi, Nagano, Gifu and Shizuoka prefectures |
| | | 1.39 | 1.36 | 0.34 | 0.464 | | Applied to Okinawa prefecture |
| | | 1.40 | 1.40 | 0.40 | 0.423 | | Applied to prefectures other than above |
| Broad leaf trees | Japanese beech | 1.58 | 1.32 | 0.26 | 0.573 | 0.48 | |
| | Oak (evergreen tree) | 1.52 | 1.33 | 0.26 | 0.646 | | |
| | Japanese chestnut | 1.33 | 1.18 | 0.26 | 0.419 | | |
| | Japanese chestnut oak | 1.36 | 1.32 | 0.26 | 0.668 | | |
| | Oak (deciduous tree) | 1.40 | 1.26 | 0.26 | 0.624 | | |
| | Japanese popular | 1.33 | 1.18 | 0.26 | 0.291 | | |
| | Alder | 1.33 | 1.25 | 0.26 | 0.454 | | |
| | Japanese elm | 1.33 | 1.18 | 0.26 | 0.494 | | |
| | Japanese zelkova | 1.58 | 1.28 | 0.26 | 0.611 | | |
| | Cercidiphyllum | 1.33 | 1.18 | 0.26 | 0.454 | | |
| | Japanese big-leaf | 1.33 | 1.18 | 0.26 | 0.386 | | |
| | Maple tree | 1.33 | 1.18 | 0.26 | 0.519 | | |
| | Amur cork | 1.33 | 1.18 | 0.26 | 0.344 | | |
| | Linden | 1.33 | 1.18 | 0.26 | 0.369 | | |
| | Kalopanax | 1.33 | 1.18 | 0.26 | 0.398 | | |
| | Paulownia | 1.33 | 1.18 | 0.26 | 0.234 | | |
| | Exotic broad leaf trees | 1.41 | 1.41 | 0.16 | 0.660 | | |
| | Japanese birch | 1.31 | 1.20 | 0.26 | 0.468 | | |
| | Other broad leaf trees | 1.37 | 1.37 | 0.26 | 0.469 | | Applied to Chiba, Tokyo, Kochi, Fukuoka, Nagasaki, Kagoshima, and Okinawa prefectures |
| | | 1.52 | 1.33 | 0.26 | 0.646 | | Applied to Mie, Wakayama, Oita, Kumamoto, Miyazaki, and Saga prefectures |
| | | 1.40 | 1.26 | 0.26 | 0.624 | | Applied to prefectures other than above |

Note: BEF: Biomass expansion factor (20 = age class); R: Root-to-shoot ratio; D: Wood density; CF: Carbon Fraction

- ***Activity Data (Area)***

➢ ***Determining the forest area***

Forest areas of intensively managed forests, semi-natural forests, forests with less standing trees and bamboo under the forest planning system were obtained from the *Forest Status Survey* until FY2004 and has been from the NFRDB since FY2005 and onward. Data from FY1991 to FY1994, FY1996 to

FY2001, and FY2003 to FY2004 are estimated by linear interpolation. In addition, area data of Sakhalin fir, Yezo spruce, Japanese chestnut oak and Oak (deciduous tree) before FY1990 are not available individually; therefore, these data are estimated from "other conifer" and "other broad leaf" area divided by the area ratio in FY1995.

Table 6-16 Classifications in Forest Status Survey (before 2004) and NFRDB (after 2005)

| Conifer trees | | Broad leaf trees | |
|---|---|---|---|
| Before 2004 | After 2005 | Before 2004 | After 2005 |
| Japanese cedar | Japanese cedar | Japanese chestnut oak | Japanese chestnut oak |
| Hinoki cypress | Hinoki cypress | Oak (deciduous tree ) | Oak (deciduous tree ) |
| Pine | Japanese red pine | Other broad leaf | Japanese beech |
| | Japanese black pine | | Oak (evergreen tree) |
| Japanese larch | Japanese larch | | Japanese chestnut |
| Sakhalin fir | Sakhalin fir | | Japanese poplar |
| Yezo spruce | Yezo spruce | | Alder |
| | Sakhalin spruce | | Japanese elm |
| Other conifer | Sawara cypress | | Japanese zelkova |
| | Hiba arborvitae | | Cercidiphyllum |
| | Momi fir | | Japanese big-leaf magnolia |
| | Japanese hemlock | | Maple tree |
| | Japanese umbrella pine | | Amur cork |
| | Japanese yew | | Japanese lime |
| | Ginkgo | | Linden |
| | Exotic conifer trees | | Kalopanax |
| | Other needle leaf | | Paulownia |
| | | | Exotic broad leaf trees |
| | | | Other broad leaf |

➢ ***Obtaining the land area of "Forest land remaining Forest land"***

This land area is estimated by subtracting the cumulative total area of land converted to forest land during the past 20 years from the total area of forest land in the year subject to estimation. All areas of land converted to forest land are assumed to be intensively managed forests. For the activity data of land converted to forest land, see section 6.5.2.b)1).

Table 6-17 Area of forest land remaining forest land within the past 20 years

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forest land remaining Forest land | kha | 24,501.9 | 24,674.1 | 24,714.2 | 24,868.5 | 24,853.8 | 24,873.8 | 24,877.8 | 24,871.3 | 25,088.7 | 25,033.6 | 24,829.9 | 24,736.6 | 24,809.1 | 24,852.3 |
| Intensively managed forests | kha | 9,839.4 | 10,132.8 | 10,168.7 | 10,212.8 | 10,204.4 | 10,192.6 | 10,190.3 | 10,183.6 | 10,156.5 | 10,144.9 | 10,125.5 | 10,053.6 | 10,073.0 | 10,077.1 |
| Semi-natural forests | kha | 13,354.5 | 13,220.3 | 13,195.2 | 13,315.7 | 13,349.6 | 13,360.8 | 13,359.5 | 13,355.2 | 13,369.3 | 13,380.7 | 13,401.4 | 13,389.2 | 13,426.2 | 13,441.2 |
| Cut-over forests and lesser stocked forests | kha | 1,159.0 | 1,171.0 | 1,197.4 | 1,186.0 | 1,142.8 | 1,161.7 | 1,169.0 | 1,170.8 | 1,400.6 | 1,355.6 | 1,150.0 | 1,146.9 | 1,155.2 | 1,167.0 |
| Bamboo | kha | 149.0 | 150.0 | 152.9 | 154.0 | 157.1 | 158.6 | 159.1 | 161.7 | 162.3 | 152.4 | 153.0 | 146.8 | 154.8 | 167.0 |

Reference: *Forest Status Survey, National Forest Resources Database* (Forestry Agency)

### *2) Carbon Stock Changes in Dead Organic Matter and Soils in "Forest land remaining Forest land"*

● ***Estimation Method***

In accordance with the decision tree provided in the *2006 IPCC Guidelines*, these pools are estimated by the Tier 3 method.

Carbon stock changes in pools of dead wood, litter and mineral soils are estimated by multiplying average carbon stock changes per unit area per forest management type by the land area of each forest management type.

$$\Delta C_{dls} = \sum_{k,m,j} \{A_{k,m,j} \times (d_{k,m,j} + l_{k,m,j} + S_{k,m,j})\}$$

$\triangle C_{dls}$ : Annual change in carbon stocks in dead wood, litter and soil [t-C/yr]
$A$ : Area [ha]
$d$ : Average carbon stock change per unit area in dead wood [t-C/ha/yr]
$l$ : Average carbon stock change per unit area in litter [t-C/ha/yr]
$s$ : Average carbon stock change per unit area in soil [t-C/ha/yr]
$k$ : Type of forest management
$m$ : Age class or forest age
$j$ : Tree species

In Japan, organic soil mainly occurs in Hokkaido. In Japanese GHG inventory, two categories of soil type, “muck soil” and “peat soil”, are treated as organic soils. In Japan, it is not thought probable that the trouble would be taken to do drainage and plant trees on land with organic soil not suitable for the growing of forestry tree species, when forestry management have been at severe condition during some decades. Moreover, there are many cases where areas with organic soil have a precious natural environment, and the change of the land configuration or character are being regulated in these places by law and regulations. In addition, when we consulted with persons who have demonstrable expertise in forest soil environments, it was confirmed that they have never heard of such cases of soil drainage in forest lands with organic soils in Japan. Given the above, it is thought that soil drainage in forest land with organic soils is not implemented in Japan; therefore the emissions for this category are reported as “NO”.

- ***Parameters***

Average carbon stock changes per unit area for dead wood, litter and soils are calculated by the CENTURY-jfos model, which was modified from the CENTURY model (Colorado State University) to be applicable to Japanese climate, soil, and vegetation conditions.

➢ ***Key Assumptions and Parameters for the CENTURY-jfos Model***

Since it is thought that the amounts of tree growth and stable soil carbon stocks were thought to vary depending on climatic or locational conditions, the data of climatic values and soil carbon stocks were aggregated for each tree species in each prefecture (Table 6-18). It was assumed that forests have continually existed and been routinely utilized, and that their soil carbon stocks have been in a nearly steady state. Next, the parameters in the CENTURY-jfos model were adjusted. First, the growth parameters of above-ground biomass were adjusted so that the model be fitted to the growth in the yield tables in association with climatic values calculated per prefecture and per tree species. Second, the parameters were adjusted so that soil carbon stocks after the 60-year cutting age after a spinup of 3,000 years be fitted to the parameters for each of the prefectures and tree species calculated by Morisada et al. (2004). The methodologies of adjusting each parameter are in accordance with Sakai *et al*. (2010).

Tuning of the CENTURY-jfos Model

The Forestry and Forest Products Research Institute adjusted the CENTURY model in order to apply it to the Japanese forest environment. That is, forests were classified by predominant tree species (Japanese Cedar, Hinoki Cypress, Pine species, Japanese Larch, Sakhaline Fir, Sakhaline Spruce, broad leaf trees, and other conifer trees), and the geographical distribution of the tree species and soil types underneath were identified for each prefecture. The climate conditions to run the model were prepared from the mesh climate data provided by the Meteorological Agency of Japan (Japan Meteorological Agency, 2002). The model was adjusted with parameters on tree growth so that the tree growth in the model conformed to yield tables, and it was also tuned so that its output of carbon stocks in soil conformed to actual values based on field surveys for each prefecture and tree species (Table 6-18). The model after these modifications was named as the CENTURY-jfos model. After the tuning, carbon stocks in dead wood, litter and soil, and their stock changes were calculated by the CENTURY-jfos for different types of forest management such as management with thinning or without thinning.

Average annual carbon stock changes per unit area in dead wood, litter and soil are calculated for 1 – 19 age classes (for 100 years) for each type of forest management by means of CENTURY-jfos in order to estimate carbon stock changes in these carbon pools using the same activity data as for living biomass.

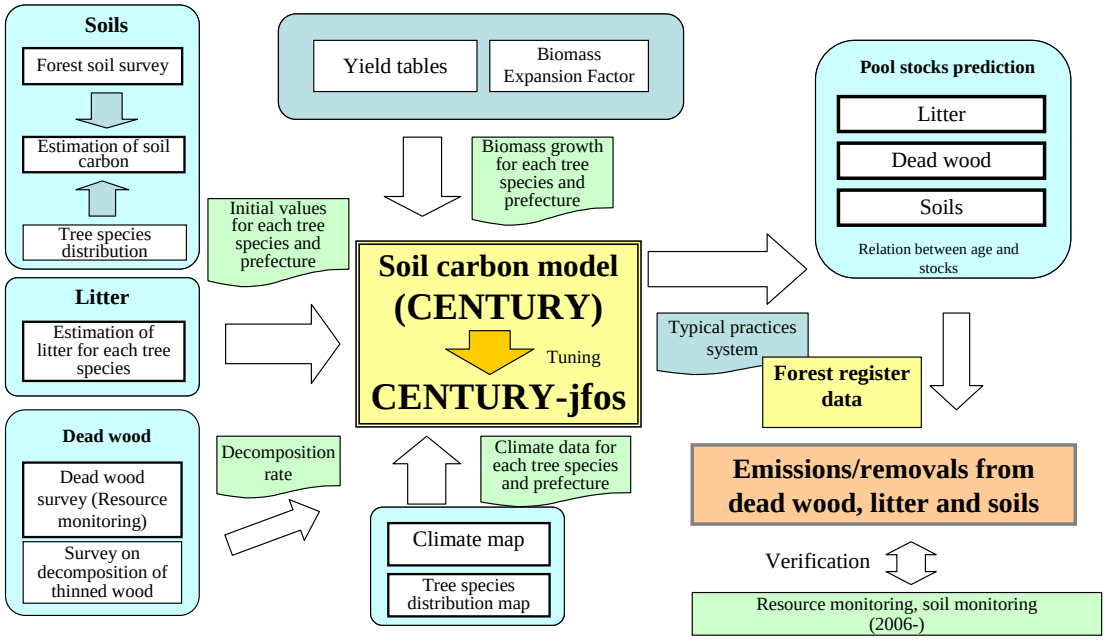


Figure 6-3 Estimation of emissions/removals in dead wood, litter and soils

Table 6-18 Standard soil carbon stocks used for the CENTURY-jfos model

(t-C/ha [30 cm depth])

| Prefecture No. | Prefecture | Tree Species | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Japanese Cedar | Hinoki Cypress | Pine species | Japanese Larch | Sakhaline Fir | Sakhaline Spruce | Broad Leaf Trees | Other Conifer Trees |
| 1 | Hokkaido | 98.0 | NA | 95.0 | 91.0 | 88.0 | 93.7 | 91.0 | 83.5 |
| 2 | Aomori | 92.1 | NA | 94.3 | 83.3 | 109.1 | NA | 89.0 | 89.8 |
| 3 | Iwate | 89.5 | 93.6 | 92.7 | 93.9 | 98.1 | NA | 91.3 | 93.3 |
| 4 | Miyagi | 86.1 | 70.8 | 78.5 | 90.3 | 110.9 | NA | 82.8 | 80.5 |
| 5 | Akita | 81.1 | NA | 72.4 | 81.0 | 108.5 | NA | 82.6 | 79.6 |
| 6 | Yamagata | 83.2 | 79.7 | 68.0 | 81.0 | 97.4 | NA | 74.4 | 76.9 |
| 7 | Fukushima | 84.3 | 83.7 | 81.1 | 89.3 | 108.6 | NA | 81.4 | 85.0 |
| 8 | Ibaraki | 84.3 | 83.4 | 97.6 | NA | NA | NA | 91.2 | 90.8 |
| 9 | Tochigi | 83.0 | 86.1 | 91.6 | 100.6 | 133.4 | NA | 93.1 | 96.4 |
| 10 | Gunma | 88.7 | 88.3 | 93.9 | 95.1 | 98.1 | NA | 86.5 | 93.9 |
| 11 | Saitama | 81.3 | 82.4 | 96.2 | 106.8 | NA | NA | 85.8 | 94.7 |
| 12 | Chiba | 93.9 | 85.7 | 65.6 | NA | NA | NA | 84.6 | 76.4 |
| 13 | Tokyo | 79.2 | 81.6 | 85.7 | 94.7 | NA | NA | 63.9 | 84.3 |
| 14 | Kanagawa | 91.9 | 99.8 | 89.8 | NA | NA | NA | 94.9 | 99.1 |
| 15 | Niigata | 83.9 | 51.3 | 63.4 | 86.7 | 133.0 | NA | 85.3 | 86.9 |
| 16 | Toyama | 90.3 | NA | 72.5 | 88.5 | 106.0 | NA | 94.5 | 100.2 |
| 17 | Ishikawa | 82.7 | 80.2 | 70.2 | NA | 133.4 | NA | 86.6 | 74.3 |
| 18 | Fukui | 88.7 | 85.8 | 79.8 | NA | NA | NA | 90.1 | 80.6 |
| 19 | Yamanashi | 93.0 | 93.9 | 98.0 | 99.3 | NA | NA | 93.9 | 95.6 |
| 20 | Nagano | 102.1 | 100.5 | 96.0 | 108.4 | 106.0 | NA | 97.9 | 103.3 |
| 21 | Gifu | 100.5 | 94.8 | 79.1 | 99.6 | 107.8 | NA | 95.8 | 93.9 |
| 22 | Shizuoka | 94.6 | 96.7 | 69.1 | 90.7 | NA | NA | 90.0 | 93.7 |
| 23 | Aichi | 91.2 | 85.0 | 60.1 | NA | NA | NA | 78.5 | 77.2 |
| 24 | Mie | 92.1 | 84.4 | 63.8 | 97.1 | NA | NA | 78.7 | 80.5 |
| 25 | Shiga | 83.5 | 73.0 | 59.6 | NA | NA | NA | 79.5 | 65.8 |
| 26 | Kyoto | 74.0 | 67.4 | 63.3 | NA | NA | NA | 66.4 | 64.6 |
| 27 | Osaka | 78.9 | 74.0 | 60.9 | NA | NA | NA | 67.5 | 66.0 |
| 28 | Hyogo | 88.3 | 71.8 | 53.0 | 123.6 | NA | NA | 63.4 | 61.9 |
| 29 | Nara | 79.6 | 69.8 | 65.5 | NA | NA | NA | 73.4 | 69.4 |
| 30 | Wakayama | 72.1 | 70.5 | 58.2 | NA | NA | NA | 62.8 | 69.9 |
| 31 | Tottori | 73.8 | 74.9 | 75.6 | 121.2 | NA | NA | 72.3 | 75.4 |
| 32 | Shimane | 69.0 | 66.6 | 61.2 | 77.3 | NA | NA | 64.6 | 63.2 |
| 33 | Okayama | 80.3 | 73.7 | 51.4 | 121.2 | NA | NA | 65.2 | 63.6 |
| 34 | Hiroshima | 74.0 | 71.8 | 54.0 | 71.2 | NA | NA | 65.0 | 58.7 |
| 35 | Yamaguchi | 64.9 | 60.9 | 49.3 | NA | NA | NA | 55.2 | 54.8 |
| 36 | Tokushima | 72.9 | 63.7 | 63.6 | NA | NA | NA | 66.7 | 63.7 |
| 37 | Kagawa | 57.7 | 61.9 | 56.6 | NA | NA | NA | 57.2 | 57.7 |
| 38 | Ehime | 80.1 | 75.1 | 63.2 | 85.4 | NA | NA | 67.4 | 74.1 |
| 39 | Kochi | 81.4 | 76.1 | 73.8 | NA | NA | NA | 74.1 | 76.2 |
| 40 | Fukuoka | 97.3 | 88.9 | 77.5 | NA | NA | NA | 86.5 | 88.3 |
| 41 | Saga | 83.6 | 83.0 | 69.1 | NA | NA | NA | 79.6 | 82.9 |
| 42 | Nagasaki | 82.9 | 84.5 | 82.6 | NA | NA | NA | 78.9 | 84.5 |
| 43 | Kumamoto | 108.7 | 96.0 | 79.3 | NA | NA | NA | 93.5 | 95.6 |
| 44 | Oita | 109.9 | 100.5 | 108.3 | 130.3 | NA | NA | 99.1 | 101.4 |
| 45 | Miyazaki | 106.1 | 102.0 | 93.7 | NA | NA | NA | 98.0 | 99.6 |
| 46 | Kagoshima | 108.4 | 102.4 | 75.7 | NA | NA | NA | 90.8 | 97.0 |
| 47 | Okinawa | 58.5 | NA | 58.9 | NA | NA | NA | 58.0 | 58.5 |

- ***Activity Data (Area)***

Forest area data provided by the NFRDB were used for the estimation as activity data input to CENTURY-jfos model. In addition, areas of organic soils in forest land were estimated as reference values by means of soil maps and status of distribution of organic soils in each prefecture. Furthermore, organic soils exist only in semi-natural forests in Japan; hence, all areas of organic soils are reported in semi-natural forests, and areas of organic soils in intensively managed forests, bamboo and forests with less standing trees are reported as “NO”.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

The uncertainties of the parameters and activity data for living biomass were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty estimates for dead organic matter and soil were assessed by calculating the variance of outputs from the CENTURY-jfos model. As a result, the uncertainty estimate was 13% for the total removals by forest land remaining forest land. Uncertainty estimates regarding the major parameters in this category are shown in Table 6-19.

Table 6-19 Uncertainty estimates regarding major parameters in the forest land category

| | | | Uncertainty Estimates [%] | Country Specific (CS) or Default(D) | Remarks |
|---|---|---|---|---|---|
| Forest land area | | | 5.9 | CS | Estimated based on uncertainty estimates of land areas in the NFRDB. Used 5.9% without distinguishing tree species. |
| Volume of timber per area | | | 22.0 | CS | Estimated based on analysis of comparison between yield table and measured data |
| Biomass Expansion Factor | Japanese cedar | ≦20 | 3.5 | CS | Estimated based on measured values |
| | | ＞20 | 1.1 | CS | |
| | Hinoki cypress | ≦20 | 3.2 | CS | |
| | | ＞20 | 1.6 | CS | |
| | Oak (deciduous tree) | ≦20 | 8.6 | CS | |
| | | ＞20 | 2.1 | CS | |
| Wood density | Japanese cedar | | 2.5 | CS | |
| | Hinoki cypress | | 1.7 | CS | |
| | Oak (deciduous tree) | | 1.6 | CS | |
| Carbon fraction of dry matter | All tree species | | 6.0 | D | Estimated taking into account the *2006 IPCC Guidelines* default value. |
| Dead wood | All forests | | 22.1 | CS | Result of uncertainty analysis of CENTURY-jfos model. |
| Litter | | | 51.0 | | |
| Soils | | | 19.9 | | |

- ***Time-series Consistency***

There were no data for forest areas from FY1991 to FY1994, from FY1996 to FY2001, and from FY2003 to FY2004. Therefore, the time-series consistency was ensured by estimating these forest areas by means of interpolation.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

- ***Correction in accordance with revision of AR area***

Areas of intensively managed forests in forest land remaining forest land was recalculated because areas of afforestation and reforestation (AR areas), which is used as original data for determining areas of forests converted from other land-use, were recalculated. Following the revision, carbon stock changes

in living biomass, dead organic matter and mineral soils in this category were recalculated for all years. For details in the revision of estimation method of AR and D areas, please see the Chapter 11, 11.5.1.7, "Review of AR and D areas".
See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

None.

## 6.5.2. Land converted to Forest land (4.A.2)

### *a) Category Description*

This subcategory deals with the carbon stock changes in forest land converted from other land-use categories within 20 years. The net removal in this subcategory in FY2018 was 934 kt-$CO_2$. This represents a decrease of 86.0% below the FY1990 value and a decrease of 7.1% below the FY2017 value. Removals since 1990 have been in consistent decreasing trend. The reason of the consistent decrease trend is inferred that the number of proprietors of forestry business who newly expand their areas for planting trees has decreased because profitability of forestry business in Japan has declined.

### *b) Methodological Issues*

#### *1) Carbon stock change in Living Biomass in "Land converted to Forest land"*

- ***Estimation Method***

In the Tier 2 method, the annual carbon stock change in land converted to forest land ($\Delta C_{LF}$) is to be estimated by summing the loss of carbon stock due to conversion ($\Delta C_L$) and the change of carbon stock accumulated after conversion ($\Delta C_F$). However, it is difficult to extract removals occurred on land converted to forest land directly from the data of the NFRDB because it deals with the stock change of living biomass of both forest land remaining forest land and land converted to forest land after land conversion collectively. On the other hand, it can be assumed that forest land subjected to AR activities under Article 3, paragraph 3, of the Kyoto Protocol and land converted to forest land have similar nature. Therefore, $\Delta C_F$ was estimated by multiplying the area of converted land by the carbon stock change per unit area due to AR activities. The $\Delta C_F$ value is reported all together under rice field converted to forest land in the CRF. $\Delta C_L$ was estimated and reported for each land-use category. For conversions from rice field, upland field and grassland, the carbon stock losses of living biomass with conversion were estimated. For conversions from wetlands, settlements and other land, carbon stocks of living biomass are assumed as 0, the carbon losses are reported as "NA".

$$\Delta C_{LF} = \Delta C_L + \Delta C_F$$

$$\Delta C_L = \sum_i \left\{ A_i \times \left( B_a \times CF_a - B_{b_i} \times CF_{bi} \right) \right\}$$

$$\Delta C_F = A_{LF} \times IEF_{AR}$$

| | |
|---|---|
| $\Delta C_{LF}$ | : Annual carbon stock change in land converted to forest land [t-C/yr] |
| $\Delta C_L$ | : Annual carbon stock change at the land conversion [t-C/yr] |
| $\Delta C_F$ | : Carbon stock change in the converted land within 20 years since conversion [t-C/yr] |
| $i$ | : Land–use category before conversion |

| | |
|---|---|
| $A_i$ | : Annual increase of land area that has been converted from land-use type i to forest [ha/yr] |
| $B_a$ | : Dry matter weight biomass per unit area immediately after conversion to forest [t-C/yr] (default value=0) |
| $B_{b,i}$ | : Dry matter biomass weight per unit area before conversion from land-use type i to forest [t-C/yr] |
| $A_{LF}$ | : Area of converted forest land within 20 years [ha] |
| $IEF_{AR}$ | : Average carbon stock change per unit area due to AR activities (equal to the implied removal factor) [t-C/ha/yr] |
| $CF_a$ | : Carbon fraction of dry matter after conversion (forest land) [t-C/t-d.m.] |
| $CF_{bi}$ | : Carbon fraction of dry matter in land-use type before conversion [t-C/t-d.m.] |

- ***Parameters***

➢ ***Per unit area removals of Afforestation and Reforestation activities***

The average value of carbon stock change per unit area due to AR activities between FY2008 and FY2010 (3.0 t-C/ha/yr) was applied to all reporting years, and for AR area and amount of removal, confirmed values in first commitment period of Kyoto Protocol were fixed.

➢ ***Biomass stock in each Land-Use Category***

The parameter of cropland and grassland before conversion, shown in Table 6-8a, is used. However, carbon stocks were used for cropland instead of biomass stock.

➢ ***Carbon Fraction of Dry Matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland) was applied in accordance with the *2006 IPCC Guidelines.*

- ***Activity Data (Area)***

The areas of land converted to forest land within 20 years were calculated by summing the annually converted areas during the past 20 years. The estimation methods for annually converted areas from each land-use category are described below.

➢ ***Total area of "Land converted to Forest land"***

It is logically presumed that the areas of land converted to forest land include AR areas, forest land restored from degraded land by natural succession, and land whose land-use categories are changed to forest land due to other reasons. However, it does not occur in general in Japan that forest land restored from degraded land by natural succession usually would be determined as "Forests under Forest Law Article 5 and 7.2" as indicated in Table 6-2. Therefore, such areas are classified as remaining land categories. Hence, it is regarded that the areas of land converted to forest land are similar to the AR areas, and that the areas are determined in accordance with the concept of "overlap" described as a time series consistency and recalculation approach on section 5.3.3.1 in Volume 1 of the *2006 IPCC Guidelines*, by using the AR areas and areas of forested cropland reported in the *Statistics of Cultivated and Planted Area*. Since the AR areas are identified in detail by utilizing orthophotos taken at the end of 1989 and satellite images taken from FY2005 onwards, the annual areas of land converted to forest land in and after 2005 were regarded as the same as the areas obtained by utilizing the method of estimating annual AR areas in KP-LULUCF and the annual AR areas were used. For further information on determining AR areas, see section 11.4.2.3 in Chapter 11.

The annual AR areas before FY2005 are not directly obtained from orthophotos interpretation. Thus,

the area of land converted to forest land before FY2005 are estimated separately from FY1990 to FY2004 and FY1971 to FY1989 respectively taking into account available information.

- ***From FY1990 to FY2004***

The annual areas of land converted to forest land from FY1990 to FY2004 are calculated by simply dividing the total AR area of FY 2005 (=total land converted to forest area for the period from FY1990 to FY2005), by numbers of years from FY1990 to FY2004.

- ***From FY1971 to FY1989***

The annual areas of land converted to forest land before FY1990 are calculated by using forest area and deforestation area obtained from statistics provided by the *World Census of agriculture and Forestry* (MAFF). The *Statistics of Cultivated and Planted Area* (MAFF) was also used as an anxious data for obtaining land use category level information. In concrete terms, the areas are calculated by the following procedures.

1. Forest area change from FY1970 to FY1980 and FY1980 to FY1990 are calculated by using the forest areas obtained from the statistics in FY1970, FY1980 and FY1990 respectively;

2. Total areas of land converted to forest land in the same 10 years' periods are calculated by using the 10 years total deforestation area obtained from the statistics and the changed areas of forest calculated in Step 1;

3. The difference between the total afforestation area on agriculture land in 10 years (calculated from the *Statistics of Cultivated and Planted Area* (MAFF)) and the total area of land converted to forest land of 10 years calculated in Step 2 is assumed as the afforestation area on the land other than agricultural land;

4. The ratios of the 10-year cumulative afforestation area on agricultural land and on non-agriculture lands for the periods from FY1970 to FY1979 and FY1980 to FY1989 are calculated. Annual afforestation areas on non-agricultural land area calculated by multiplying the estimated ratio above to the annual afforestation area on agriculture land obtained from statistics.

- ***Areas of "Cropland and Grassland converted to Forest Land"***

The areas of cropland converted to forest land before FY2004 were determined by utilizing the areas of forested cropland reported in the *Statistics of Cultivated and Planted Area*. As its subcategories, the areas of cropland converted to forest land are categorized to rice fields converted to forest land, upland fields converted to forest land and orchards converted to forest land. The areas of rice fields converted to forest land are determined by utilizing the areas of forested by planting on rice fields provided by the *Statistics of Cultivated and Planted Area*. The areas of upland fields and orchards converted to forest land are estimated by dividing the areas of forested by planting on arable land, also provided by the *Statistics of Cultivated and Planted Area*, by means of the existing area ratios of upland fields, orchards and pasture land.

The areas of grassland converted to forest land are calculated by summing the areas of forested by planting on pasture land estimated from the data in the *Statistics of Cultivated and Planted Area* and those of forested by planting on grazed meadow reported in *A Move and Conversion of Cropland* (MAFF).

The areas of cropland or grassland converted to forest land since FY2005 were respectively estimated by multiplying the percentage of the number of plots interpreted as conversion from cropland or

grassland to forest land in the total number of AR plots, by the annual AR area obtained by utilizing the method of estimating AR areas in KP-LULUCF.

➢ ***Areas of "Wetlands, Settlements or Other land converted to Forest land"***

The areas of wetlands, settlements, and other land converted to forest land cannot be obtained directly from statistics for the years before FY2004. Therefore, they are estimated by subtracting the summed areas of cropland converted to forest land and grassland converted to forest land from the total area of land converted to forest land, and by multiplying the difference by ratios of areas of wetlands, settlements, and other land converted to forest land, which are estimated based on trend of results of AR identification.

The areas of wetlands, settlements or other land converted to forest land since FY2005 were respectively estimated by multiplying the percentage of the number of plots interpreted as conversion from wetlands, settlements or other land to forest land in the total number of AR plots, by the annual AR area obtained by utilizing the method of estimating AR areas in KP-LULUCF.

Table 6-20 Area of land converted to forest land (single year)

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Forest land | kha | 4.89 | 4.89 | 4.89 | 4.89 | 3.24 | 3.24 | 2.73 | 2.73 | 0.97 | 0.97 | 0.84 | 0.84 | 0.09 | 0.09 |
| Cropland converted to Forest land | kha | 2.71 | 1.22 | 1.08 | 0.57 | 1.64 | 1.64 | 1.30 | 1.30 | 0.51 | 0.51 | 0.22 | 0.22 | 0 | 0 |
| Rice field | kha | 0.92 | 0.47 | 0.41 | 0.17 | 0.67 | 0.70 | 0.47 | 0.47 | 0.19 | 0.18 | 0.07 | 0.08 | 0 | 0 |
| Upland field | kha | 1.31 | 0.57 | 0.51 | 0.31 | 0.76 | 0.74 | 0.66 | 0.66 | 0.26 | 0.27 | 0.12 | 0.12 | 0 | 0 |
| Orchard | kha | 0.49 | 0.19 | 0.15 | 0.09 | 0.21 | 0.20 | 0.17 | 0.17 | 0.07 | 0.07 | 0.030 | 0.03 | 0 | 0 |
| Grassland converted to Forest land | kha | 0.67 | 0.31 | 0.28 | 0.17 | 0.87 | 0.87 | 1.01 | 1.01 | 0.24 | 0.24 | 0.43 | 0.43 | 0.08 | 0.08 |
| Wetlands converted to Forest land | kha | NO | NO | NO | NO | NO | NO | 0.03 | 0.03 | 0.01 | 0.01 | NO | NO | NO | NO |
| Settlements converted to Forest land | kha | 0.75 | 1.68 | 1.77 | 2.07 | 0.58 | 0.58 | 0.34 | 0.34 | 0.14 | 0.14 | 0.14 | 0.14 | 0.01 | 0.01 |
| Other land converted to Forest land | kha | 0.75 | 1.68 | 1.77 | 2.07 | 0.16 | 0.16 | 0.05 | 0.05 | 0.07 | 0.07 | 0.04 | 0.04 | NO | NO |

Reference: *Forestry Status Survey, National Forest Resources Database* (Forestry Agency)

Table 6-21 Area of Land converted to forest land within the past 20 years

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Forest land | kha | 448.4 | 222.8 | 161.9 | 123.7 | 94.1 | 92.5 | 90.3 | 88.1 | 84.2 | 80.3 | 76.3 | 72.2 | 67.4 | 62.6 |
| Cropland converted to Forest land | kha | 121.9 | 57.7 | 40.6 | 30.0 | 29.4 | 28.3 | 27.2 | 26.7 | 25.8 | 24.9 | 23.9 | 23.0 | 21.8 | 20.6 |
| Rice field | kha | 53.8 | 23.7 | 15.9 | 11.0 | 11.3 | 11.1 | 10.7 | 10.5 | 10.0 | 9.7 | 9.3 | 8.9 | 8.4 | 8.0 |
| Upland field | kha | 46.8 | 23.7 | 17.7 | 14.0 | 13.7 | 13.2 | 12.7 | 12.6 | 12.2 | 11.9 | 11.4 | 11.0 | 10.5 | 9.9 |
| Orchard | kha | 21.4 | 10.3 | 6.9 | 4.9 | 4.3 | 4.0 | 3.8 | 3.7 | 3.5 | 3.4 | 3.2 | 3.1 | 2.9 | 2.7 |
| Grassland converted to Forest land | kha | 19.3 | 11.6 | 9.0 | 7.3 | 8.3 | 8.5 | 8.9 | 9.5 | 9.4 | 9.3 | 9.5 | 9.6 | 9.4 | 9.2 |
| Wetlands converted to Forest land | kha | NO | NO | NO | NO | 0.03 | 0.03 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Settlements converted to Forest land | kha | 153.6 | 76.7 | 56.1 | 43.2 | 29.1 | 29.0 | 28.3 | 27.3 | 25.9 | 24.5 | 22.9 | 21.4 | 19.7 | 18.0 |
| Other land converted to Forest land | kha | 153.6 | 76.7 | 56.1 | 43.2 | 27.3 | 26.7 | 25.8 | 24.5 | 23.0 | 21.5 | 19.8 | 18.2 | 16.4 | 14.7 |

Reference: *Forestry Status Survey, National Forest Resources Database* (Forestry Agency)

### *2) Carbon Stock Changes in Dead Organic Matter and Soils in "Land converted to Forest land"*

- ***Estimation Method***

Carbon stock changes in dead wood, litter and mineral soils were calculated under the assumption that these carbon stocks change linearly over 20 years from those in land-use categories other than forest land to those in forest land. The calculation was implemented by applying the average carbon stocks obtained by the CENTURY-jfos model. Emissions from organic soils in this category were reported as "NO" in the same manner as forest land remaining forest land.

$$\Delta C_{LF_i} = A_i \times \left(C_{after} - C_{before_i}\right)/20$$

$\Delta C_{LF\,i}$ : Annual change in carbon stocks in dead wood, litter or soils in land-use category *i* converted to forest land [t-C/yr]

$A_i$ : Area of land-use category *i* being converted to forest land within the past 20 years [ha]
$C_{after}$ : Average carbon stocks per unit area in land-use category after conversion (forests) [t-C/ha]
$C_{before\ i}$ : Average carbon stocks per unit area in land-use category *i* before conversion [t-C/ha]
*i* : Land-use category

- ***Parameters***

Parameters for each carbon pool in Table 6-9 (dead wood), Table 6-10(litter) and Table 6-11 (soil) were used, in particular, for the categories cropland, grassland, wetlands, settlements and other land before conversion and for the category forest land after conversion.

- ***Activity Data (Area)***

➢ ***Total areas of "Land converted to Forest land"***

See Table 6-21.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

The uncertainties of the parameters and activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. As a result, the uncertainty estimate was 13% for the entire removal from land converted to forest land.

- ***Time-series Consistency***

Time-series consistency for this subcategory is ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

- ***Correction in accordance with revision of AR area***

As it was mentioned in 6.5.1.e), areas of forest land converted from other land-use categories due to the correction of AR area were recalculated. Accordingly, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated from FY1990 to FY2017.

- ***Correction of biomass carbon stocks of annual crops in cropland before conversion***

Since biomass carbon stocks of annual crops in cropland were corrected, living biomass stock losses in cropland converted to other land use categories were corrected and carbon stock changes of living biomass in forest land converted from cropland were recalculated for all years.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

- ***Carbon Stock Changes in Soils in "Cropland and Grassland converted to Forest Land"***

The areas converted to forest land from upland fields, orchards and pasture land are estimated by multiplying the total areas converted from cropland to forest land by each area ratio of upland fields,

orchards and pasture land. However, this estimation method may not represent the actual condition of these areas. Hence, improvement of the validity of the estimation method and land-area identification is an issue to be examined in the future.

## 6.6. Cropland (4.B)

Cropland is the land that produces annual and perennial crops; it includes temporarily fallow land. Cropland in Japan's inventory consists of rice fields, upland fields, orchards and cultivation abandoned agricultural land.

In FY2018, Japan's cropland area was about 4.24 million ha, which is equivalent to about 11.2% of the national land. The area of organic soil in cropland is about 0.218 million ha. The emissions from this category in FY2018 were 3,530 kt-$CO_2$ (excluding 35.2 kt-$CO_2$ eq. of non-$CO_2$ emissions from drained organic soils and drainage ditches, 7.1 kt-$CO_2$ eq. of $N_2O$ emissions resulting from nitrogen mineralization resulting from change of land use or management of mineral soils, and 20.6 kt-$CO_2$ eq. of $CH_4$ and $N_2O$ emissions resulting from biomass burning); this represents a decrease of 69.8% below the FY1990 value and a decrease of 10.8% below the FY2017 value.

In this section, cropland is divided into two subcategories, "Cropland remaining Cropland (4.B.1.)" and "Land converted to Cropland (4.B.2.)", and describes them separately in the following subsections.

Table 6-22 Emissions and removals in cropland resulting from carbon stock changes

| Gas | Category | Carbon pool | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 4.B. Cropland | Total | kt-$CO_2$ | 11,697 | 5,436 | 34 | 2,266 | 8,007 | 5,503 | 5,908 | 4,929 | 3,658 | 4,422 | 4,350 | 4,831 | 3,956 | 3,530 |
| | | Living Biomass | kt-$CO_2$ | 1,371 | 456 | 216 | 230 | 339 | 302 | 288 | 269 | 200 | 201 | 252 | 254 | 163 | 190 |
| | | Dead Wood | kt-$CO_2$ | 299 | 60 | 19 | 30 | 46 | 46 | 43 | 42 | 27 | 26 | 26 | 26 | 9 | 8 |
| | | Litter | kt-$CO_2$ | 144 | 29 | 9 | 15 | 22 | 22 | 21 | 21 | 13 | 13 | 13 | 13 | 4 | 4 |
| | | Mineral soil | kt-$CO_2$ | 8,231 | 3,251 | -1,834 | 375 | 5,986 | 3,520 | 3,946 | 2,984 | 1,804 | 2,567 | 2,444 | 2,924 | 2,161 | 1,702 |
| | | Organic soil | kt-$CO_2$ | 1,653 | 1,640 | 1,624 | 1,617 | 1,613 | 1,612 | 1,611 | 1,612 | 1,614 | 1,615 | 1,615 | 1,615 | 1,619 | 1,625 |
| | 4.B.1. Cropland remaining Cropland | Total | kt-$CO_2$ | 10,098 | 5,100 | -67 | 2,102 | 7,767 | 5,278 | 5,699 | 4,713 | 3,550 | 4,306 | 4,225 | 4,700 | 3,928 | 3,507 |
| | | Living Biomass | kt-$CO_2$ | 280 | 245 | 157 | 121 | 177 | 154 | 151 | 127 | 144 | 137 | 179 | 175 | 167 | 205 |
| | | Dead Wood | kt-$CO_2$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | | Litter | kt-$CO_2$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | | Mineral soil | kt-$CO_2$ | 8,231 | 3,251 | -1,834 | 375 | 5,986 | 3,520 | 3,946 | 2,984 | 1,804 | 2,567 | 2,444 | 2,924 | 2,161 | 1,702 |
| | | Organic soil | kt-$CO_2$ | 1,588 | 1,603 | 1,609 | 1,606 | 1,604 | 1,603 | 1,602 | 1,602 | 1,602 | 1,602 | 1,602 | 1,601 | 1,600 | 1,599 |
| | 4.B.2. Land converted to Cropland | Total | kt-$CO_2$ | 1,598 | 337 | 101 | 164 | 239 | 226 | 209 | 216 | 108 | 116 | 125 | 131 | 28 | 23 |
| | | Living Biomass | kt-$CO_2$ | 1,091 | 211 | 59 | 109 | 161 | 148 | 137 | 142 | 56 | 63 | 73 | 79 | -3 | -15 |
| | | Dead Wood | kt-$CO_2$ | 299 | 60 | 19 | 30 | 46 | 46 | 43 | 42 | 27 | 26 | 26 | 26 | 9 | 8 |
| | | Litter | kt-$CO_2$ | 144 | 29 | 9 | 15 | 22 | 22 | 21 | 21 | 13 | 13 | 13 | 13 | 4 | 4 |
| | | Mineral soil | kt-$CO_2$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | Organic soil | kt-$CO_2$ | 65 | 37 | 15 | 11 | 9 | 9 | 9 | 11 | 13 | 13 | 14 | 14 | 19 | 26 |

### 6.6.1. Cropland remaining Cropland (4.B.1)

#### *a) Category Description*

This subcategory deals with carbon stock changes in cropland, which has remained as cropland during the past 20 years. The emissions from this subcategory in FY2018 were 3,507 kt-$CO_2$ (excluding GHG emissions other than carbon stock changes); this represents a decrease of 65.3% below the FY1990 value and a decrease of 10.7% below the FY2017 value. Carbon stock changes in mineral soils have greatly contributed to the increase/decrease trend of emissions/removal amount in this category. $CO_2$ emissions from mineral soils in FY2018 were 1,702 kt-$CO_2$; a 79.3% decrease compared to FY1990

and a 21.2% decrease compared to FY2017.
From FY1990 to FY2003, the emissions had a decreasing trend and even reached removal. However, after turning back to emissions in FY2004, emissions have been increasing continuously, while temporal decrease can be seen. Then, an increase has been continuously shown with transitory emission decrease at a time. It is considered that the time-series variability is mainly caused by annual changes of amount of carbon input into soils (especially, carbon input of compost) and climate (especially, temperature). Carbon stock changes have been estimated by using a modeling method, explained below; therefore, the changes at the national level were affected by the sum of measurement result of each local area. It is considered that the variability in Hokkaido prefecture, which holds more than 25% of upland field in Japan, have a relatively large influence on the carbon stock changes at the national level, because the year-to-year variability in upland field was especially larger than among three categories of cropland. Roughly to say, the overall carbon fluctuation tends to be roughly linked to the trend of the compost manure input to soil, and One tendency can be seen that variations in crop yields act as finer annual fluctuations.
Carbon stock changes in living biomass are estimated for the carbon stock change in perennial tree crops (fruit trees) according to the *2006 IPCC Guidelines*.

Carbon stock changes in dead organic matter are estimated as zero (0) by applying the Tier 1 method, which assumes that the carbon stocks are not changed, according to section 5.2.2.1 in Volume 4 of the *2006 IPCC Guidelines*. Thus, the carbon stock changes are reported as "NA".

Carbon stock changes in mineral soils in rice field, upland field and orchard were estimated by applying Tier 3 model (Roth C, Rothamsted Carbon Model). In addition, carbon stocks changes in mineral soil organic carbon by biochar amendments in cropland were estimated. The amount of emission reduction by the effect of carbon stocks by biochar in FY2018 is 5.02 kt-$CO_2$. On-site $CO_2$ emissions from drained inland organic soils in rice fields and upland fields were estimated. Off-site $CO_2$ emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields were estimated.

$CO_2$ emission from organic soils in orchards and in cultivation abandoned agricultural land were reported as "NO" because tillage and drainage of organic soils in orchard and in cultivation abandoned agricultural land were not implemented. The area of cropland remaining croplands within the past 20 years was shown in Table 6-23. Besides, this area contained both land of mineral soils and organic soils.

Table 6-23 Areas of cropland remaining cropland within the past 20 years

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cropland remaining Cropland | kha | 4,597 | 4,463 | 4,417 | 4,385 | 4,346 | 4,339 | 4,317 | 4,312 | 4,305 | 4,295 | 4,279 | 4,258 | 4,228 | 4,199 |
| Rice fields | kha | 2,768 | 2,707 | 2,628 | 2,545 | 2,493 | 2,484 | 2,462 | 2,453 | 2,446 | 2,438 | 2,426 | 2,412 | 2,394 | 2,377 |
| Upland fields | kha | 1,186 | 1,140 | 1,119 | 1,136 | 1,150 | 1,154 | 1,152 | 1,152 | 1,150 | 1,146 | 1,142 | 1,139 | 1,131 | 1,124 |
| Orchards | kha | 426 | 371 | 328 | 318 | 308 | 306 | 303 | 300 | 296 | 293 | 289 | 284 | 280 | 274 |
| Cultivation abandonment area | kha | 217 | 244 | 343 | 386 | 394 | 396 | 401 | 407 | 412 | 418 | 423 | 423 | 423 | 423 |

### *b) Methodological Issues*

#### *1) Carbon Stock Changes in Living Biomass in "Cropland remaining Cropland (Orchard)"*

- ***Estimation Method***

As for living biomass, only perennial woody species are targeted for estimation. Therefore, carbon stock changes in living biomass only in orchards are estimated by applying the Tier 2 estimation method (the stock–difference method) described in section 5.2.1.1 in Volume 4 of the *2006 IPCC Guidelines*.

The carbon stocks in living biomass in orchards are calculated by multiplying cultivation area of each orchard tree by dry matter biomass weight per tree, planting density, and carbon fraction of dry matter. The carbon stocks in above- and below ground biomass were calculated by using the root-to-shoot ratio. These parameters except the carbon fraction are determined for each type of orchard tree.

$$\Delta C = C_{t+1} - C_t$$

$$C_t = \sum_j \left(A_{t,j} \times D_j \times W_j\right) \times \frac{10}{1000} \times CF$$

Note: 10/1000 is for unit conversion

| | |
|---|---|
| $\Delta C$ | : Carbon stock change in living biomass in Orchard [t-C/yr] |
| $C_t$ | : Total Carbon in living biomass at time t [t-C] |
| $A_t$ | : Cultivation area of orchard at time t [ha] |
| $D$ | : Planting density [tree/10a] |
| $W$ | : Dry matter weight of above-ground biomass per tree [kg/tree] |
| $CF$ | : Carbon fraction of dry matter [t-C/t-d.m.] |
| $j$ | : Type of orchard tree |

- ***Parameters***

According to Tier 2 method described in the *2006 IPCC Guidelines*, country specific parameters of the planting density, dry matter biomass weight per tree, and root-to- shoot ratio were set for major orchard trees based on existing research reports.

Dry matter biomass weight for tea tree are 48 t-d.m./ha; the dry matter biomass weight for fruit orchard tree are 8～24 t-d.m./ha, the root-shoot ratio is 7:3-5:4. The country specific carbon fraction of dry matter of forest (broad leaf : 0.48 t-C/t-d.m.) was applied as the carbon fraction of dry matter of orchard trees.

- ***Activity Data (change of cultivation area)***

Changes of cultivation area were estimated for 15 major orchard trees by each prefecture by subtracting cultivation area in the previous year from these in the current year. The cultivation area for 15 major orchard trees was identified by existing statistics (*the Statistics of Cultivated and Planted Area* by the MAFF). As for fruit trees other than 15 major orchard trees, the cultivation area was also identified by existing statistics. As the area of "newly-established" and "deserted" is not identified by orchard type in this statistic, only the apparent amount of change after land conversion is used as activity data. Therefore, this activity data (area) used for estimation in living biomass includes area of orchard land converted from other land-use.

### *2) Carbon Stock Changes in Soils in "Cropland remaining Cropland"*

- ***Estimation Method***

➢ ***Carbon stock changes in mineral soils***

Japan uses a Tire 3 method to estimate soil organic C stock changes in agriculture land (cropland and managed grassland) by calculating carbon stock changes of soil over time based on the Rothamsted Carbon Model (Roth C).

Figure 6-4 is conceptual diagram of Roth C. Roth C is a soil carbon dynamic model validated by using long-term field experiments (Coleman and Jenkinson, 1996). In order to apply the model to Japanese agricultural conditions, the model was tested against long-term experimental data sets in Japanese agricultural lands. It was found that the original model could be applied for non-volcanic upland soils without any modification or calibration (Shirato and Taniyama, 2003), however, the model required modification for Andosols and paddy soils by taking unique mechanisms of soil C dynamics in these soils into account. For Andosols, the decomposition rate constant of the HUM (humified organic matter) pool of Roth C was reduced because the presence of Al-humus complexes enhances its stability and resistance to decomposition (Shirato *et al.* 2004). For paddy soils, the decomposition rate constants of all four active C pools was reduced on the basis of differences in organic matter decomposition rates between upland and paddy (submerged in the rice growing season) soil conditions (Shirato and Yokozawa, 2005).

Since the land use data used for the model estimation (grid based data set) and used for the official land classification in GHG inventory (statistical data) are not very consistent, the GHG inventory do not use the carbon stock change calculation results directly from the Roth C model, but use Roth C to calculate the average C stock change rates per hectare in each prefecture and in each sub-category (rice field, upland crop fields, orchards and managed grassland). The carbon stock changes (t-C/year) were calculated by multiplying the average carbon stock changes in each year by land use subcategory (rice fields, upland fields, orchards and pastural land) calculated by the Roth C model by the mineral soil area of each prefecture obtained from existing statistics.

In the model calculation, land unit which was recorded once as cropland since FY1970 was regarded as cropland and used for calculation; the result of the calculation includes all croplands, regardless of whether or not land conversion. The estimation equation is as follows:

$$\Delta C_{national} = \sum_{i,j} \left( \Delta SOC_{i,j} \times A_{i,j} \right)$$

| | |
|---|---|
| $\Delta C_{national}$ | : Carbon stock changes in mineral soils [t-C/yr] |
| $\Delta SOC$ | : Carbon stock changes in mineral soils per unit area [t-C/ha/yr], estimated from the Roth C model |
| $A$ | : Area of cropland with mineral soil obtained from statistics [ha] |
| $i$ | : Prefecture |
| $j$ | : Type of land use subcategory in cropland |

- ***Carbon stock change of mineral soil organic carbon associated with biochar amendments***

Carbon stocks change in mineral soil organic carbon in cropland by biochar amendments were estimated by applying Tier 1 method provided in 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (hereafter 2019 Refinement). This estimation includes hard charcoal, soft charcoal, bamboo charcoal, fine coal and sawdust coal produced in Japan considering the availability of its production data.

Furthermore, since information on amount of biochar applied into each subcategory (rice field, upland field and orchard) is not available, the carbon stock changes were estimated and reported collectively in mineral soils in cropland remaining cropland. The estimation equation is as follows:

$$\Delta BC_{Mineral} = \sum_{p} \left( BC_{TOT_p} \times F_{C_p} \times F_{perm_p} \right)$$

$\Delta BC_{Mineral}$ : Total carbon stock changes in mineral soils associated with biochar amendment, tonnes [t-C/yr]
$BC_{TOTp}$ : Mass of biochar applied into mineral soil during the inventory year for each biochar production type p [t-d.m/yr]
$F_{Cp}$ : Organic carbon content of biochar for p [t-C/t-d.m]
$F_{perm_p}$ : Fraction of biochar carbon for biochar p remaining (unmineralized ) after 100 years [t-C/t-C]
$p$ : Biochar type (hard charcoal, soft charcoal, bamboo charcoal, fine coal and sawdust coal)

➢ ***$CO_2$ emissions from organic soils***

For estimating $CO_2$ emissions from organic soils, emissions from plowing organic soils (on-site emissions), and emissions from water-soluble carbons (off-site emissions) in rice fields and in upland fields were estimated.

- ***On-site $CO_2$ emissions from organic soils***

On-site $CO_2$ emissions from organic soils in rice fields and upland fields were estimated by applying Tier 1, 2 estimation method described in section 5.2.3.1 in Volume 4 of the *2006 IPCC Guidelines*. Tier 2 method was applied to land-use subcategories for which country-specific emission factors can be used. The estimation equation is as follows:

$$\Delta C_{os} = \sum_c (A \times EF)_c$$

$\Delta C_{OS}$ : Carbon stock changes in organic soils (emissions) [t-C/yr]
$A$ : Area of organic soils [ha]
$EF$ : $CO_2$ emission factor [t-C/ha/yr]
$c$ : Climate zone

- ***Off-site $CO_2$ emissions via waterborne carbon losses from drained inland organic soils***

Off- site CO2 emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields were estimated by applying Tier 1 estimation method described in 2.2.1.2 section in the *Wetlands Guidelin*es. The estimation equation is as follows:

$$CO_2\text{-}C_{DOC} = \sum (A \times EF_{DOC})$$

$$EF_{DOC} = DOC_{FLUX_{NATURAL}} \times (1 + \Delta DOC_{DRAINAGE}) \times F_{rac_{DOC-CO_2}}$$

$CO_2$-$C_{DOC}$ : Annual off-site $CO_2$-C emissions due to DOC loss from drained organic soils [t-C/yr]
$A$ : Land area of drained organic soils in land-use subcategory [ha]
$EF_{DOC}$ : Emission factors for annual $CO_2$ emissions doe to DOC loss from drained organic soils [t-C/ha/yr]
$DOC_{FLUX\_NATURAL}$ : Flux of DOC from natural (undrained ) organic soil [t-C/ha/yr]
$\Delta DOC_{DRAINAGE}$ : Proportional increase in DOC flux from drained sites relative to undrained sites
$Frac_{DOC\text{-}CO2}$ : Conversion factor for proportion of DOC converted to $CO_2$ following export from site

● ***Parameters***

➢ ***Assumption and parameters necessary for mineral soil modeling***

As shown in Figure 6-4, soil carbon is divided into five compartments with different decomposition

rates and the amount change of soil carbon is calculated monthly; input parameters are weather data (monthly average temperature, precipitation, and open-pan evaporation), soil property data (soil clay content, depth of surface soil, carbon content at the starting year, and bulk density), land use data and other activity data (carbon input from crop residue and organic manure). To apply the model to nation-wide estimation, input data was determined using the existing statistical material, map data and questionnaire survey with the resolution of 1km mesh for weather, 100m mesh for soil property and land use data, and amount of carbon input was adjusted by prefecture and by land use subcategory (rice fields, upland fields, orchards, pasture land).

The weather, soil property and land use data are available as spatially explicit data set, while carbon input from crop residue and organic manure are calculated by statistical data and survey data available based on public administration boundary basis. In addition, as for the input amount of crop residue, the amount of crop residue to be returned to soil is calculated by multiplying various factor by the crop yields obtained from statistical data by each prefecture. However, since the input amount of organic manure can not be obtained from statistical data by land use subcategory, the questionnaire survey results by crops (rice, upland crops, vegetables, fruit trees, tea, feedstuff, pasture grass) for FY1980, FY1985, FY1990, FY1995, FY2000, FY2010 are used.

The model is implemented at the national scale using the input data, and the soil carbon stock amount per unit area are calculated monthly with a standard mesh (100 m × 100 m). The sum of the monthly values is the value of that year and the difference from the previous year is the amount of soil carbon change (t-C/ha/year) per unit area for that year. By overlapping with soil carbon change per unit area per standard mesh and the administrative boundary data, soil carbon change amount (t-C/ha/year) per unit area by prefecture and by land use subcategory (rice fields, upland fields, orchard, pasture land) were obtained.

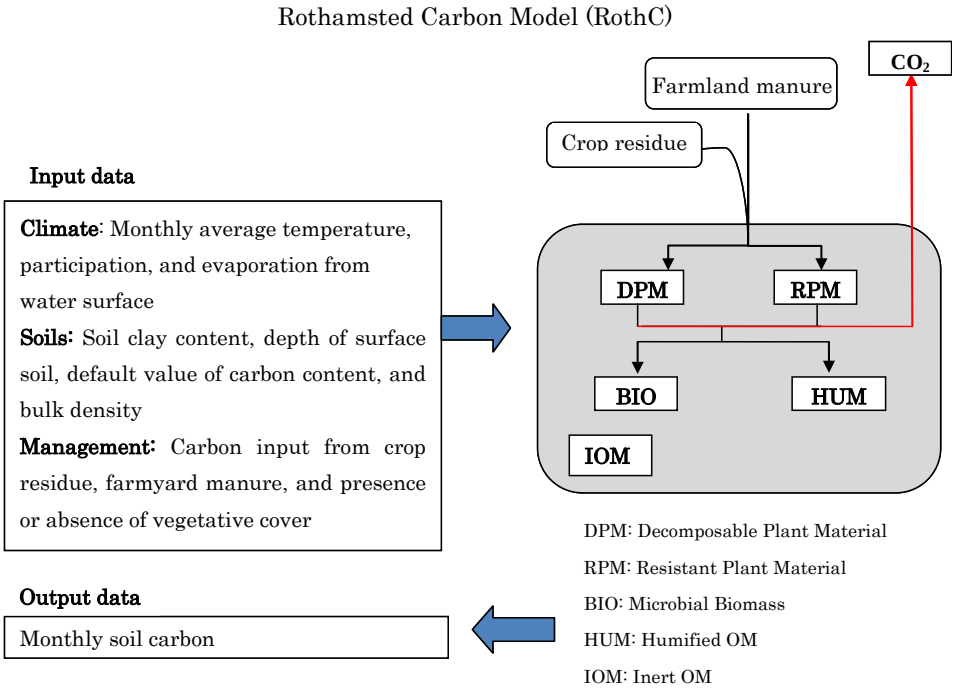


Figure 6-4 Roth C model

- ***Parameters of biochar (carbon content and fraction of carbon remaining after 100 years)***

As for organic carbon content of biochar, the default value (0.77 t-C/t-d.m.) of heat treatment process for wood material provided in the *2019 Refinement* (Table 4Ap.1), was applied.

Fraction of carbon remaining after 100 years is based on the firing temperature of each biochar in Japan and the default value provided in the *2019 Refinement* (Table 4Ap.2). The default value (0.89 t-C/t-C) corresponding to firing temperature of 600℃ or more was applied to hard charcoal, soft charcoal and sawdust coal; default value (0.80t-C/t-C) corresponding to firing temperature of 450 to 600℃ was applied to fine coal.

Regarding bamboo charcoal, since a research focusing on bamboo charcoal components in Japan was obtained by Nagumo et al. (2014), country-specific value (43.6%) was applied. This value corresponds to the value including the organic carbon content and the fraction of carbon remaining after 100 years.

- ***$CO_2$ emission factors from organic soils (on-site)***

The following $CO_2$ emission factors from organic soils in rice fields and upland fields were applied to the estimation.

Table 6-24 $CO_2$ emission factors resulting from cultivation of organic soils

| Type of land use | Climate zone | Emission factors [t-C/ha/yr] | Reference |
|---|---|---|---|
| Rice field | Cold temperate | 1.55 | Measured data[1)] |
| | Warm temperate | 1.55 | Data measured for cold temperate was applied.[2)] |
| Upland field | Cold temperate | 4.18 | Measured data |
| | Warm temperate | 10.0 | Default value (*2006 IPCC Guidelines*, Vol.4, Table 5.6) |

Note:

1) Measured data of rice field was set as if emission in waterlogging period was zero (0).
2) The emission factor of rice field in warm temperate was excluded in default values in *the 2006 IPCC Guidelines*; hence, the country-specific factor in cold temperate was applied as substitute.

- ***$CO_2$ emissions factors from organic soils (off-site)***

Tier 1 default parameters described in the *Wetlands Guidelines* were applied to the estimation.

Table 6-25 Default DOC emission factors for drained organic soils

| Climate zone | $DOC_{FLUX\_NATURAL}$ [t-C/ha/yr] | $DOC_{DRAINAGE}$ | $Frac_{DOC\text{-}CO2}$ | $EF_{DOC}$ [t-C/ha/yr] |
|---|---|---|---|---|
| Temperate | 0.21 | 0.60 | 0.9 | 0.31 |

Reference: the *Wetlands Guidelines*: Table 2.2

- ***Activity Data (Area)***

- ***Area of mineral soils***

Areas of mineral soils in cropland applied for Roth C model were estimated from the reported area in the *Statistics of Cultivated and Planted Area*, divided as Rice field (only the area with rice really planted), upland field (including the area divided into rice field with other crops planted and with no crops) and orchards; and the areas of organic soils in each divided area (Table 6-26) is subtracted. As for calculation, this Roth C model is widely applied for area which was recorded once as cropland since FY1970 (was regarded as cropland); therefore, the area includes area (mineral soils) of land converted to cropland.

- ***Amount of biochar applied into cropland***

The amount of biochar applied to cropland, what is activity data, was calculated by multiplying the

amount of wood charcoal production for agriculture use, by the proportion of biochar applied to cropland and the ratio of mineral soil area to total soil area.

As for the amount of wood charcoal production for agriculture use, the values classified as "agricultural use" obtained from *Statistical Survey on production of Special Forest Products* (MAFF), were applied. In addition, complete time series data were made using interpolation and allocation methods due to lack of data for some years. Moreover, since wood charcoal were also used for "feed and other uses", the amount of biochar amendments applied to cropland were calculated by subtracting wood charcoal production for "feed and other uses", from the amount of wood charcoal production for "agricultural use". Based on expert's judgments, it can be assumed that the proportion of biochar applied to cropland is 95%. In addition, since it is difficult to obtain the amount of biochar production applied to mineral soil and organic soil in cropland separately, it is assumed that the same proportion (amount of biochar applied to cropland per unit area) of biochar production applied to all cropland for mineral soil and for organic soil in Japan. Therefore, the amount of biochar production applied to cropland in mineral soil and in organic soils were calculated based on percentage of total cropland occupied by mineral and organic soils as reported in GHG inventories.

However, since there is no default fraction of biochar C remaining after 100 years for organic soil in the *2019 Refinement* and data and information are not also available in Japan, carbon stock change associated with biochar amendments to organic soil in cropland was not subject to estimation. In addition, since the amount of import and export of biochar for "agricultural use" is infinitesimal, import and export of biochar applied to cropland were not estimated.

- ***Area of organic soils***

Since information on areas of organic soils in agricultural land in FY1992 and FY2001 is available, the time-series organic soil area was calculated by implementing the following 1 to 3 for each year;

1. Calculating area of organic soil in agricultural land (rice field, upland field, orchard) for FY1992 and FY2001;

2. Adding area of organic soil of agricultural land converted from other land-use to 1;

3. Subtracting area of organic soil of land converted from agricultural land from 1;

The total organic soil area of agricultural land converted from other land-use within 20 years were reported in cropland converted from land category, and the organic soil area other than those were reported in cropland remaining cropland category. In addition, organic soil area in FY1992 through FY2001 were calculated by interpolation of area of FY1992 and FY2001 by means of linear expression.

The organic soil area in converted agricultural land is basically calculated by multiplying the total land use area for each land use category, by the organic soil rate in the original land use category. However, as for the conversion from wetlands, the ratio of organic soil in land converted from wetlands was set as 0%, because organic soil did not exist in the soil map around the reclaimed wetland that falls into this activity.

As for the conversion from agricultural land, organic soil area were estimated for each land-use (rice field, upland field, orchard) for each land conversion site, by multiplying organic soil ratio in converted land that occurred between FY1992 and FY2001, by the total area of land converted to other land use.

This estimation has been conducted for each prefecture. The estimated areas of organic soils are as follows (sum of area of cropland remaining cropland and area of cropland converted from other land-

use). The areas of cultivated organic soil in the Agriculture sector (see section 3.D.a.6) are reported as the active mass actually cultivated in organic soil of agricultural land, and includes all areas of organic soil for rice field and upland field and the renewal ratio (3%) of pasture lands, while organic soils for orchard, grazed meadow and wild land are not included. As for estimation of emissions from organic soils in the LULUCF sector, the values used as activity data are the same area values as in the agricultural sector, but in the CRF of the LULUCF sector, total organic soil area are reported regardless of tillage or drainage. Hence, the areas of organic soil in cropland reported under LULUCF sector (see Table 6-25) were not the same as the areas reported under the Agriculture sector.

As shown in the Table 6-26, the area of rice fields on organic soils since 1990 has been decreased by approximately 1,300 ha. Since it is difficult to know exact soil type that accompanies with land conversion from rice fields, the ratio of organic soil area in the current rice fields is applied to the estimation. The major land uses converted from rice fields are settlements and upland fields.

Table 6-26 Areas of organic soils in cultivated cropland

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | kha | 222.1 | 219.6 | 217.8 | 216.8 | 216.5 | 216.5 | 216.4 | 216.6 | 216.8 | 216.8 | 216.8 | 216.6 | 217.0 | 217.6 |
| Rice field | kha | 161.9 | 161.3 | 160.6 | 159.9 | 159.7 | 159.6 | 159.5 | 159.7 | 160.0 | 160.2 | 160.2 | 160.2 | 160.4 | 160.7 |
| Upland field | kha | 24.7 | 24.4 | 24.2 | 24.0 | 24.0 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 23.9 | 24.0 | 24.2 |
| Orchard | kha | 1.4 | 1.2 | 0.9 | 0.9 | 0.9 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 |
| Cultivation abandonment area | kha | 34.1 | 32.6 | 32.2 | 32.0 | 32.1 | 32.1 | 32.1 | 32.1 | 32.0 | 31.9 | 31.8 | 31.7 | 31.7 | 31.8 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

For the parameters and the activity data in biomass in orchards, the uncertainties of existing statistics and the default values described in the *2006 IPCC Guidelines* were applied. For the uncertainties of carbon stock changes in mineral soil estimated by RothC model, the comparison of simulation results and observed values, when both input values and current measurement values of mineral soils are available, revealed that the uncertainty due to model structure was estimated about 10%. The uncertainty caused by input values has not been quantified yet and remains as an issue to be solved. For the uncertainties of change in mineral soil organic carbon stocks from biochar amendments, the uncertainties of statistical data and default values given in *2019 Refinement* are used. For the uncertainties of organic soil, the uncertainties of statistical data and default values given in the *2006 IPCC Guidelines* are used. As a result, the uncertainty was estimated as 41% for the entire emission from the cropland remaining cropland.

- ***Time-series Consistency***

Time-series consistency for this category is ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

Although calibration for Roth C model has not been carried out, it was confirmed that the simulation results of Roth C have matched well with the observed data using the three modified versions of the Roth C model classified by land uses and soil types (Paddy soils, Andosols and non-Andosols).

Verification and modification of plot scale were done with measured data.

Experiment fields are classified by soil characteristics into Paddy soils group, Andosols group and non-Andosols group. These 3 soil types are considered to be covered with all soil type. For detailed information, see references; Shirato & Taniyama, (2003), Shirato et al., (2004), Shirato & Yokozawa, (2005), Takata et al., (2011), Shirato, (2011) listed in this chapter.

### *e) Category-specific Recalculations*

- ***Correction in accordance with revision of D area***

Areas of deforestation (D area) is used for determining each land use area converted from forest land. Since the D area were recalculated, areas of cropland remaining cropland were recalculated for all years. With this recalculation, carbon stock changes in mineral soils and $CO_2$ emissions from organic soils were recalculated for all years. For more details on correction of estimation methodology of areas of deforestation, please see Chapter 11, 11.5.1.7 in NIR “Review of AR areas and D areas”.

- ***Correction in accordance with the revision of cultivation area of fruit trees***

With publication of statistic data of cultivation area of fruit trees, the carbon stock changes in living biomass in cropland remaining cropland after FY2016 were recalculated.

- ***Correction of carbon stock factor in mineral soil***

Since carbon stock per unit area in mineral soil in upland fields for FY2017 was corrected, carbon stock changes in cropland remaining cropland were recalculated for FY2017.

- ***New estimating for change in mineral soil organic carbon stock from biochar amendments***

Since organic carbon stock from biochar amendments in cropland were estimated in this submission, carbon stock change in mineral soil in cropland remaining cropland were calculated for all years.
See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

As tier 3 approach, Roth C model is used for estimating carbon stock change in mineral soils. For more detail explanations of outcomes of the estimation and the fluctuating factor of input values, further analysis will be continued.

## 6.6.2. Land converted to Cropland (4.B.2)

### *a) Category Description*

This subcategory deals with the carbon stock changes which occurred in the lands that were converted from other land use categories to cropland within the past 20 years. Total area of land converted to cropland within the past 20 years by FY2018 is 44.7 kha, which represents 0.1% of the national total area.

The emissions from this subcategory in FY2018 were 23 kt-$CO_2$ (excluding GHG emissions other than carbon stock changers); this represents a decrease of 98.5% below the FY1990 value and a decrease of 16.2% below the FY2017 value. Since FY1990, the emissions had decreased, with some annual variability. Increasing and decreasing of areas where converted cropland from forest, which has higher carbon stock, have an influence on the annual variability.

With respect to living biomass, its carbon stock change as a result of land-use conversion from other land use to cropland is estimated. This process includes both temporary loss of living biomass in the land before and followed gains of living biomass after conversion. However, gains in carbon stocks in orchards were estimated in cropland remaining cropland in a lump and was reported as "IE".

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to cropland. Carbon stock changes in cropland converted from land-uses other than forest land were reported as "NA" assuming that the emissions would not occur.

In regard to carbon stock changes in mineral soils, the carbon stock changes in cropland converted from forest land, grassland and wetlands were estimated in the tier 3 model in a lump for the whole cropland area, and so reported as "IE". $CO_2$ emissions (on-site and off-site) from organic soils in cropland converted from other land-use categories were estimated in rice field and upland field converted from grassland.

### *b) Methodological Issues*

#### *1) Carbon stock changes in Living Biomass in "Land converted to Cropland"*

- ***Estimation Method***

The Tier 2 method is applied for forest land converted to cropland using the country specific value of the amount of biomass accumulation. The Tier 1 method is applied for land uses other than forest land converted to cropland using default values.

$$\Delta C = \Delta C_i + \Delta C_j$$

$$\Delta C_i = A \times (CR_a \times CF_a - CR_i \times CF_i)$$

$$\Delta C_j = A \times CR_j \times CF_a$$

| | |
|---|---|
| $\Delta C$ | : Annual carbon stock change in the converted land [t-C/yr] |
| $\Delta C_i$ | : Annual carbon stock change at the time of land conversion [t-C/yr] |
| $\Delta C_j$ | : Annual carbon stock change in the converted land after conversion [t-C/yr] |
| $i$ | : Land use before conversion |
| $j$ | : Land use after conversion |
| $A$ | : Area of converted land for the current year [ha] |
| $CR_a$ | : Dry matter biomass weight per unit area immediately following conversion [t-d.m./ha/yr], default value=0 |
| $CR_i$ | : Dry matter biomass weight per unit area before land was converted from land-use type *i* [t-d.m./ha/yr] |
| $CR_j$ | : Change of dry matter biomass weight per unit area accumulated after conversion [t-d.m./ha/yr] |
| $CF_a$ | : Carbon fraction of dry matter after conversion [t-C/t-d.m.] |
| $CF_i$ | : Carbon fraction of dry matter in land-use type before conversion [t-C/t-d.m.] |

- ***Parameters***

➢ ***Biomass stock in each Land-Use Category***

The values shown in Table 6-8a and Table 6-8b are used for the estimation of biomass stock changes upon land-use conversion and subsequent changes in biomass stock due to biomass growth in the converted land.

As for the biomass carbon stocks of annual crops described in table 6-8a, since it is considered that it is not appropriate to include biomass taken from harvesting site in carbon stock of cropland, the amount of crop residues left on the cropland after harvesting, which was used to estimate crop residues plowed into agricultural soil in the Agriculture sector, was applied instead of biomass carbon stocks of annual crops. In addition, the amount of crop residues plowed into cropland differs depending on the type of crop, and the carbon content of the crop residues plowed into cropland per unit cultivation area was weighted average according to the annual cultivation area. The average value from FY1990 to FY2017 was calculated using the weighted average value each year calculated above and was applied as parameter uniformly over the whole years (Table 6-8a).

In addition, biomass carbon stocks of annual crops per unit area were also applied as biomass growth of annual crops for one year after conversion (Table 6-8b).

➢ ***Carbon Fraction of Dry Matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

● ***Activity Data (Area)***

➢ ***Areas of forest land converted to other land-use categories***

It was assumed that the areas of forest land converted to other land-use categories (cropland, grassland, wetlands, settlement and other land) were consistent with the area of deforestation (D area) reported under Article 3, paragraph 3, of the Kyoto Protocol. Thus, the area of forest land converted to cropland was estimated by allocating the D area. Since the D survey by satellite image has been conducted since FY2005, the applied method to calculate the D area for FY1970 to FY2004 and for post FY2005 are as follows, respectively.

- ***From FY1990 to FY2004***

In the period from FY1990 to FY2004, annual conversion areas from forest land to other land-use categories were identified by surveys on D areas (For further information on determining the D areas, see section 11.4.2.3 in Chapter 11). With respect to the areas before 1989, the areas were obtained from statistics provided by the *World Census of Agriculture and Forestry* and the Forestry Agency's records, but the areas obtained from the surveys on D areas were larger than those from statistics. Hence, the total areas converted from forest land are estimated by setting an adjustment factor from the ratio between the D areas since FY1990 and the areas converted from forests provided by the *World Census of Agriculture and Forestry* and the Forestry Agency's records, and multiplying the areas converted from forests since FY1970 by the adjustment factor.

To estimate areas of forest land converted to each land-use category, ratios of conversion from private forests area to other land-use categories resulting from forest land development, based on the Forestry Agency's records was set. And then, total conversion areas from forest land were multiplied by the ratios of conversion. The ratios are regarded as applicable to the total forests because conversion from private forests to other land-use categories accounts for 90% of the total areas of conversion from forest land.

- ***After FY2005***

The areas of forest land converted to cropland, grassland, wetlands, settlements and other land were estimated by multiplying the D area by the land ratios of forest land converted to each land-use category.

Both the ratio and the area were determined by the D survey. For further information on determining the D areas, see section 11.4.2.3 in Chapter 11.

➢ ***Areas of conversion from land-use categories other than forest land***

The areas of land converted from land-use categories other than forest land to cropland are determined by applying expansion area values provided by the *Statistics of Cultivated and Planted Area*. The converted areas from arable land are divided into upland fields, orchards, and pasture land proportionately by means of the current situation. The areas of rice fields, upland fields, and orchards are allocated to cropland, while the area of pasture land is allocated to grassland. In addition, settlements converted to cropland are reported as "IE" because the areas are included in other land remaining other land.

It should be noted that the area presented in the CRF "Table 4.B Sectoral background data for land use, land-use change and forestry－Cropland" is not the annually converted area in FY2018 but the sum of annually converted areas during the past 20 years.

Table 6-27 Area of land converted to cropland (single year)

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Cropland | kha | 6.0 | 2.2 | 1.8 | 1.0 | 0.9 | 0.9 | 0.9 | 4.6 | 4.5 | 3.5 | 2.0 | 1.2 | 5.3 | 7.7 |
| Forest land converted to Cropland | kha | 5.4 | 1.1 | 0.3 | 0.5 | 0.8 | 0.8 | 0.8 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.2 | 0.2 |
| Rice field | kha | 0.009 | 0.01 | 0.002 | 0.0003 | 0.06 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 |
| Upland field | kha | 3.9 | 0.8 | 0.3 | 0.4 | 0.6 | 0.5 | 0.5 | 0.5 | 0.3 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 |
| Orchard | kha | 1.5 | 0.3 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.06 | 0.06 | 0.01 | 0.02 |
| Grassland converted to Cropland | kha | 0.004 | 0.05 | 0.03 | 0.06 | 0.009 | 0.001 | 0.002 | 0.001 | 0.001 | 0.007 | 0.007 | 0.004 | 0.006 | 0.005 |
| Wetlands converted to Cropland | kha | 0.34 | 0.03 | 0.07 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Settlements converted to Cropland | kha | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| Other land converted to Cropland | kha | 0.2 | 1.1 | 1.3 | 0.4 | 0.05 | 0.04 | 0.1 | 3.8 | 4.0 | 3.1 | 1.5 | 0.7 | 5.1 | 7.5 |
| Rice field | kha | 0.2 | 1.0 | 1.3 | 0.3 | 0.05 | 0.03 | 0.1 | 3.7 | 3.7 | 2.7 | 1.2 | 0.5 | 3.2 | 3.9 |
| Upland field | kha | 0.02 | 0.03 | 0.02 | 0.1 | 0.001 | 0.01 | 0.01 | 0.1 | 0.3 | 0.3 | 0.2 | 0.2 | 1.5 | 2.9 |
| Orchard | kha | 0.01 | 0.01 | 0.01 | 0.02 | 0.0001 | 0.002 | 0.001 | 0.03 | 0.1 | 0.1 | 0.1 | 0.1 | 0.4 | 0.7 |

### *2) Carbon Stock Change in Dead Organic Matter in "Land converted to Cropland"*

● ***Estimation Method***

Carbon stock changes in dead organic matter in forest land converted to cropland were estimated by applying Tier 2 estimation method using the value of carbon stock in dead organic matter in forest land obtained by the CENTURY-jfos model. All carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as $CO_2$ within the year of conversion in accordance with the description in section 5.3.2.1 in the *2006 IPCC Guidelines*. In addition, as described in the Parameters section below, carbon stocks of dead organic matter in cropland are assumed to be zero.

$$\Delta C_{DOM} = \sum_i \left\{ \left( C_{after,i} - C_{before,i} \right) \times A \right\}$$

$\Delta C_{DOM}$ : Carbon stock changes in dead organic matter in the converted land [t-C/yr]
$C_{after,i}$ : Average carbon stock per unit area in dead wood or litter after conversion [t-C/ha]
Note: carbon stocks after conversion are assumed as "0" (zero).
$C_{before,i}$ : Average carbon stock per unit area in dead wood or litter before conversion [t-C/ha]
$A$ : Area of converted land within the year of conversion [ha]
$i$ : type of dead organic matter (dead wood or litter)

With regard to grassland converted to cropland, carbon stocks of dead wood and litter carbon pools were assumed to be minor and the stock changes could be ignored, and were thus reported as "NA". With regard to wetlands and settlements converted to cropland, these were also reported as "NA", since it is assumed that carbon stock changes are from zero to zero, supposing that basically no such carbon pools exist in reclaimed wetland and that carbon stocks in dead organic matter in settlements before conversion could be negligible. Other land converted to cropland, which is estimated to be cropland restoration, was reported as "NA", because dead wood and litter in non-forest land are assumed as zero based on the Tier 1 method described in the *2006 IPCC Guidelines*.

- ***Parameters***

Average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-9 and Table 6-10. In addition, it is assumed that they become zero immediately after conversion, and will not accumulate after conversion.

- ***Activity Data (Area)***

Annually converted areas to cropland are used for estimating carbon stock changes in dead organic matter in land converted to cropland.

### *3) Carbon Stock Changes in Soils in "Land converted to Cropland"*

- ***Estimation Method***

Carbon stock changes in mineral soils in "Land converted to Cropland" is reported under "Cropland remaining cropland" using Tier 3 modeling method as described in 6.6.1.b) 2). Therefore, carbon stock in mineral soils in cropland converted from other land use categories was reported as "IE". $CO_2$ emissions (on-site and off-site) from organic soils was estimated in rice field and in upland field converted from other land use categories. For detailed information on the emission factors and activity data, see section 6.1.1. The areas of land converted to cropland including area of mineral soil and organic soil are shown in Table 6-28 below. The area of mineral soil in cropland converted from other land use categories reported in the CRF "Table 4.B" was also used for estimating $N_2O$ emissions reported in the CRF "Table 4(III)".

Table 6-28 Area of land converted to cropland within the past 20 years

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Cropland | kha | 215.9 | 158.5 | 111.0 | 61.8 | 37.5 | 32.4 | 29.7 | 30.5 | 33.1 | 33.4 | 33.2 | 33.4 | 37.9 | 44.7 |
| Forest land converted to Cropland | kha | 125.9 | 117.2 | 96.1 | 48.8 | 23.1 | 18.5 | 16.3 | 13.7 | 13.1 | 12.4 | 11.8 | 11.5 | 11.0 | 10.5 |
| Rice field | kha | 11.4 | 7.2 | 0.9 | 0.4 | 0.5 | 0.7 | 0.7 | 0.8 | 0.9 | 1.0 | 1.2 | 1.4 | 1.4 | 1.5 |
| Upland field | kha | 76.5 | 77.2 | 67.3 | 35.0 | 16.9 | 13.5 | 11.8 | 9.9 | 9.4 | 8.9 | 8.3 | 7.9 | 7.5 | 7.0 |
| Orchard | kha | 38.1 | 32.8 | 27.9 | 13.3 | 5.7 | 4.4 | 3.7 | 3.0 | 2.8 | 2.6 | 2.3 | 2.2 | 2.1 | 1.9 |
| Grassland converted to Cropland | kha | 33.7 | 15.8 | 1.2 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 0.7 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 |
| Wetlands converted to Cropland | kha | 11.0 | 3.2 | 1.7 | 1.2 | 1.1 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 |
| Settlements converted to Cropland | kha | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| Other land converted to Cropland | kha | 45.2 | 22.2 | 12.0 | 10.8 | 12.3 | 12.1 | 11.7 | 15.2 | 18.7 | 19.9 | 20.3 | 20.9 | 25.9 | 33.3 |
| Rice field | kha | 23.3 | 13.3 | 10.7 | 9.4 | 11.0 | 10.8 | 10.4 | 13.8 | 17.1 | 18.2 | 18.4 | 18.7 | 21.9 | 25.7 |
| Upland field | kha | 11.7 | 6.1 | 1.0 | 1.1 | 1.0 | 1.0 | 1.0 | 1.1 | 1.2 | 1.3 | 1.5 | 1.7 | 3.2 | 6.1 |
| Orchard | kha | 10.2 | 2.8 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 0.8 | 1.5 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

Uncertainties of the parameters and the activity data for living biomass, dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 19% for the entire emission from the land converted to cropland.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land-use categories are different between FY1990-2004 and post FY2005 as described in section 6.6.2.b)1), time-series consistency for this subcategory is basically ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

- ***Correction in accordance with revision of D area***

Since the method of estimating D area, which is used for estimating the areas of cropland converted from forest land were recalculated, carbon stock changes in living biomass, dead organic matter and $CO_2$ emissions from organic soils in this category were recalculated for all years.

- ***Correction of carbon stocks of annual crops biomass in cropland after conversion***

Since biomass growth of annual crops in cropland (after conversion) were corrected, carbon stock changes in living biomass in land converted to cropland were recalculated for all years.
See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

- ***Methods of Obtaining Data of the area of "Grassland converted to Cropland"***

Statistical data on the area of land converted from grassland to cropland are limited to land converted from grassland (pasture land) to cropland (rice field), so the carbon stock changes in these areas have not been estimated. Therefore, the methods to detect the following area data of conversion need to be developed.

- from pasture land to upland field
- from pasture land to orchard
- from grazed meadow to rice field
- from grazed meadow to upland field
- from grazed meadow to orchard

- ***Estimation Method of Soil Carbon Stock Change upon "Land converted to Cropland"***

The estimation method will be considered when new data and information are obtained.

## 6.7. Grassland (4.C)

Grassland is generally covered with perennial pasture and is used mainly for harvesting fodder or grazing. In FY2018, Japan's grassland area was about 0.95 million ha, which is equivalent to about 2.5% of the national land. The area of organic soil in the grassland is about 0.055 million ha. The carbon stock changes in this category in FY1990 was 1,062 kt-$CO_2$ emissions, 181 kt-$CO_2$ removals in FY2017, and 266 kt-$CO_2$ removals in FY2018 (excluding 2.2 kt-$CO_2$ eq. of non-$CO_2$ emissions from drained organic soils and drainage ditches, 2.2 kt-$CO_2$ eq. of $N_2O$ emissions resulting from nitrogen mineralization resulting from change of land use or management of mineral soils, 26.4 kt-$CO_2$ eq. of $N_2O$ and $CH_4$ emissions from biomass burning).

In this section, grassland is divided into two subcategories, "Grassland remaining Grassland (4.C.1.)" and "Land converted to Grassland (4.C.2.)", and describes them separately in the following subsections.

Table 6-29 Emissions and removals from grassland resulting from carbon stock changes

| Gas | Category | Carbon pool | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 4.C. Grassland | Total | kt-$CO_2$ | 1,062 | 689 | 48 | -966 | -36 | 124 | 256 | -19 | -35 | 147 | -12 | -67 | -181 | -266 |
| | | Living Biomass | kt-$CO_2$ | 109 | 14 | -6 | 88 | 206 | 188 | 80 | 112 | 151 | 155 | 94 | 95 | 39 | 36 |
| | | Dead Wood | kt-$CO_2$ | 42 | 9 | 3 | 29 | 71 | 71 | 37 | 37 | 57 | 57 | 36 | 36 | 20 | 20 |
| | | Litter | kt-$CO_2$ | 20 | 4 | 1 | 14 | 34 | 34 | 18 | 18 | 28 | 28 | 18 | 18 | 10 | 10 |
| | | Mineral soil | kt-$CO_2$ | 862 | 633 | 20 | -1,126 | -384 | -198 | 87 | -221 | -303 | -130 | -199 | -244 | -278 | -360 |
| | | Organic soil | kt-$CO_2$ | 29 | 29 | 29 | 29 | 36 | 28 | 34 | 36 | 32 | 38 | 39 | 29 | 29 | 28 |
| | 4.C.1. Grassland remaining Grassland | Total | kt-$CO_2$ | 881 | 658 | 48 | -1,098 | -349 | -171 | 120 | -187 | -273 | -94 | -161 | -217 | -251 | -333 |
| | | Living Biomass | kt-$CO_2$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | | Dead Wood | kt-$CO_2$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | | Litter | kt-$CO_2$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | | Mineral soil | kt-$CO_2$ | 862 | 633 | 20 | -1,126 | -384 | -198 | 87 | -221 | -303 | -130 | -199 | -244 | -278 | -360 |
| | | Organic soil | kt-$CO_2$ | 20 | 25 | 28 | 28 | 34 | 27 | 32 | 34 | 31 | 36 | 38 | 27 | 27 | 27 |
| | 4.C.2. Land converted to Grassland | Total | kt-$CO_2$ | 181 | 31 | 0 | 133 | 313 | 294 | 136 | 168 | 237 | 241 | 149 | 150 | 70 | 67 |
| | | Living Biomass | kt-$CO_2$ | 109 | 14 | -6 | 88 | 206 | 188 | 80 | 112 | 151 | 155 | 94 | 95 | 39 | 36 |
| | | Dead Wood | kt-$CO_2$ | 42 | 9 | 3 | 29 | 71 | 71 | 37 | 37 | 57 | 57 | 36 | 36 | 20 | 20 |
| | | Litter | kt-$CO_2$ | 20 | 4 | 1 | 14 | 34 | 34 | 18 | 18 | 28 | 28 | 18 | 18 | 10 | 10 |
| | | Mineral soil | kt-$CO_2$ | IE,NO | IE,NO | IE,NO | IE,NO | IE,NO | IE,NO | IE,NO | IE,NO | IE,NO | IE,NO | IE,NO | IE,NO | IE,NO | IE,NO |
| | | Organic soil | kt-$CO_2$ | 9 | 4 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 |

### 6.7.1. Grassland remaining Grassland (4.C.1)

#### *a) Category Description*

In this category carbon stock changes in grassland remaining grassland during the past 20 years are reported, divided into three subcategories: "pasture land", "grazed meadow" and "wild land".

The carbon stock changes in this subcategory were 881 kt-$CO_2$ emissions in FY1990, 251 kt-$CO_2$ removals in FY2017 and 333 kt-$CO_2$ removals in FY2018 (excluding GHG emissions other than carbon stock changes).

The emissions had been decreasing since FY1990, and turned to be removals in 2000s and hit a peak in removals in FY2008. However, the removals have been on a decreasing trend since FY2009 up to now, although minor fluctuations have been repeatedly interrupted.

This high variability was largely due to carbon stock changes in mineral soils (In particular, input amount of compost).

As major impact factors on this high variabilities through time-series, input amount of carbon and yearly temperature fluctuations are considered. Amount of manure application has been on an increasing trend especially in 2000s, though the trend remained flat in following years. In addition, recently there have been no cold year; the relatively mild weather might facilitate more organic matter decomposition. Thus,

it is considered that these factors are mainly contribute to the trend.

With respect to living biomass, carbon stock changes in pasture land and grazed meadow are assumed to be in a steady state and reported as "NA" in accordance with the Tier 1 estimation method in section 6.2.1.1 in the *2006 IPCC Guidelines*.

Carbon stock changes in dead organic matter in pasture land and grazed meadow are estimated as zero (0) by applying the Tier 1 method described in section 6.2.2.1 in the *2006 IPCC Guidelines*, which assumes that the carbon stocks are not changed. Thus, the carbon stock changes are reported as "NA".

In regard to carbon stock changes in mineral soils, the carbon stock changes in pasture land were estimated by applying the Tier 3 method using Roth C model same as cropland remaining cropland. Grazed meadows were non-degraded and sustainably managed grassland, but without significant management improvements. Therefore, the default value of the carbon stock change factor for "Nominally managed (non-degraded)" in table 6.2 of the *2006 IPCC Guidelines*, which was "1.0", was applied to grazed meadows. In this case, soil carbon stocks were not changed over time; therefore, the soil carbon stock changes in grazed meadows were reported as "NA". On-site $CO_2$ emissions resulting from tillage and drainage of organic soils and off-site $CO_2$ emissions via waterborne carbon losses from drained inland organic soils in pasture land were estimated by applying Tier 1 method.

$CO_2$ emission from organic soils in grazed meadow was reported as "NO" because the tillage and drainage resulting from renewal of grazed meadow are not implemented.

Carbon stock changes in all carbon pools in wild land are reported as "NA" because anthropogenic management is not implemented to the wild land in general.

Table 6-30 Areas of grassland remaining grassland within the past 20 years

| Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grassland remaining Grassland | | kha | 709.8 | 856.6 | 950.9 | 978.2 | 967.3 | 965.0 | 927.2 | 925.6 | 922.7 | 928.8 | 927.1 | 913.4 | 920.7 | 917.5 |
| | Pasture land | kha | 324.8 | 495.7 | 584.1 | 601.7 | 590.9 | 588.6 | 587.2 | 585.6 | 582.7 | 578.8 | 577.1 | 573.4 | 570.7 | 567.5 |
| | Grazed meadow | kha | 105.0 | 100.9 | 96.8 | 96.5 | 96.4 | 96.4 | 96.4 | 96.4 | 96.3 | 96.3 | 96.3 | 96.3 | 96.3 | 96.2 |
| | Wild land | kha | 280.0 | 260.0 | 270.0 | 280.0 | 280.0 | 280.0 | 243.6 | 243.6 | 243.7 | 253.7 | 253.7 | 243.7 | 253.7 | 253.8 |

### *b) Methodological Issues*

#### *1) Carbon Stock Changes in Soils in "Grassland remaining Grassland"*

- ***Estimation Method***

➢ ***Carbon stock changes in mineral soils***

Carbon stock change in mineral soils in pasture land was estimated by using the Tier 3 modeling method same as 6.6.1.b)2) cropland remaining cropland (4.B.1)

➢ ***On-site $CO_2$ emissions resulting from cultivation in organic soils***

With respect to $CO_2$ emissions from organic soils in pasture land were estimated by applying the Tier 1 estimation method described in section 6.2.3.1 in the *2006 IPCC Guidelines*. The estimation method is the same as cropland remaining cropland.

➢ ***Off-site $CO_2$ emissions via waterborne carbon losses from drained inland organic soils***

Off-site $CO_2$ emissions via waterborne carbon losses from drained inland organic soils were estimated by applying Tier 1 estimation method described in section 2.2.1.2 in the *Wetlands Guidelines.* The estimation method is the same as cropland remaining cropland (4.B.1).

- ***Parameters***

➢ ***Assumption for the Roth C model and parameters for estimating mineral soils***

The parameters used are omitted because they are the same as cropland remaining cropland (4.B.1).

➢ ***$CO_2$ emission factors from organic soils (EF)***

Because there is little research data on $CO_2$ emission factor that is suitable for grassland in Japan, the default value provided in *the Wetlands Guidelines* (Table 2.1, 6.1 t-C/ha/year) which is considered to be most appropriate for the emission factor under the distribution of pasture land and current management system in Japan, was applied. As for off-site $CO_2$ emissions, the same parameters as cropland remaining cropland (4.B.1) were used.

- ***Activity Data***

➢ ***Area of mineral soils***

The area of mineral soils applied for Roth C model is calculated by subtracting area of organic soils in pasture land from total area of pasture land reported in the *Statistics of Cultivated and Planted Area*. The area of mineral soil in grassland (pasture land) reported in the CRF "Table 4.C" are also used for estimating $N_2O$ emissions reported in the CRF "Table 4(III)".

➢ ***Area of organic soils***

Areas of organic soils in pasture land remaining pasture land and in pasture land converted from other land-use were obtained by applying the method same as section 6.6.1.b)2). The activity data (the actual area for conducting cultivation and drainage) was calculated by multiplying renewal ratio of pasture land by the area of organic soils in pasture land. For the renewal ratio of pasture land, the values (Hokkaido and other than Hokkaido) published in the report of "Survey on actual situation of grassland management for feed" (Hatano,2017) which investigated the management status of pastures were applied (see section 11.4.2.7.a.in Chapter 5 in this NIR). Moreover, about renewal ratio of pasture land before FY2005, the average value between FY2006 and FY2010 was applied because the survey has not been implemented. Also, since there are no survey values for FY2016 and for FY2017, the average values from FY2006 to FY2010 were used as well. The area of organic soil in grazed meadow and in wild land in FY2009 were calculated by multiplying the area of grazed meadow (*World Census of agriculture and Forestry*) and wild land (*Land Use Status Survey*) in FY2009, by ratio of organic soil area obtained from GIS (Geographic information system) data analysis results in FY2009. The area of organic soil before FY2009 and after FY2009 were calculated by adding organic soil area in grazed meadow and wild land converted other land-use to FY2009, and by subtracting organic soil area in land converted from grazed meadow and wild land from FY2009.

In addition, as described in section 6.6.1, since the area of organic soil reported in the Agriculture sector does not include areas of organic soil in grazed meadow and in wild land, the area of organic soil reported in LULUCF sector is different to the value reported in the Agriculture sector.

Table 6-31 Area of organic soil in grassland remaining grassland

| Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grassland remaining Grassland | | kha | 45.9 | 52.2 | 56.7 | 57.5 | 57.4 | 57.3 | 55.5 | 55.4 | 55.3 | 55.7 | 55.5 | 54.9 | 55.3 | 55.2 |
| | Pasture land | kha | 28.2 | 35.4 | 39.4 | 39.8 | 39.7 | 39.6 | 39.5 | 39.5 | 39.4 | 39.2 | 39.1 | 39.0 | 38.9 | 38.8 |
| | Grazed meadow | kha | 4.6 | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| | Wild land | kha | 13.2 | 12.2 | 12.7 | 13.2 | 13.2 | 13.2 | 11.4 | 11.4 | 11.4 | 11.9 | 11.9 | 11.4 | 11.9 | 11.9 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

Uncertainties of carbon stock change in mineral soil are the same as cropland remaining cropland (4.B.1); therefore, the description is omitted. Uncertainties of existing statistical data and the default values described in the *Wetlands Guidelines* were applied to estimate $CO_2$ emissions from organic soil. As a result, the uncertainty was estimated as 9% of the total emissions grassland remaining grassland.

- ***Time-series Consistency***

Time-series consistency for this category is ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

- ***Correction in accordance with revision of D area***

Areas of deforestation (D area) is used for determining each land use area converted from forest land. Since the D area were recalculated, areas of grassland remaining grassland were recalculated for all years. With this recalculation, carbon stock change in mineral soils and $CO_2$ emissions from organic soils were recalculated for all years.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

As Tier 3 approach, Roth C model is used for estimating carbon stock change in mineral soils. For more detail explanations of outcomes of the estimation and the fluctuating driver of input values, further analysis will be continued.

## 6.7.2. Land converted to Grassland (4.C.2)

### *a) Category Description*

This subcategory deals with the carbon stock changes, which occurred in the lands that were converted from other land-use categories to grassland within the past 20 years. The emission in this category in FY2018 was 67 kt-$CO_2$ ; this represents a decrease of 63.0% below the FY1990 value and a decrease of 4.4% below the FY2017 value. With respect to living biomass, its carbon stock changes as a result of land-use conversion from other land use to grassland are estimated. The carbon stock changes include both temporary loss of living biomass in the land before and subsequent gain after conversion.

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to grassland. Carbon stock changes in grassland converted from land-uses other than forest land were reported as “NA” or “NO” because suitable knowledge for estimating carbon stocks for the land-use categories was not available, or because it was assumed that no carbon stock change occurred, respectively.

Carbon stock changes in soils as a result of land-use conversion from other land use to grassland were estimated. With respect to carbon stock changes in mineral soils, the carbon stock changes in grassland converted from forest land, cropland, wetlands and other land were estimated together for the whole grassland, and reported in grassland remaining grassland ("IE" in land converted to grassland). $CO_2$ emissions from organic soils in pasture land converted from cropland were estimated. $CO_2$ emission in forest land converted to grassland were reported as "NO" because conversion of organic soil area from forest land to grassland was not implemented in general in Japan. $CO_2$ emissions from organic soils in grassland converted from wetlands and Other land were reported as "IE" because the emissions were included in those in grassland remaining grassland.

Carbon stock changes in each carbon pool in settlements converted to grassland are reported as "NO" because the land conversion from settlements to grassland is not implemented in general in Japan.

### *b) Methodological Issues*

#### *1) Carbon stock changes in Living biomass in "Land converted to Grassland"*

- ***Estimation Method***

The Tier 2 method was applied to estimate forest land and cropland (rice fields) converted to grassland (pasture lands) using country specific and provisional values of the amount of biomass accumulation. The Tier 1 method was used for land uses other than forest land and cropland (rice fields) converted to grassland (pasture lands) using default value. The equations are given in section 6.6.2.b)1). While the annually converted areas were used for estimating the loss of living biomass upon land-use conversion, the biomass growth after land-use conversion was estimated by summing the converted areas for the latest five years, assuming that it takes five years after conversion to reach a steady state with a constant growing rate.

- ***Parameters***

➢ ***Biomass stock in each Land-Use Category***

The values shown in Table 6-8a and Table 6-8b are used for the estimation of biomass stock changes upon land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

➢ ***Carbon Fraction of Dry Matter***

Average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied as the carbon fraction of dry matter of forest. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines.*

- ***Activity Data (Area)***

For the estimation of carbon stock change in living biomass in grassland converted from other land-use categories, the annually converted areas were used for estimating the loss (Table 6-32) and the areas of summing the converted areas for the latest five years are used for estimating the biomass growth after land-use conversion (Table 6-33).

➢ ***Area Converted from Forestland***

As described in 6.6.2.b)1), the methodology of "Areas of forest land converted to other land-use categories" is applied.

➢ ***Area Converted from other than Forestland***

As shown in Table 6-2, grassland is treated as a part of arable land in statistics of Japan. Therefore, the procedure to obtain the area of the grassland converted from other land-use categories is as described in 6.6.2.b)1). Areas of settlements converted to grassland are reported as "NO" because land conversion from settlements to grassland does not occur.

It should be noted that the area presented in the CRF "Table 4.C Sectoral background data for land use, land-use change and forestry－Grassland" is not the annually converted area in FY2018 but the sum of annually converted areas during the past 20 years.

Table 6-32 Area of land converted to grassland (single year)

| Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Grassland | | kha | 1.8 | 0.8 | 1.1 | 2.3 | 2.0 | 2.0 | 1.3 | 1.1 | 1.5 | 1.4 | 1.2 | 1.3 | 1.3 | 2.0 |
| | Forest land converted to Grassland | kha | 0.8 | 0.2 | 0.1 | 0.5 | 1.3 | 1.3 | 0.7 | 0.7 | 1.0 | 1.0 | 0.7 | 0.7 | 0.4 | 0.4 |
| | Cropland converted to Grassland | kha | 0.9 | 0.6 | 1.0 | 1.7 | 0.7 | 0.7 | 0.6 | 0.4 | 0.3 | 0.3 | 0.4 | 0.5 | 0.5 | 0.4 |
| | Wetlands converted to Grassland | kha | 0.12 | 0.01 | 0.03 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Settlements converted to Grassland | kha | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Other land converted to Grassland | kha | 0.01 | 0.01 | 0.01 | 0.04 | 0.0003 | 0.004 | 0.003 | 0.05 | 0.1 | 0.1 | 0.1 | 0.1 | 0.4 | 1.2 |

Table 6-33 Area of land converted to grassland within the past 5 years

| Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Grassland | | kha | 11.6 | 5.1 | 5.1 | 7.2 | 11.0 | 10.7 | 10.0 | 8.7 | 7.8 | 7.3 | 6.5 | 6.5 | 6.8 | 7.2 |
| | Forest land converted to Grassland | kha | 4.7 | 1.4 | 0.5 | 0.7 | 5.1 | 5.8 | 6.0 | 5.3 | 4.9 | 4.7 | 4.1 | 4.1 | 3.8 | 3.1 |
| | Cropland converted to Grassland | kha | 6.5 | 3.4 | 4.5 | 6.2 | 5.7 | 4.6 | 3.8 | 3.2 | 2.6 | 2.2 | 1.9 | 1.9 | 2.0 | 2.1 |
| | Wetlands converted to Grassland | kha | 0.3 | 0.1 | 0.03 | NO | 0.2 | 0.2 | 0.2 | 0.2 | NO | NO | NO | NO | NO | NO |
| | Settlements converted to Grassland | kha | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Other land converted to Grassland | kha | 0.1 | 0.2 | 0.04 | 0.3 | 0.1 | 0.1 | 0.02 | 0.1 | 0.2 | 0.3 | 0.5 | 0.6 | 1.0 | 2.0 |

### *2) Carbon Stock Change in Dead Organic Matter in "Land converted to Grassland"*

- ***Estimation Method***

In this category, carbon stock changes in dead organic matter in forest land converted to grassland were estimated. The Tier 2 estimation method was applied to the subcategory using country specific values of the carbon stocks before and after conversion. It should be noted that the carbon stocks of dead organic matter after conversion to grassland are assumed as zero (Tier 1 method in the *2006 IPCC Guidelines* Vol.4 section 6.3.2), because there are no quantitative data of them, although a subtle but certain amount of carbon stocks does generally exist on the soil surface. As described in section 6.6.2.b)2), cropland converted to grassland were reported as "NA" since the carbon stocks before and after conversion were assumed as zero. As for wetlands and other land converted to grassland, they include only reclamation and restoration. Thus, they were reported as "NA"[7], for the same reasons as described in section 6.6.2.b)2).

- ***Parameters***

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Tables 6-9 and 6-10. The average carbon stocks in these categories from FY1990 to FY2004 are not estimated; therefore those in FY2005 are substituted for them. In addition, it is assumed that they become zero immediately after conversion, and are not accumulated after conversion. All carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as $CO_2$ within the year of conversion in accordance with the description in section 6.3.2.2 in the *2006 IPCC Guidelines*.

[7] Cropland in the Japanese statistics includes pasture land which falls into grassland.

- ***Activity Data (Area)***

The sum of annually converted areas from other land-use categories to grassland for the past 20 years was regarded as the area of land converted to grassland during the past 20 years. The areas are shown in Table 6-34.

Table 6-34 Areas of land converted to grassland within the past 20 years

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Grassland | kha | 321.8 | 165.0 | 60.6 | 28.9 | 27.9 | 28.1 | 28.0 | 27.7 | 28.4 | 29.0 | 29.4 | 30.0 | 30.3 | 31.1 |
| Forest land converted to Grassland | kha | 182.6 | 106.4 | 35.1 | 7.3 | 7.9 | 8.4 | 8.7 | 8.8 | 9.7 | 10.6 | 11.1 | 11.6 | 11.9 | 12.2 |
| Cropland converted to Grassland | kha | 70.6 | 38.5 | 23.9 | 20.7 | 19.0 | 18.8 | 18.5 | 18.0 | 17.7 | 17.5 | 17.3 | 17.2 | 16.8 | 16.2 |
| Wetlands converted to Grassland | kha | 1.7 | 1.6 | 1.0 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Settlements converted to Grassland | kha | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Other land converted to Grassland | kha | 66.8 | 18.6 | 0.5 | 0.6 | 0.6 | 0.6 | 0.5 | 0.6 | 0.6 | 0.7 | 0.8 | 0.9 | 1.4 | 2.6 |

### *3) Carbon Stock Change in Soils in "Land converted to Grassland"*

- ***Estimation Method***

Carbon stock changes in mineral soils in pasture land was estimated by applying the Tier 3 estimation method same as section 6.6.1.b)2). For the estimation, land which was once pasture land since 1970's was regarded as pastures land and used for calculation; the result of the calculation includes all grassland, regardless of land conversion. Therefore, carbon stock in mineral soil was reported regardless of whether or not land conversion has been occurred and carbon stock in pasture land converted from other land use was reported as "IE" since it was included in carbon stock in pasture land remaining pasture land. $CO_2$ emissions (on-site and off-site) from organic soils were estimated in pastures land converted from other land use using the same method as in cropland converted from other land use. For detailed information on the emission factors and activity data, see section 6.6.1.b)2).

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 19% for the entire removal from the land converted to grassland.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.6.1.b)1), time-series consistency for this subcategory is basically ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

- ***Correction in accordance with revision of D area***

Since the D area, which is used for estimating the areas of grassland converted from forest land were

recalculated, carbon stock changes in living biomass, dead organic matter and $CO_2$ emissions from organic soils in this category were recalculated for all years.

- ***Correction of carbon stocks of annual crops biomass in cropland before conversion***

Since carbon stocks of annual crops biomass in cropland were corrected, living biomass stock losses in land converted from cropland were estimated in this submission. Therefore, carbon stock changes of living biomass in grassland converted from cropland were recalculated for all years.

See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

- ***Method of Obtaining Data of the "Areas of Cropland converted from Other Land-use Categories to Grassland"***

The method used to obtain data on the area converted to grassland needs to be improved. For example, currently, the area of lands converted from forest land to grassland is estimated by multiplying the summed areas of forest land converted to cropland and grassland by the ratio of grazing land to the summed area. However, this estimation method may not represent the actual status of these areas. Therefore, the validity of the estimation method needs to be reviewed, and, if necessary, a new method of obtaining the area data should be developed.

- ***Method of Obtaining Data of the "Area of Cropland converted to Grassland"***

The area of Cropland converted to Grassland cannot be obtained from statistics except for the land-use conversion from cropland (rice field) to grassland (pasture land). For this reason, the estimates of the carbon stock changes in this land-use category may not fully reflect the actual conditions. Therefore, the methods used to detect the following area data need to be developed.

- from upland field to pasture land
- from orchard to pasture land
- from rice field to grazed meadow
- from upland field to grazed meadow
- from orchard to grazed meadow.

- ***Estimation Method of Soil Carbon Stock Change upon "Land-Use Conversion from Other Land to Cropland"***

The estimation method will be revised when new data and information are obtained.

## 6.8. Wetlands (4.D)

Wetlands are lands that are covered with or soaked in water throughout the year. They do not fall into the categories of forest land, cropland, grassland, or settlements. The *2006 IPCC Guidelines* divides wetlands into three large groups: peat land, flooded land, and other wetlands. However, emissions and removals from other wetlands are not reported in Japan.

In FY2018, Japan's wetland area was about 1.35 million ha, which is equivalent to about 3.6% of the national land. The emissions from this category in FY2018 were 17 kt-$CO_2$ emissions; this represents a decrease of 80.9% below the FY1990 value and a decrease of 0.1% below the FY2017 value.

In this section, wetlands is divided into two subcategories, "Wetlands remaining Wetlands (4.D.1.)" and

"Land converted to Wetlands (4.D.2.)", and describes them separately in the following subsections.

Table 6-35 Emissions and removals in wetlands resulting from carbon stock changes

| Gas | Category | Carbon pool | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 4.D. Wetlands | Total | kt-$CO_2$ | 91 | 359 | 426 | 42 | 121 | 114 | 59 | 68 | 24 | 24 | 59 | 59 | 17 | 17 |
| | | Living Biomass | kt-$CO_2$ | 65 | 257 | 305 | 30 | 85 | 79 | 41 | 50 | 16 | 17 | 40 | 41 | 12 | 12 |
| | | Dead Wood | kt-$CO_2$ | 17 | 69 | 82 | 8 | 24 | 24 | 12 | 12 | 5 | 5 | 12 | 12 | 4 | 4 |
| | | Litter | kt-$CO_2$ | 8 | 33 | 39 | 4 | 12 | 12 | 6 | 6 | 2 | 2 | 6 | 6 | 2 | 2 |
| | | Mineral soil | kt-$CO_2$ | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA |
| | | Organic soil | kt-$CO_2$ | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA |
| | 4.D.1. Wetlands remaining Wetlands | Total | kt-$CO_2$ | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA |
| | | Living Biomass | kt-$CO_2$ | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA |
| | | Dead Wood | kt-$CO_2$ | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA |
| | | Litter | kt-$CO_2$ | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA | NO,NE,NA |
| | | Mineral soil | kt-$CO_2$ | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA |
| | | Organic soil | kt-$CO_2$ | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA |
| | 4.D.2. Land converted to Wetlands | Total | kt-$CO_2$ | 91 | 359 | 426 | 42 | 121 | 114 | 59 | 68 | 24 | 24 | 59 | 59 | 17 | 17 |
| | | Living Biomass | kt-$CO_2$ | 65 | 257 | 305 | 30 | 85 | 79 | 41 | 50 | 16 | 17 | 40 | 41 | 12 | 12 |
| | | Dead Wood | kt-$CO_2$ | 17 | 69 | 82 | 8 | 24 | 24 | 12 | 12 | 5 | 5 | 12 | 12 | 4 | 4 |
| | | Litter | kt-$CO_2$ | 8 | 33 | 39 | 4 | 12 | 12 | 6 | 6 | 2 | 2 | 6 | 6 | 2 | 2 |
| | | Mineral soil | kt-$CO_2$ | NA,NE | NA,NE | NA,NE | NA,NE | NA,NE | NA,NE | NA,NE | NA,NE | NA,NE | NA,NE | NA,NE | NA,NE | NA,NE | NA,NE |
| | | Organic soil | kt-$CO_2$ | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO | NA,NE,NO |

### 6.8.1. Wetlands remaining Wetlands (4.D.1)

#### *a) Category Description*

This subcategory deals with carbon stock changes in wetlands which have remained as wetlands during the past 20 years.

For carbon stock change in organic soil managed for peat extraction, as a result of the domestic survey, it is found out that although peat extraction is carried out in Japan, estimating emissions with high accuracy is difficult. Therefore, based on the amount of emissions expected, carbon stock changes in organic soils that are managed for peat extraction are reported as "NE" under the revision of the UNFCCC Guidelines. "Flooded land remaining flooded land" is not calculated at the present time as this is treated in an appendix in the *2006 IPCC Guidelines* and reported as "NE". "Other wetlands remaining other wetlands" are reported as "NA" because the activity is not defined at the present time in Japan.

Table 6-36 Areas of wetlands remaining wetlands within the past 20 years

| Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wetlands remaining Wetlands | | kha | 1,280.3 | 1,293.8 | 1,321.2 | 1,316.5 | 1,308.1 | 1,307.9 | 1,318.0 | 1,318.9 | 1,319.5 | 1,320.0 | 1,321.4 | 1,314.2 | 1,334.7 | 1,337.0 |
| | Organic soils managed for peat extraction | kha | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| | Flooded land | kha | 1,280.3 | 1,293.8 | 1,321.2 | 1,316.5 | 1,308.1 | 1,307.9 | 1,318.0 | 1,318.9 | 1,319.5 | 1,320.0 | 1,321.4 | 1,314.2 | 1,334.7 | 1,337.0 |
| | other wetlands | kha | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

#### *b) Methodological Issues*

##### *1) Emission from peats extraction*

For adaptation of standard for small emission, the following estimation was implemented. A result of domestic survey, peats are extracted in Japan, but accurate emissions are not able to estimate. A rough calculation of emission from peat extraction was made both at "on-site" and "off-site" with the Tier1 methodology in Chapter 7 of the *2006 IPCC guidelines*. The peat extraction is carried out mainly in Hokkaido area, where is located in the northernmost part of Japan. So that we applied climatic zone as "Boreal and Temperate" and its soil condition as "Nutrient-Poor" under expert judgment in our preliminary calculation. To calculate on-site $CO_2$ emissions, we use the value, about "150ha" for peat extraction area that from private company of peat extraction. And we also use the default values of EF,

0.2tC/ha (Boreal and Temperate, Nutrient- Poor on Table 7.4, Chp.7, Vol.4, 2006 *IPCC Guidelines*), and the result of this calculation is approximately 0.1kt-$CO_2$.To calculate off-site $CO_2$ emissions, we use the value from National production data, which is available since 2003, ranged from 17 to 34kt in air-dry weight basis. And we also use the default value of carbon fractions, 0.45tC/t(dry) (Boreal and Temperate, Nutrient- Poor on Table 7.5, Chp.7, Vol.4, 2006 *IPCC Guidelines*). So the result of this calculation is ranged from 30 to 50 kt-$CO_2$. Furthermore, $N_2O$ emissions from peat extraction are not included in these calculations, as the estimation is necessary only for "Nutrient –Rich" area in Tier 1 method. As a result of these calculations, we regarded that the emissions from peat extraction as "NE" in insignificant level of emissions. This value is below from threshold suggested by paragraph 37b) of Annex 1 in Decision 24/CP19 and country specific standard of 90 kt-$CO_2$ (this value is 0.1 % of the removals from LULUCF section in 2005). Please refer to annex 5 of NIR, for more information about our criteria for "NE".

***c) Category-specific Recalculations***

- ***Correction in accordance with revision of D area***

Areas of deforestation (D area) is used for determining each land use area converted from forest land. Since the D area were recalculated, areas of wetlands remaining wetlands were recalculated for all years. See Chapter 10 for impact on trend.

### 6.8.2. Land converted to Wetlands (4.D.2)

***a) Category Description***

This subcategory deals with the carbon stock changes which occurred in the land that was converted from other land-use categories to wetlands, particularly to flooded land (i.e., dams) within the past 20 years. The emissions from this subcategory in FY2018 were 17 kt-$CO_2$ emissions, this represents a decrease of 80.9% below the FY1990 value and a decrease of 0.1% below the FY2017 value.

With respect to living biomass, its carbon stock change (losses of living biomass in the land before conversion) as a result of land-use conversion from other land use to wetlands is estimated.

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated the carbon stock change in wetlands converted from forest land. Carbon stock changes in other subcategories were reported as "NA", supposing that no carbon stock change occur.

Carbon stock changes in soils in forest land converted to wetlands were reported as "NA". This was because after the areas came to be reservoirs (dams), and their soils were supposed to become anaerobic condition; hence $CO_2$ emissions resulting from organic matter decomposition seemed to be extremely little. Since methodology is not provided by the *2006 IPCC Guidelines* and due to lack of data, carbon stock changes in soils in wetlands (flooded land) converted from land use other than forest land were not estimated. Therefore, the carbon stock changes in the carbon pool were reported as "NE".

***b) Methodological Issues***

***1) Carbon stock change in Living biomass in "Land converted to Wetlands"***

- ***Estimation Method***

The Tier 2 method was applied for the land converted to wetlands (flooded land). The equations are

given in section 6.6.2.b)1).

- ***Parameters***

➢ ***Biomass stock in each Land-Use Category***

The values shown in Table 6-8a and Table 6-8b are used for the estimation of biomass stock changes resulting from land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

➢ ***Carbon Fraction of Dry Matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

- ***Activity Data (Area)***

Areas of land converted to wetlands (dam) were estimated based on the area of dam converted from forest land and the ratio of forest land among the area of land-use categories before conversion. The area of forest land converted to wetlands was calculated by the method described in section 6.6.2.b)1). With respect to areas of each land-use type before conversion to dam, percentages of each land area converted to dams from agricultural land (cropland and grassland), settlements and Other land were estimated based on the numbers of dwellings and agricultural land which were submerged into some large-scale dams. Breakdown of wetland areas converted from agricultural land into from cropland and grassland was determined based on the ratio of current area the same manner of other land-use categories. The differences between the areas of wetlands converted from forest land, cropland, grassland, and settlements and the total dam conversion area were regarded as other land converted to wetlands.

It should be noted that the area presented in the CRF "Table 4.D Sectoral background data for land use, land-use change and forestry－Wetlands" is not the annually converted area in FY2018 but the sum of annually converted areas during the past 20 years.

Table 6-37 Area of land annually converted to wetlands (single year)

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Wetlands | kha | 0.43 | 1.72 | 2.04 | 0.20 | 0.60 | 0.60 | 0.31 | 0.31 | 0.13 | 0.13 | 0.31 | 0.31 | 0.09 | 0.09 |
| Forest land converted to Wetlands | kha | 0.31 | 1.24 | 1.48 | 0.15 | 0.43 | 0.43 | 0.22 | 0.22 | 0.09 | 0.09 | 0.22 | 0.22 | 0.07 | 0.07 |
| Cropland converted to Wetlands | kha | 0.02 | 0.10 | 0.13 | 0.01 | 0.04 | 0.04 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 |
| Rice field | kha | 0.01 | 0.02 | 0.09 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.003 | 0.01 | 0.01 | 0.01 | 0.003 | 0.003 |
| Upland field | kha | 0.01 | 0.05 | 0.03 | 0.001 | 0.01 | 0.01 | 0.01 | 0.01 | 0.003 | 0.002 | 0.006 | 0.005 | 0.002 | 0.002 |
| Orchard | kha | 0.005 | 0.02 | 0.01 | 0.0004 | 0.003 | 0.003 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.0005 | 0.001 |
| Wetlands converted to Wetlands | kha | 0.007 | 0.029 | 0.019 | 0.001 | 0.006 | 0.006 | 0.004 | 0.004 | 0.002 | 0.001 | 0.003 | 0.003 | 0.001 | 0.001 |
| Settlements converted to Wetlands | kha | 0.002 | 0.006 | 0.007 | 0.001 | 0.002 | 0.002 | 0.001 | 0.001 | 0.0005 | 0.0005 | 0.001 | 0.001 | 0.0003 | 0.0003 |
| Other land converted to Wetlands | kha | 0.09 | 0.34 | 0.41 | 0.04 | 0.12 | 0.12 | 0.06 | 0.06 | 0.03 | 0.03 | 0.06 | 0.06 | 0.02 | 0.02 |

### *2) Carbon Stock Change in Dead Organic Matter in "Land converted to Wetlands"*

- ***Estimation Method***

➢ ***Carbon stock changes in Dead Organic Matter***

Carbon stock changes in dead organic matter in forest land converted to wetlands were estimated by applying the Tier 2 estimation method as described in section 6.6.2.b)2).

- ***Parameters***

➢ ***Carbon Stocks in Dead Organic Matter***

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Tables 6-9 and 6-10. It is assumed that they become zero immediately after conversion, and are not accumulated after conversion.

- ***Activity Data (Area)***

The area of land that was converted to wetlands during the past 20 years is determined by subtracting the estimated area that was not converted during the past 20 years from the total area of wetlands in those years. The areas are shown in Table 6-38 below.

Table 6-38 Area of land converted to wetlands within the past 20 years

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Wetlands | kha | 28.5 | 24.7 | 27.0 | 21.5 | 19.8 | 20.0 | 19.9 | 19.0 | 18.5 | 18.0 | 16.6 | 13.9 | 13.4 | 11.2 |
| Forest land converted to Wetlands | kha | 20.6 | 17.9 | 19.6 | 15.5 | 14.4 | 14.5 | 14.4 | 13.8 | 13.4 | 13.1 | 12.0 | 10.1 | 9.7 | 8.1 |
| Cropland converted to Wetlands | kha | 1.8 | 1.5 | 1.6 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.0 | 0.9 | 0.8 | 0.7 |
| Rice field | kha | 0.7 | 0.5 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.4 |
| Upland field | kha | 0.8 | 0.7 | 0.7 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 |
| Orchard | kha | 0.3 | 0.3 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Grassland converted to Wetlands | kha | 0.3 | 0.3 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 |
| Settlements converted to Wetlands | kha | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.05 | 0.05 | 0.04 |
| Other land converted to Wetlands | kha | 5.7 | 4.9 | 5.4 | 4.3 | 4.0 | 4.0 | 4.0 | 3.8 | 3.7 | 3.6 | 3.3 | 2.8 | 2.7 | 2.2 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 21% of the total emissions from the land converted to wetlands for year which emissions are calculated.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.6.2.b)1), time-series consistency for this subcategory is basically ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

- ***Correction in accordance with revision of D area***

Since the D area, which is used for estimating the areas of wetlands converted from forest land were recalculated, carbon stock changes in living biomass for all years and dead organic matter after FY2005 in this category were recalculated.

- ***Correction of carbon stocks of annual crops biomass in cropland before conversion***

Since carbon stocks of annual crops biomass in cropland were corrected, living biomass stock losses in

land converted from cropland were estimated. Therefore, carbon stock changes of living biomass in wetlands converted from cropland were recalculated for all years.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

- ***Validity of the Assumption used in the Method of Estimating the Area of Wetlands***

Under the present estimation method, wetlands are assumed to consist of "water surfaces", "rivers" and "canals", as defined in the national land-use classification, and the whole area is estimated by summing the areas covered by these three land types. However, this estimation method may fail to cover the entire wetland area. The validity of the assumption used in the estimation method is now under revision.

- ***Method of Obtaining Data of the Area of Storage Reservoirs***

Storage reservoirs (excluding dams) can be considered as artificial flooded land, but the area they cover are not included in the area of flooded land. Therefore, a method used to obtain data on the area covered by the reservoirs needs to be considered.

- ***Estimation Method of Soil Carbon Stock Change upon "Land-Use Conversion from Other Land to Wetlands"***

The estimation method will be considered when new data and information are obtained.

## 6.9. Settlements (4.E)

Settlements are all developed land, including transportation infrastructure and human habitats, and preclude lands that have been placed in other land-use categories. In settlements, trees existing in urban green areas such as urban parks and special greenery conservation zones absorb carbon.

In FY2018, Japan's settlement area was about 3.87 million ha, equivalent to about 10.2% of the national land. The carbon stock changes in this category was 2,865 kt-$CO_2$ emissions in FY1990, 156 kt-$CO_2$ removals in FY2017, and 27 kt-$CO_2$ removals in FY2018 (excluding 6.6 kt-$CO_2$ eq. of $CH_4$ and $N_2O$ emissions from organic soils drainage activities in settlements converted from other land use categories).

In this section, settlements are divided into two subcategories, "Settlements remaining Settlements (4.E.1.)" and "Land converted to Settlements (4.E.2.)", and described separately in the following subsections.

Carbon pools estimated in settlements are living biomass, dead organic matter and soils. Dead organic matters for several subcategories are included in living biomass stock changes.

Urban green areas included in the activity data are divided into two categories; urban green facilities established as urban parks and others, and special greenery conservation zones for which conservation measures are taken and permanent protection is ensured.

- ***Urban green areas***

・ Urban Green Facilities (urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas by greenery promoting system for private green space, green areas along rivers and erosion control sites, green areas around government buildings and green areas around public rental housing).

・ Special Greenery Conservation Zones

Table 6-39 Emissions and removals in settlements resulting from carbon stock changes

| Gas | Category | Carbon pool | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 4.E. Settlements | Total | kt-$CO_2$ | 2,865 | 1,288 | -447 | -962 | -296 | -384 | -814 | -570 | -443 | -283 | 107 | 196 | -156 | -27 |
| | | Living Biomass | kt-$CO_2$ | 1,875 | 728 | -537 | -928 | -466 | -557 | -843 | -601 | -563 | -406 | -97 | -12 | -239 | -115 |
| | | Dead Wood | kt-$CO_2$ | 826 | 575 | 292 | 230 | 364 | 363 | 261 | 260 | 316 | 315 | 366 | 365 | 276 | 275 |
| | | Litter | kt-$CO_2$ | 384 | 261 | 122 | 91 | 158 | 158 | 109 | 109 | 137 | 137 | 164 | 164 | 121 | 121 |
| | | Mineral soil | kt-$CO_2$ | -270 | -323 | -368 | -394 | -386 | -381 | -372 | -368 | -361 | -355 | -352 | -346 | -339 | -331 |
| | | Organic soil | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 4.E.1. Settlements remaining Settlements | Total | kt-$CO_2$ | -1,386 | -1,666 | -1,879 | -2,041 | -2,052 | -2,040 | -1,994 | -1,960 | -1,910 | -1,785 | -1,665 | -1,586 | -1,512 | -1,424 |
| | | Living Biomass | kt-$CO_2$ | -1,154 | -1,377 | -1,543 | -1,673 | -1,685 | -1,675 | -1,636 | -1,603 | -1,559 | -1,437 | -1,320 | -1,246 | -1,178 | -1,097 |
| | | Dead Wood | kt-$CO_2$ | IE,NE | IE,NE | IE,NE | IE,NE | IE,NE | IE,NE | IE,NE | IE,NE | IE,NE | IE,NE | IE,NE | IE,NE | IE,NE | IE,NE |
| | | Litter | kt-$CO_2$ | -11 | -13 | -15 | -17 | -17 | -17 | -16 | -16 | -16 | -16 | -16 | -15 | -15 | -15 |
| | | Mineral soil | kt-$CO_2$ | -222 | -276 | -321 | -351 | -351 | -348 | -342 | -341 | -335 | -331 | -329 | -324 | -319 | -312 |
| | | Organic soil | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 4.E.2. Land converted to Settlements | Total | kt-$CO_2$ | 4,251 | 2,954 | 1,432 | 1,079 | 1,756 | 1,656 | 1,180 | 1,390 | 1,467 | 1,502 | 1,772 | 1,782 | 1,356 | 1,397 |
| | | Living Biomass | kt-$CO_2$ | 3,029 | 2,104 | 1,006 | 745 | 1,218 | 1,119 | 793 | 1,002 | 996 | 1,031 | 1,223 | 1,234 | 939 | 982 |
| | | Dead Wood | kt-$CO_2$ | 826 | 575 | 292 | 230 | 364 | 363 | 261 | 260 | 316 | 315 | 366 | 365 | 276 | 275 |
| | | Litter | kt-$CO_2$ | 394 | 274 | 138 | 108 | 174 | 175 | 125 | 125 | 153 | 153 | 179 | 179 | 136 | 136 |
| | | Mineral soil | kt-$CO_2$ | -48 | -47 | -47 | -43 | -35 | -33 | -30 | -28 | -25 | -24 | -23 | -21 | -20 | -19 |
| | | Organic soil | kt-$CO_2$ | 65 | 59 | 55 | 49 | 43 | 41 | 39 | 36 | 35 | 33 | 32 | 31 | 29 | 29 |

### 6.9.1. Settlements remaining Settlements (4.E.1)

#### *a) Category Description*

This subcategory deals with carbon stock changes in living biomass, litter of dead organic matter and soils in urban green areas in settlements remaining settlements, which have remained settlements without conversion during the past 20 years. This subcategory is divided into three subparts: “Special Greenery Conservation Zones”, “Urban Green Facilities” and “Other”. In these subparts, carbon stock changes in the “Special Greenery Conservation Zones” and “Urban Green Facilities” are estimated. In addition, carbon stock changes reported in “Revegetation (RV)” activities under Article 3, paragraph 4, of the Kyoto Protocol correspond to those in the “Urban Green Facilities” constructed in and after 1990[8]. However, “Special Greenery Conservation Zones” are not included in the areas of the Revegetation activities. In the CRF tables, “Special Greenery Conservation Zones” are described as “Urban Green Areas not subject to RV”, “Urban Green Facilities” as “Urban Green Areas subject to RV”, and “Other” as “Other than Urban Green Areas”, respectively. Carbon stock changes that are possibly included in the subpart “Other”, such as trees in gardens in personal residences, are reported as “NE” because their activity data are not available. Moreover, with respect to litter and soils, carbon stock changes in urban parks and green areas at ports are reported due to limited availability of parameters. The net removal by this subcategory in FY2018 was 1,424 kt-$CO_2$; this represents an increase of 2.7% over the FY1990 value and a decrease of 5.8% below the FY2017 value.

#### *b) Methodological Issues*

##### *1) Carbon Stock Changes in Living Biomass in “Settlements remaining Settlements”*

- ***Estimation Method***

Due to the differences of characteristics of urban green areas, the Tier 2a method is used for special greenery conservation zones that are communal green areas, and Tier 2b is used for urban green facilities.

The results of field survey on green area in settlements in Japan revealed that the trees have been growing for more than default growth period of 20 years, which are set in the Tier 2a and Tier 2b of the

[8] The “Special Greenery Conservation Zones” are not included in Revegetation because they do not meet its definition.

*2006 IPCC Guidelines*. It was concluded that, for up to 30 year tree, estimating gain of carbon stocks using the same factor as the 0~20 year trees absorption would be possible. Therefore, carbon stock changes in urban green areas younger than 30 years after establishment are estimated in the same way as 0~20 year urban green area.

➢ ***Tier 2a: Special Greenery Conservation Zones***

$$\Delta C_{SSaLB} = \Delta C_{LBaG} - \Delta C_{LBaL}$$

$$\Delta C_{LBaG} = A \times PW \times BI$$

$\Delta C_{SSaLB}$ : Changes in carbon stocks in living biomass in special greenery conservation zones [t-C/yr]

$\Delta C_{LBaG}$ : Gains in carbon stocks due to growth in living biomass in special greenery conservation zones [t-C/yr]

$\Delta C_{LBaL}$ : Losses in carbon stocks due to losses in living biomass in special greenery conservation zones [t-C/yr]. Note: assumed as "0" (zero) in accordance with the *2006 IPCC Guidelines*

$A$ : Area of special greenery conservation zones younger than or equal to 30 years since designation [ha]

$PW$ : Rate of forested area (rate of forested area per park area). Note: assumed as 100%

$BI$ : Growth per crown cover area [t-C/ha crown cover/yr]

➢ ***Tier 2b: Urban Green Facilities***

$$\Delta C_{SSbLB} = \sum_i \left(\Delta C_{LBbG_i} - \Delta C_{LBbL_i}\right)$$

$$\Delta C_{LBbG_i} = \Delta B_{LBbG_i}$$

$$\Delta B_{LBbG_i} = \sum_j NT_{i,j} \times C_{Rate_{i,j}}$$

$\Delta C_{SSbLB}$ : Changes in carbon stocks in living biomass in urban green facilities [t-C/yr]

$\Delta C_{LBbGi}$ : Gains in carbon stocks due to growth in living biomass in urban green facilities *i* [t-C/yr]

$\Delta C_{LBbLi}$ : Losses in carbon stocks due to losses in living biomass in urban green facilities *i* [t-C/yr]. Note: assumed as "0" (zero) in accordance with the *2006 IPCC Guidelines*

$\Delta B_{LBbGi}$ : Annual biomass growth in urban green facilities *i* [t-C/yr)

$C_{Ratei,j}$ : Annual living biomass growth in urban green facility *i* in climate type *j* per tree [t-C/tree/yr) See Table 6-40

$NT_{i,j}$ : Number of trees in urban green facility *i* in climate type *j*

$i$ : Types of urban green facilities (urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas by greenery promoting systems for private green space, green areas along rivers and erosion control sites, green areas around government buildings, or green areas around public rental housing)

$j$ : Climate type (Hokkaido, other than Hokkaido)

● ***Parameters***

➢ ***Tier 2a: Annual rate of living biomass growth per crown cover area (special greenery conservation areas)***

The default value, 2.9 t-C/ha crown cover/yr, indicated in the *2006 IPCC Guidelines* (p. 8.9) is taken for the annual rate of living biomass growth of trees per crown cover area in special greenery conservation zones.

➢ ***Tier 2b: Annual rate of living biomass growth per tree (urban green facilities)***

The following parameters are taken as the annual living biomass growth rates per tree in urban green

facilities.

Table 6-40 Annual biomass growth rate per tree in urban green facilities

| Climate category | | Annual living biomass growth per tree [t-C/tree/yr] | Remarks |
|---|---|---|---|
| Urban green facilities | Hokkaido | (Other than green areas on roads)<br>0.0098<br>(Green areas on roads)<br>0.0103 | Default values 0.0033-0.0142 [t-C/tree/y] provided in the *2006 IPCC Guidelines* (p. 8.10, Table 8.2) and the annual growth rates of living biomass for the trees in Japan (0.0204 for Japanese zelkova, 0.0103 for ginkgo, 0.0095, for bamboo-leaf oak and 0.0122 t-C/tree/yr for camphor tree) are combined with the distribution ratio of tree types in sampled urban parks[9]. For green areas on roads, the distribution ratio of tree species indicated by the surveys in green areas on roads[10] is taken into account. |
| | Areas other than Hokkaido | (Other than green areas on roads)<br>0.0105<br>(Green areas on roads)<br>0.0108 | |

- ***Activity Data***

The areas of settlements remaining settlements in a certain year reported in the CRF tables are estimated by subtracting the cumulative total area of land converted to settlements during the past 20 years in a year subject to estimation from the total area of settlements in the year subject to estimation. Moreover, in the CRF tables, the areas of settlements remaining settlements are reported in three subparts: "Special Greenery Conservation Zones", "Urban Green Facilities" and "Other". Within these subparts, carbon stock changes in trees less than or equal to 30-year growth in "Special Greenery Conservation Zones" and "Urban Green Facilities" are estimated.

Japan assumes trees less than or equal to 30-year growth as those growing in urban green areas less than or equal to 30 years since establishment or designation. With respect to Tier 2a, tree crown areas in the "Special Greenery Conservation Zones" are applied as activity data. Tier 2b applies the number of tall trees planted in the "Urban Green Facilities" as activity data.

Table 6-41 Areas of settlements remaining settlements within the past 20 years

| Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Settlements remaining Settlements | | kha | 2,344.9 | 2,681.2 | 2,900.4 | 3,090.5 | 3,245.3 | 3,288.7 | 3,319.2 | 3,372.6 | 3,404.6 | 3,441.6 | 3,465.3 | 3,486.7 | 3,520.9 | 3,538.1 |
| | Urban green facilities | kha | 89.8 | 107.1 | 121.2 | 131.4 | 131.6 | 130.8 | 127.6 | 125.5 | 122.3 | 114.8 | 107.7 | 102.9 | 98.4 | 92.9 |
| | Special greenery conservation zones | kha | 1.9 | 3.7 | 3.8 | 4.1 | 4.2 | 4.2 | 4.4 | 4.4 | 4.5 | 4.5 | 4.6 | 4.7 | 4.7 | 4.7 |
| | Other | kha | 2,253.3 | 2,570.4 | 2,775.4 | 2,955.0 | 3,109.4 | 3,153.7 | 3,187.1 | 3,242.6 | 3,277.9 | 3,322.3 | 3,352.9 | 3,379.2 | 3,417.8 | 3,440.5 |

- ***Tier 2a: Tree crown areas ("Special Greenery Conservation Zones")***

The tree crown areas of the special greenery conservation zones are calculated by multiplying the area of special greenery conservation zones determined by the Ministry of Land, Infrastructure, Transport and Tourism by the rate of tree crown area, which is assumed to be 100%.

[9] The annual growth rates of living biomass for these trees are calculated by using the growth curve for each tree species, which were developed based on the results of surveys conducted by the National Institute for Land and Infrastructure Management (NILIM) of the MLIT (Matsue et al., 2009) and the average trunk diameter at breast height for each tree species (Parks and Green Spaces Division of the MLIT, 2005), which were determined from the results of surveys in urban parks.

[10] The distribution ratio of tree types is taken from the MLIT(2009), which covered green areas on roads throughout Japan.

Table 6-42 Areas of special greenery conservation zones younger than or equal to 30 years since notification

| Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | | kha | 1.9 | 3.7 | 3.8 | 4.1 | 4.2 | 4.2 | 4.4 | 4.4 | 4.5 | 4.5 | 4.6 | 4.7 | 4.7 | 4.7 |
| | Green space conservation zones | kha | 0.6 | 0.9 | 1.4 | 1.9 | 2.0 | 1.9 | 1.9 | 2.0 | 2.0 | 2.0 | 2.1 | 2.2 | 2.2 | 2.2 |
| | Suburban green space conservation zones | kha | 1.2 | 2.7 | 2.4 | 2.2 | 2.3 | 2.3 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |

➢ ***Tier 2b: Number of tall trees ("Urban Green Facilities")***

The number of tall trees in urban green facilities is calculated according to the same methods that are used for revegetation activities under Article 3, paragraph 4, of the Kyoto Protocol. Brief descriptions of the calculation methods for each urban green facility are stated below. In addition, for a detailed description of these calculation methods see section 11.4.2.7.a. in Chapter 11 in this NIR.

- ***Urban parks, green areas at ports, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around government buildings, and green areas around public rental housing***

The number of tall trees is calculated by (1) calculating the areas falling under this category by multiplying each area by the area ratio of land conversion area for the whole country, and then (2) calculating the number of tall trees in the calculated areas by multiplying each of the areas by the number of tall trees per area. The number of tall trees per area for each urban green facility is shown in the table below.

Table 6-43 Number of tall trees per area

| Item | Unit | Number of tall trees per area | |
|---|---|---|---|
| | | Hokkaido | Areas other than Hokkaido |
| Urban parks | tree/ha | 329.5 | 222.3 |
| Green areas at ports | tree/ha | 329.5 | 222.3 |
| Green areas around sewage treatment facilities | tree/ha | 129.8 | 429.2 |
| Green areas along rivers and erosion control | tree/ha | 1470.8 | 339.0 |
| Green areas around government buildings | tree/ha | 108.8 | 108.8 |
| Green areas around public rental housings | tree/ha | 219.9 | 219.9 |

- ***Green areas on roads***

Activity data (the number of tall trees) in these facilities are calculated by the following procedures.

1. The number of tall trees planted during 30 years after establishing green areas on roads is calculated by using data from the "*Road Tree Planting Status Survey*" which had been implemented in FY1987, FY1992, FY2007 and each corresponding fiscal year during the commitment period,
2. The number of tall trees calculated in Step 1 is multiplied by the ratio of the number of tall trees planted on the roads whose planted area is more than 500 $m^2$,
3. The number of tall trees calculated in Step 2 is multiplied by the area ratio of settlements remaining settlements.

The values of Step 3 become the number of tall trees constituting the activity data on green areas on roads.

- ***Green areas by greenery promoting systems for private green space***

Activity data (the number of tall trees) are available for each facility. Therefore, the total number of tall trees is used as activity data.

### *2) Carbon Stock Changes in litter in "Settlements remaining Settlements"*

In this category carbon stock changes in litter in urban parks and green areas at ports are estimated. Carbon stock changes in dead wood result in "IE" because they are included in carbon stock changes in living biomass. Carbon stock changes in litter in the subcategories other than urban parks and green areas at ports are not estimated due to the difficulties of obtaining such activity data.

- ***Estimation Method***

In accordance with the decision tree provided in the *2006 IPCC Guidelines*, a country-specific method is applied for this estimation. The estimation method is described below.

$$\Delta C_{SSLit} = \sum_i \left( A_i \times L_{it_i} \right)$$

$\Delta C_{SSLit}$ : Carbon stock changes in litter in settlements remaining settlements [t-C/yr]
$A$ : Area of urban parks and green areas at ports in settlements remaining settlements [ha]
$L_{it}$ : Carbon stock change in litter per area in urban parks or green areas at ports [t-C/ha/yr]
$i$ : Type of Urban Green Facilities (urban parks or green areas at ports)

- ***Parameters***

For litter, Japan estimates carbon stock changes only in branches and leaves dropped naturally from tall trees. Carbon stock changes in litter per urban park area is calculated by using annual accumulation of litter per tree (Hokkaido and other prefectures: 0.0006 t-C/tree/yr) based on the results of field surveys in urban parks, and the number of tall trees per area and the ratio of litter moved to off-site due to management including cleaning (54.4%). As a result, carbon stock changes in litter per urban park area have been calculated to 0.0882 t-C/ha/yr for Hokkaido and 0.0594 t-C/ha/yr for other prefectures. In addition, the carbon fraction in litter is assumed to be 0.4 t-C/t-d.m. which is a default value provided in the *2006 IPCC Guidelines* (p. 8.21).

- ***Activity Data***

Activity data on this category are the same as those on living biomass in urban parks and green areas at ports, as described in activity data of "Remaining land: Above-ground biomass, Below-ground biomass" (section 11.5.1.1.f. a) of Chapter 11.

### *3) Carbon Stock Changes in Soils in "Settlements remaining Settlements"*

Urban parks, for which the carbon stock changes in soils per area were determined, and Green areas at ports, whose management practices are similar with those for urban parks, are the subject of estimation. In general, soils in RV land are not organic soils (peat soils and muck soils). Therefore, organic soils are reported as "NO", and only mineral soils are estimated.

- ***Estimation Method***

Carbon stock changes in soils on settlements is estimated based on Tier 2 (Country specific data are used) estimation method.

$$\Delta C_{SSSoils} = \sum_i \left( \Delta C_{Mineral_i} - L_{Organic_i} \right)$$

$$\Delta C_{Mineral_i} = A_i \times \Delta C_{Soil_i}$$

$\Delta C_{SSSoils}$ : Annual carbon stock changes in soils in settlements remaining settlements [t-C/yr]
$\Delta C_{Mineral}$ : Annual carbon stock changes in mineral soils in settlements remaining settlements [t-C/yr]
$L_{Organic}$ : Annual carbon stock changes in organic soils in settlements remaining settlements (=0) [t-C/yr]
$A$ : Area of settlements remaining settlements [ha]
$C_{Soil}$ : Annual carbon stock changes in soils per area of settlements remaining settlements [t-C/ha/yr]
$i$ : Type of Urban Green Facilities (Urban parks and Green areas at ports)

- ***Parameters***

As described in section 11.5.1.1.f. d), carbon stock changes in soils per area of Urban parks and Green areas at port (integrated annual amount change during 0-20 years after establishment is 1.28t-C/ha/yr, integrated annual amount change during 21-30 years after establishment is 1.38t-C/ha/yr) are estimated based on the results of surveys conducted in urban parks which have been established within 30 years (Tonosaki et al., 2013, Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism, 2015). Thus, this value is applicable to Urban parks and Green areas at port which were established within 30 years.

- ***Activity Data***

Activity data on this category are the same as the area of urban parks and green areas at ports, as described in activity data of "Remaining land: Above-ground biomass, Below-ground biomass" (section 11.5.1.1.f. a) of Chapter 11).

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

The default values shown on page 8.10 in the *2006 IPCC Guidelines* were applied to the annual carbon stock changes for trees in special greenery conservation zones. Following the decision tree, the uncertainty was determined ±50% through application of the standard value shown in the *2006 IPCC Guidelines* (page 8.12).

Moreover, the uncertainty estimates for living biomass in special greenery conservation zones apply expert judgment according to the decision tree for activity data.

Meanwhile, the uncertainty estimates for living biomass, dead organic matter and soil in urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas by greenery promoting systems for private green space, green areas along rivers and erosion control sites, green areas around government buildings and green areas around public rental housing are 41%, 61%, 38%.

As a result, the uncertainty estimate was 33% for the entire removal by settlements remaining settlements.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different

between FY1990-2004 and post 2005, as described in section 6.6.2.b)1), time-series consistency for this subcategory is basically ensured.

#### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

#### *e) Category-specific Recalculations*

- ***Correction in accordance with revision of D area***

Areas of deforestation (D area) is used for determining each land use area converted from forest land. Since D area were recalculated, areas of Settlements remaining Settlements and carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years.

See Chapter 10 for impact on trend.

#### *f) Category-specific Planned Improvements*

- ***Growth Rate of Living Biomass per Unit of Greening Area in "Special Greenery Conservation Zones"***

The default values in the *2006 IPCC Guidelines* were applied to the living biomass growth rate per unit of greening area in special greenery conservation zones. However, the growth data needs to be further examined, and parameter that can be finally applied as the growth ratio should be determined. Therefore, based on the characteristics of greening activity, the most appropriate parameters need to be found.

- ***Validity of the Assumption used in the Method of Estimating the Area of Settlements***

The validity of the assumption is under re-examination.

### 6.9.2. Land converted to Settlements (4.E.2)

#### *a) Category Description*

This subcategory deals with the carbon stock changes in lands converted to settlements, which were converted from other land-use categories to settlements within the past 20 years. With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to settlements. However, the area of wetlands converted to settlements and other land converted to settlements cannot be obtained by the current method. Thus, carbon stock changes in these carbon pools were reported as "NO".

The net emissions by this subcategory in FY2018 were 1,397 kt-$CO_2$; this represents a decrease of 67.1% below the FY1990 value and an increase of 3.0% over the FY2017 value. Emissions from land converted to settlements increased from FY1990 to FY1993. After 1993, the emissions have been on a decreasing trend by 2003, and have been fluctuated since 2003 up to now. These trends resulted from annual changes of areas of land-use conversion area from forest land to settlements.

### *b) Methodological Issues*

#### *1) Carbon stock changes in Living Biomass in "Land converted to Settlements"*

- ***Estimation Method***

Carbon stock changes in living biomass in land converted to settlements are estimated by calculating the carbon stock changes before and after conversion and adding annual carbon stock changes in "Land converted to urban green facilities". The carbon stock changes in living biomass before and after conversion are estimated by applying the equation in section 2.3.1.2 in Volume 4 of the *2006 IPCC Guidelines* (multiplying the land area converted from each land use to settlements by the difference between the values of living biomass stock before and after conversion, and by the carbon fraction). Biomass stocks in land converted to urban green areas are increased due to the growth of trees planted after conversion. Hence, carbon stock changes in living biomass in land converted to urban green facilities are estimated by calculating carbon stock changes before and after conversion and adding annual carbon stock changes after conversion that are estimated by applying the Tier 2b method in section 8.2.1.1 in Volume 4 of in the *2006 IPCC Guidelines*.

$$\Delta C_{LSLB} = \sum_I \left\{ A_I \times \left( CR_a \times CF_a - CR_{b_I} \times CF_{bI} \right) \right\} + \sum_i \left( \Delta C_{LS(UG)G_i} - \Delta C_{LS(UG)L_i} \right)$$

$$\Delta C_{LS(UG)G_i} = \Delta B_{LS(UG)G_i}$$

$$\Delta B_{LS(UG)G_i} = \sum_j NT_i \times C_{Rate_{i,j}}$$

| | |
|---|---|
| $\Delta C_{LSLB}$ | : Carbon stock changes in living biomass in land converted to settlements [t-C/yr] |
| $A_I$ | : Area of land converted annually to settlements from land-use type *I* [ha/yr] |
| $CR_a$ | : Carbon reserves immediately following conversion to settlements [t-d.m./ha], default＝0 |
| $CR_{bI}$ | : Biomass dry matter in land-use type *I* immediately before conversion to settlements [t-d.m./ha] |
| $CF_a$ | : Carbon fraction of dry matter after conversion (settlements) [t-C/t-d.m.] |
| $CF_{bI}$ | : Carbon fraction of dry matter in land-use type before conversion [t-C/t-d.m.] |
| $I$ | : Type of land before conversion |
| $\Delta C_{LS(UG)Gi}$ | : Annual carbon stock gain in living biomass in land converted to urban green facility *i* due to growth in living biomass [t-C/yr] |
| $\Delta C_{LS(UG)Li}$ | : Annual carbon stock loss in living biomass due to loss of living biomass [t-C/yr]<br>Note: the averaged ages of estimated trees are less than or equal to 30 years old; therefore, the loss is assumed as "0" (zero) based on the domestic survey and in accordance with the *2006 IPCC Guidelines* |
| $\Delta B_{LS(UG)Gi}$ | : Annual living biomass growth in land converted to urban green facility *i* [t-C/yr] |
| $C_{Rate\ i,j}$ | : Annual living biomass growth in urban green facility *i* in climate type *j* per tree [t-C/tree/yr]<br>See Table 6-40 |
| $NT_{i,j}$ | : Number of trees in urban green facility *i* in climate type *j* |
| $i$ | : Type of urban green area after conversion (urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas by greenery promoting systems for private green space, green areas along rivers and erosion control sites, green areas around government buildings, or green areas around public rental housing) |
| $j$ | : Climate type (Hokkaido, areas other than Hokkaido) |

- ***Parameters***

➢ ***Living biomass stocks for each land-use category***

Tables 6-8a and 6-8b show the living biomass stocks before and after conversion. Carbon stock losses

due to loss of living biomass are assumed as "0" (zero) based on the domestic survey (*Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism (MLIT)*, 2015) and in accordance with the *2006 IPCC Guidelines*, because trees subject to estimation are all younger than or equal to 30 years old. Table 6-40 shows the annual living biomass growth of trees in land converted to urban green areas.

➢ ***Carbon fraction of dry matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

● ***Activity Data***

➢ ***Land Areas converted to Settlements***

With respect to the area of land converted to settlements, only the areas converted to settlements from forest land, cropland and grassland are determined. Since no data is available on the area converted to settlements from wetlands or other land, "IE" was allocated to those land-use categories. Instead, they are reported as "IE" since they are included in "Other land remaining Other land".

It should be noted that the area presented in the CRF "Table 4.E Sectoral background data for land use, land-use change and forestry－Settlements" is not the annually converted area in FY2018 but the sum of annually converted areas during the past 20 years.

- ***Conversion from Forest land***

Areas of forest land converted to settlements were estimated as described in section 6.6.2.b).1).

- ***Conversion from Cropland***

For former rice fields, upland fields, and orchards (according to "*Area Statistics for Cultivated and Commercially Planted Land*"), the areas of land converted to factories, roads, housing, and forest roads are used.

- ***Conversion from Grassland***

Pasture land in land converted to factories, roads, housing, and forest roads in "*Area Statistics for Cultivated and Commercially Planted Land*" and grazed meadow land converted to settlements in "*A Move and Conversion of Cropland"* were subject to this category.

Table 6-44 Area of land converted to settlements (single year)

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Settlements | kha | 39.5 | 33.0 | 21.9 | 14.7 | 16.1 | 15.1 | 12.2 | 12.2 | 14.6 | 16.2 | 17.4 | 17.2 | 14.3 | 18.6 |
| Forest land converted to Settlements | kha | 14.9 | 10.4 | 5.3 | 4.2 | 6.6 | 6.6 | 4.7 | 4.7 | 5.8 | 5.8 | 6.7 | 6.7 | 5.1 | 5.1 |
| Cropland converted to Settlements | kha | 21.4 | 19.5 | 14.5 | 9.2 | 8.2 | 7.2 | 6.3 | 6.4 | 7.5 | 8.8 | 9.0 | 8.9 | 7.8 | 11.6 |
| Rice field converted to Settlements | kha | 13.0 | 12.1 | 9.5 | 6.0 | 5.0 | 4.1 | 3.5 | 3.9 | 4.3 | 5.0 | 5.1 | 5.3 | 4.6 | 7.4 |
| Upland field converted to Settlements | kha | 0.5 | 0.3 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| Orchard converted to Settlements | kha | 12.5 | 11.8 | 9.2 | 5.8 | 4.8 | 4.0 | 3.4 | 3.8 | 4.2 | 5.0 | 5.1 | 5.2 | 4.6 | 7.3 |
| Grassland converted to Settlements | kha | 3.2 | 3.1 | 2.1 | 1.3 | 1.3 | 1.3 | 1.2 | 1.1 | 1.4 | 1.6 | 1.6 | 1.5 | 1.4 | 1.8 |
| Wetlands converted to Settlements | kha | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| Other land converted to settlements | kha | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |

➢ ***Area and number of trees in "Land converted to urban green areas"***

The areas of land converted to urban green areas are calculated by multiplying the whole area of each urban green area by the area ratio of land conversion area for settlements. The number of trees is calculated by multiplying each urban green area converted from other land-use categories by the number

of trees per area. For detailed information regarding these activity data see section 11.4.2.7.a.in Chapter 11 in this NIR.

### *2) Carbon Stock Change in Dead Organic Matter in "Land converted to Settlements"*

In this category carbon stock changes in dead wood and litter in settlements converted from forest land, and those in litter in land converted to urban parks and green areas at ports are estimated.

With respect to dead wood, only the carbon stock change in forest land converted to settlements was estimated. The Tier 2 method was applied to the estimation in accordance with the method for conversion from other land use to cropland in the *2006 IPCC Guidelines*. Carbon stock changes in dead wood in land converted to urban green facilities are reported as "IE" because they are included in living biomass.

In regard to litter, the carbon stock changes in settlements converted from forest land and land converted to urban parks and green areas at ports are estimated. The Tier 2 method is applied to the estimation of the carbon stock changes in settlements converted from forest land in accordance with the method for conversion from other land use to cropland in the *2006 IPCC Guidelines*. Carbon stock changes in litter in land converted to urban parks and green areas at ports are estimated by applying Japan's country-specific estimation method due to the lack of an estimation method in the *2006 IPCC Guidelines*. Carbon stock changes in litter in land converted to urban green areas other than urban parks and green areas at ports are not estimated due to the difficulties of obtaining their activity data.

The area of wetlands converted to settlements and other land converted to settlements cannot be obtained by the current method. Thus, carbon stock changes in these carbon pools were reported as "NO".

- ***Estimation Method***

$$\Delta C_{LS} = \Delta C_{FS} + \Delta C_{LSLit}$$

$\Delta C_{LS}$ : Carbon stock changes in dead organic matter in settlements converted from other land use categories [t-C/yr]

$\Delta C_{FS}$ : Carbon stock changes in dead organic matter in settlements converted from forest land [t-C/yr]

$\Delta C_{LSLit}$ : Carbon stock changes in litter in urban parks and green areas at ports converted from land use categories [t-C/yr]

- ***Carbon stock changes in dead organic matter in "Settlements converted from Forest land"***

Carbon stock changes in dead organic matter in forest land converted to settlements are estimated by using the CENTURY-jfos model. In addition, all carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as $CO_2$ within the year of conversion.

$$\Delta C_{FS} = \sum_i \left\{ \left( C_{after_i} - C_{before_i} \right) \times A \right\}$$

$\Delta C_{FS}$ : Carbon stock changes in dead organic matter in forest land converted to settlements [t-C/yr]

$C_{after,i}$ : Carbon stock in dead wood or litter after conversion [t-C/ha] Note: carbon stocks after conversion are assumed as "0" (zero).

$C_{before,i}$ : Carbon stock in dead wood or litter before conversion [t-C/ha]

$A$ : Area of forest land converted to settlements in a year subject to estimation [ha]

$i$ : Type of dead organic matter (dead wood or litter)

➢ ***Carbon stock changes in litter in "Urban parks and green areas at ports converted from land-use categories other than Forest land"***

$$\Delta C_{LSLit} = \sum_{I,i} \left\{ A_i \times \left( C_{AfterLit_i} - C_{BeforeLit_I} \right) + A_i \times Lit_i \right\}$$

$\Delta C_{LSLit}$ : Carbon stock changes in litter in urban parks and green areas at ports converted from land-use categories [t-C/yr]
$A$ : Area of urban parks or green areas at ports converted from land-use categories for the past year [ha]
$C_{AfterLit,}$ : Carbon stock in litter after conversion [t-C/ha]
$C_{BeforeLit}$ : Carbon stock in litter before conversion [t-C/ha]
$Lit$ : Annual carbon stock changes per area in litter in urban parks or green areas at ports converted from land-use categories [t-C/ha/yr]
$I$ : Land-use type before conversion
$i$ : Type of urban green facilities after conversion (urban parks or green areas at ports)

- ***Parameters***

➢ ***Carbon stocks in dead organic matter in "Forest land converted to Settlements"***

Average carbon stocks in dead wood and litter in forest land before conversion are shown in Tables 6-9 and 6-10. The average carbon stocks in these categories from FY1990 to FY2004 are not estimated; therefore the carbon stocks in FY2005 are substituted for them. In addition, it is assumed that they become zero immediately after conversion, and are not accumulated after conversion.

➢ ***Carbon stocks in litter in "Urban parks and green areas at ports converted from land-use categories other than Forest land"***

When urban parks and green areas at ports are converted from land-use categories other than forest land, litter stocked before conversion does not moved to off-site because the soil ground before conversion, including litter, stays after conversion, or is covered with additional soils by soil dressing. Hence, litter stocked before conversion does not decrease after conversion. In addition, litter stocks scarcely increase immediately after conversion because newly planted trees do not immediately produce litter. Due to these facts, carbon stock changes before and after conversion are regarded as "0" (zero). Litter stocks accumulated in a year after conversion are calculated by the same method with urban parks and green areas at ports in settlements remaining settlements. This is based on the research finding that litter stocks are accumulated in the same way with settlements remaining settlements, namely accumulated by natural drop of fallen leaves and branches from trees in land converted to urban parks and green areas.

- ***Activity Data***

➢ ***Carbon stocks in dead organic matter in "Forest land converted to Settlements"***

The cumulative value of the area of land that was converted from forest land to settlements within the past 20 years was used. For the areas, see Table 6-44.

Table 6-45 Area of land converted to settlements within the past 20 years

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Settlements | kha | 864.1 | 747.8 | 693.6 | 607.5 | 514.7 | 490.3 | 459.8 | 426.4 | 403.4 | 385.4 | 369.7 | 356.3 | 341.1 | 331.9 |
| Forest land converted to Settlements | kha | 284.2 | 281.5 | 261.5 | 218.5 | 161.0 | 152.7 | 140.2 | 126.0 | 118.0 | 112.9 | 109.2 | 107.7 | 105.3 | 103.1 |
| Cropland converted to Settlements | kha | 520.6 | 409.1 | 376.8 | 338.8 | 307.8 | 293.7 | 278.0 | 261.3 | 247.9 | 236.5 | 226.0 | 215.3 | 204.0 | 197.6 |
| Rice field converted to Settlements | kha | 320.9 | 252.1 | 236.6 | 215.2 | 197.6 | 188.7 | 178.9 | 168.3 | 159.3 | 151.8 | 144.8 | 137.2 | 129.1 | 124.4 |
| Upland field converted to Settlements | kha | 137.2 | 110.5 | 101.8 | 91.9 | 83.4 | 79.8 | 75.7 | 71.3 | 68.3 | 65.5 | 63.1 | 60.9 | 58.6 | 57.5 |
| Orchard converted to Settlements | kha | 62.4 | 46.5 | 38.5 | 31.6 | 26.8 | 25.2 | 23.4 | 21.7 | 20.4 | 19.2 | 18.1 | 17.2 | 16.3 | 15.7 |
| Grassland converted to Settlements | kha | 59.3 | 57.2 | 55.3 | 50.3 | 45.9 | 44.0 | 41.7 | 39.2 | 37.5 | 36.0 | 34.5 | 33.2 | 31.9 | 31.2 |
| Wetlands converted to Settlements | kha | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| Other land converted to settlements | kha | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |

➢ ***Carbon stock changes in litter in "Land converted to urban parks and green areas at ports"***

Areas of land converted to urban green areas are calculated in the same manner as the carbon stock changes in living biomass in land converted to urban green areas. They are calculated by multiplying the areas of urban parks and green areas at ports by the area ratio of land conversion area to the settlements, respectively. For detailed information regarding these areas see section 11.5.1.1.f f) in Chapter 11 in this NIR.

### *3) Carbon Stock Change in Soils in "Land converted to Settlements"*

In this category, forest land converted to settlements, urban parks and green areas at ports, the management practices of which were similar with those in urban parks, were subject to estimation.

- ***Estimation Method***

Carbon stock changes in soils in land converted to settlements are estimated based on Tier 2 (Country specific methodology and data are used) estimation method.

$$\Delta C_{LSSoils_{all}} = \Delta C_{FSSoils} + \Delta C_{LSSoils}$$

$\Delta C_{LSSoils\_all}$ : Carbon stock changes in soils in land converted to settlements [t-C/yr]
$\Delta C_{FSSoils}$ : Carbon stock changes in soils in forest land converted to settlements [t-C/yr]
$\Delta C_{LSSoils}$ : Carbon stock changes in urban parks and green areas at ports in settlements converted from other land use [t-C/yr]

$$\Delta C_{LSSoils} = \sum_i \left(\Delta C_{LSMineral_i} - L_{LSOrganic_i}\right)$$

$$\Delta C_{LSMineral_i} = \Delta A_i \times \left(C_{AfterSoil} - C_{BeforeSoil}\right) + A_i \times \Delta C_{Soil_i}$$

$\Delta C_{LSMineral}$ : Annual carbon stock changes in mineral soils in urban parks and green areas at port following land-use conversion [t-C/yr]
$L_{LSOrganic}$ : Annual carbon stock changes in organic soils in urban parks and green areas at port in settlements converted from land use other than from forest land (=0) [t-C/yr]
$\Delta A$ : Area of urban parks and green areas at port converted from other land use within a year [ha/yr]
$C_{AfterSoil}$ : Soil carbon stocks immediately after land-use conversion [t-C/ha]
$C_{BeforeSoil}$ : Soil carbon stocks before land-use conversion [t-C/ha]
$A$ : Area of urban parks and green areas at port converted from other land use [ha]
$\Delta C_{Soil}$ : Annual carbon stock changes in soils per land area of urban parks and green areas at

port following land-use conversion [t-C/ha/yr]

*i* : Type of urban green facilities (urban parks or green areas at ports)

- ***Parameters***

Parameters described in Table 6-11 were applied to estimation of carbon stock changes in mineral soils in forest land converted to settlements. In addition, when urban parks were constructed, soils in the areas before conversion were almost never moved to off-site. In general, these soils stay in the same places after conversion or covered by additional soils. Therefore, carbon stock changes in soils resulting from land conversion did not occur.

The parameters same as for urban parks and green areas at port in settlements remaining settlements were used for estimation of carbon stock changes in mineral soils in urban green facilities converted from other land use.

- ***Activity Data***

➢ ***Forest land converted to settlements***

The values shown in Table 6-45 were applied to forest land converted to settlements.

➢ ***Settlements converted from land use other than forest land***

The activity data of settlements converted from other land use were the same as urban parks and green areas at port described in section 11.5.1.1.f. f) in Chapter 11.

***4) $CO_2$ emissions from organic soils in "Land converted to Settlements"***

- ***Estimation Method***

When land with organic soil is converted to settlements, it is common for the ground to be improved in accordance with the purpose of land use. However, it could not be denied that oxidation of organic soil occurred under construction work, for example, on road in soft ground being conducted on the premise of land subsidence. For $CO_2$ emissions from drainage of organic soils in land converted to settlements, according to the *Wetlands Guidelines*, $CO_2$ emissions from plowing organic soils (on-site emissions) and emissions from water-soluble carbon (off-site emissions) in land converted to settlements are estimated. The estimation equation is the same as 6.6.1b) 2).

- ***Parameters***

For $CO_2$ emissions from organic soils in Settlements converted from other land use categories, since specific default emission factors for settlements have not been provided in the *2006 IPCC Guidelines* and the *Wetlands Guidelines* and country specific factors based on actual condition in Japan is under investigation, it was assumed that settlements converted from other land use would occur mainly from rice fields, $CO_2$ emission factor from organic soil in rice field was applied. (see Section 6.6.1).

- ***Activity data***

The activity data was organic soils area in settlements within 20 years after conversion. The organic soil area obtained from other lands was estimated in the same way as described in section 6.6.1. This area was also used for estimating $CH_4$ and $N_2O$ emissions reported in the CRF "Table 4(II)".

### c) Uncertainties and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of the parameters and activity data for living biomass and dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty estimate was 21% for the entire emission from land converted to settlements.

- ***Time-series consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.6.2.b)1), time-series consistency for this subcategory is basically ensured.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) Category-specific Recalculations

- ***Correction in accordance with revision of D area***

Since the D area, which is used for estimating the areas of Settlements converted from forest land were recalculated, carbon stock changes in living biomass, dead organic matter, carbon stock change in mineral soil and $CO_2$ emissions from organic soils in this category were recalculated for all years.

- ***New estimating for $CH_4$ and $N_2O$ emissions associated with drainage of organic soils in settlements converted from other land use categories***

Since $CO_2$ emissions from organic soil land converted to settlements is estimated in this submission, $CO_2$ emissions from this category were recalculated for all years.

- ***Correction of carbon stocks of annual crops biomass in cropland before conversion***

Since carbon stocks of annual crops biomass in cropland were corrected, living biomass stock losses in land converted from cropland were estimated, and carbon stock changes of living biomass in settlements converted from cropland were recalculated for all years.

See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

- ***Validity of the Assumption used in the Method of Estimating the Area of Settlements***

The areas of forest land converted to settlements are presently assumed as “roads”, “human habitats”, “school reservations”, “parks and green areas”, “road sites”, “environmental facility sites”, “golf courses”, “ski courses” and “other recreation sites” in the national land-use categorization; however, this assumption may fail to cover all the areas. Therefore, the validity of the assumption needs to be re-examined.

## 6.10. Other land (4.F)

Other land consists of land areas that are not included in the other five land-use categories. As concrete examples of other land, the *2006 IPCC Guidelines* indicates bare land, rock, ice, and all land areas that do not fall into any of the five categories. In FY2018, Japan's other land area was about 2.47 million ha, which is equivalent to about 6.5% of the national land. The classification of other land is shown in Table 6-46 below[11].

Table 6-46 Land included in the other land category

| Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other land | | kha | 2,204 | 2,267 | 2,223 | 2,206 | 2,276 | 2,275 | 2,310 | 2,304 | 2,300 | 2,295 | 2,302 | 2,314 | 2,335 | 2,357 |
| | Defense Facility Site | kha | 139 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 139 | 139 | 135 | 135 | 135 |
| | Coast | kha | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 |
| | Northern Territories | kha | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 |
| | Wasteland | kha | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Other | kha | 1,516 | 1,577 | 1,534 | 1,517 | 1,586 | 1,585 | 1,620 | 1,615 | 1,610 | 1,607 | 1,613 | 1,629 | 1,650 | 1,672 |

The emissions from this category in FY2018 were 164 kt-$CO_2$; this represents a decrease of 86.1% below the FY1990 value and a decrease of 0.9% below the FY2017 value.

In this section, other land is divided into two subcategories, "Other land remaining Other land (4.F.1.)" and "Land converted to Other land (4.F.2.)", and describes them separately in the following subsections.

Table 6-47 Emissions and removals resulting from carbon stock changes in other land

| Gas | Category | Carbon pool | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 4.F. Other land | Total | kt-$CO_2$ | 1,180 | 976 | 706 | 189 | 272 | 254 | 317 | 221 | 182 | 190 | 198 | 207 | 165 | 164 |
| | | Living Biomass | kt-$CO_2$ | 782 | 641 | 453 | 102 | 164 | 149 | 235 | 141 | 105 | 116 | 121 | 132 | 99 | 101 |
| | | Dead Wood | kt-$CO_2$ | 205 | 165 | 117 | 18 | 43 | 43 | 30 | 29 | 29 | 29 | 33 | 33 | 28 | 28 |
| | | Litter | kt-$CO_2$ | 98 | 79 | 56 | 8 | 21 | 21 | 14 | 14 | 14 | 14 | 16 | 16 | 14 | 14 |
| | | Mineral soil | kt-$CO_2$ | 95 | 90 | 80 | 61 | 44 | 41 | 38 | 36 | 33 | 30 | 28 | 26 | 25 | 21 |
| | | Organic soil | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 4.F.1. Other land remaining Other land | Total | kt-$CO_2$ | | | | | | | | | | | | | | |
| | | Living Biomass | kt-$CO_2$ | | | | | | | | | | | | | | |
| | | Dead Wood | kt-$CO_2$ | | | | | | | | | | | | | | |
| | | Litter | kt-$CO_2$ | | | | | | | | | | | | | | |
| | | Mineral soil | kt-$CO_2$ | | | | | | | | | | | | | | |
| | | Organic soil | kt-$CO_2$ | | | | | | | | | | | | | | |
| | 4.F.2. Land converted to Other land | Total | kt-$CO_2$ | 1,180 | 976 | 706 | 189 | 272 | 254 | 317 | 221 | 182 | 190 | 198 | 207 | 165 | 164 |
| | | Living Biomass | kt-$CO_2$ | 782 | 641 | 453 | 102 | 164 | 149 | 235 | 141 | 105 | 116 | 121 | 132 | 99 | 101 |
| | | Dead Wood | kt-$CO_2$ | 205 | 165 | 117 | 18 | 43 | 43 | 30 | 29 | 29 | 29 | 33 | 33 | 28 | 28 |
| | | Litter | kt-$CO_2$ | 98 | 79 | 56 | 8 | 21 | 21 | 14 | 14 | 14 | 14 | 16 | 16 | 14 | 14 |
| | | Mineral soil | kt-$CO_2$ | 95 | 90 | 80 | 61 | 44 | 41 | 38 | 36 | 33 | 30 | 28 | 26 | 25 | 21 |
| | | Organic soil | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

### 6.10.1. Other land remaining Other land (4.F.1)

#### *a) Category Description*

This subcategory deals with carbon stock changes in other land remaining other land during the past 20 years. The land area of this subcategory is determined by subtracting the summed areas of the other five land-use categories from the total national land area shown in the *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan* compiled by the Geospatial Information Authority of Japan. However, carbon stock changes in this subcategory are not considered in accordance with the *2006 IPCC Guidelines*.

[11] The *Defense of Japan* (Ministry of Defense) for "Defense Facility Site", the *Digital national land information* (MLIT) for "Coast" and *Land Survey of Prefectures, Shi, Ku, Machi and Mura* (GSI) for "Northern Territories"

Table 6-48 Areas of other land remaining other land within the past 20 years

| Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other land remaining Other land | kha | 2,287.7 | 2,344.8 | 2,299.0 | 2,198.1 | 2,289.9 | 2,271.5 | 2,310.3 | 2,307.2 | 2,098.4 | 2,146.6 | 2,367.3 | 2,502.3 | 2,417.6 | 2,398.3 |

### *b) Category-specific Recalculations*

There have been no source-specific recalculations

### *c) Category-specific Planned Improvements*

There have been no source-specific recalculations.

## 6.10.2. Land converted to Other land (4.F.2)

### *a) Category Description*

This subcategory deals with carbon stock changes in the land converted to other land within the past 20 years. The land area of this subcategory includes land converted for soil and stone mining, land damaged by natural disasters. “The land used for soil and stone mining activities” is the land which is artificially disturbed and the soil carbon in surface layer are removed and are considered not exist. Therefore, this categorization also takes the consistency of statistical division into consideration. By reading from satellite images to detect the land conversion, “the land used for soil and stone mining activities” is allocated under “Other land”.

The emissions from this subcategory in FY2018 were 164 kt-$CO_2$. This represents a decrease of 86.1% below the FY1990 value and a decrease of 0.9% below the FY2017 value.

With respect to living biomass, its carbon stock change as a result of land use conversion from forest land, cropland and grassland to other land were estimated.

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to other land. Carbon stock changes in dead organic matter in other subcategories (conversion from cropland and grassland) were reported as “NA”, since dead organic matter pools before and after conversion were assumed to be zero, as described in section 6.6.2.b)2) and 6.7.2.b)2).

With respect to carbon stock changes in soils, carbon stock changes in soils in forest land converted to other land are estimated. Carbon stock changes in soils in cropland and grassland converted to other land are reported as “NA” because it is assumed that the pools of soils before and after conversion are the same.

In addition, the area of wetlands converted to other land and settlements converted to other land cannot be obtained by the current method. Thus, carbon stock changes in these carbon pools were reported as “NO”.

### *b) Methodological Issues*

#### *1) Carbon stock change in Living Biomass in “Land converted to Other land”*

- ***Estimation Method***

The Tier 2 method was applied as described in section 6.6.2.b)1). Carbon stock changes due to biomass growth in other land were assumed as zero.

- ***Parameters***

➢ ***Biomass stock in each Land-Use Category***

The values shown in Tables 6-8a and 6-8b are used for the estimation of biomass stock changes upon land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

➢ ***Carbon Fraction of dry matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with *the 2006 IPCC Guidelines*.

- ***Activity Data (Area)***

Only the areas converted from forest land and cropland to other land are determined. Since no data were available on the area converted from wetlands and settlements to other land, estimations for those land-use categories could not be made. Instead, they are reported as "IE" since they are included in "Other land remaining Other land".

It should be noted that the area presented in the CRF "Table 4.F Sectoral background data for land use, land-use change and forestry－Other land" is not the annually converted area in FY2018 but the sum of annually converted areas during the past 20 years.

➢ ***Conversion from Forest Land***

See section 6.6.2.b)1).

➢ ***Conversion from Cropland***

For former rice fields, upland fields, and orchards, the area classified as "other, natural disaster damage" is used according to *the Area Statistics for Cultivated and Commercially Planted Land*.

➢ ***Conversion from Grassland***

For former pasture land and grazed meadow land, the area of former pasture land classified as "other, natural disaster damage" (according to *the Area Statistics for Cultivated and Commercially Planted Land*) and the area of former grazed meadow land which is classified as "other, classification unknown" (*the Move and Conversion of Cropland*) are used.

Table 6-49 Area of land converted to other land (single year)

| Category | | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Other land | | | kha | 6.2 | 6.1 | 4.3 | 5.0 | 2.2 | 1.8 | 18.2 | 3.1 | 1.5 | 2.8 | 2.0 | 3.5 | 1.2 | 1.4 |
| | Forest land converted to Other land | | kha | 3.7 | 3.0 | 2.1 | 0.3 | 0.8 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.6 | 0.5 | 0.5 |
| | Cropland converted to Other land | | kha | 2.2 | 2.6 | 2.0 | 4.5 | 1.2 | 0.9 | 16.8 | 2.3 | 0.8 | 2.0 | 1.2 | 2.7 | 0.6 | 0.8 |
| | | Rice field | kha | 1.2 | 1.5 | 1.6 | 4.2 | 0.8 | 0.6 | 14.9 | 1.7 | 0.3 | 1.3 | 0.8 | 2.3 | 0.3 | 0.5 |
| | | Upland field | kha | 0.7 | 0.9 | 0.3 | 0.2 | 0.4 | 0.2 | 1.6 | 0.5 | 0.4 | 0.5 | 0.4 | 0.4 | 0.2 | 0.3 |
| | | Orchard | kha | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | Grassland converted to Other land | | kha | 0.4 | 0.5 | 0.2 | 0.2 | 0.2 | 0.1 | 0.8 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 |
| | Wetlands converted to Other land | | kha | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Settlements converted to Other land | | kha | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |

### *2) Carbon Stock Changes in Dead Organic Matter in "Land converted to Other land"*

- ***Estimation Method***

Carbon stock changes in dead organic matter in forest land converted to other land were estimated by applying the Tier 2 estimation method as described in section 6.6.2.b)2).

- ***Parameters***

➢ ***Carbon Stocks in Dead Organic Matter in "Other Land converted from Forest Land"***

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Tables 6-9 and 6-10. It is assumed that carbon stocks become zero immediately after conversion, and are not accumulated after conversion.

- ***Activity Data (Area)***

The values of annually converted area from each land-use category to other land during the past 20 years are summed up to obtain the total area that is converted to other land during the same time period.

Table 6-50 Area of land converted to other land within the past 20 years

| Category | | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land converted to Other land | | | kha | 173.4 | 150.3 | 130.3 | 110.9 | 90.1 | 85.7 | 97.9 | 96.0 | 90.1 | 85.7 | 81.6 | 80.4 | 76.4 | 73.7 |
| | Forest land converted to Other land | | kha | 102.4 | 97.2 | 86.2 | 65.4 | 47.1 | 44.2 | 40.6 | 37.8 | 34.3 | 31.3 | 28.9 | 26.8 | 23.5 | 21.3 |
| | Cropland converted to Other land | | kha | 55.8 | 41.1 | 36.9 | 38.3 | 36.3 | 35.1 | 50.5 | 51.5 | 49.7 | 48.8 | 47.4 | 48.6 | 47.9 | 47.5 |
| | | Rice field | kha | 32.4 | 20.9 | 20.3 | 22.8 | 23.2 | 22.6 | 36.9 | 38.1 | 37.1 | 36.8 | 36.1 | 37.9 | 37.4 | 37.1 |
| | | Upland field | kha | 16.1 | 14.2 | 12.0 | 11.5 | 10.0 | 9.5 | 10.4 | 10.3 | 9.7 | 9.4 | 8.8 | 8.4 | 8.3 | 8.2 |
| | | Orchard | kha | 7.3 | 5.9 | 4.5 | 4.0 | 3.2 | 3.0 | 3.2 | 3.1 | 2.9 | 2.7 | 2.5 | 2.3 | 2.3 | 2.2 |
| | Grassland converted to Other land | | kha | 15.1 | 12.0 | 7.3 | 7.3 | 6.6 | 6.3 | 6.8 | 6.7 | 6.0 | 5.6 | 5.3 | 5.1 | 5.0 | 4.9 |
| | Wetlands converted to Other land | | kha | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Settlements converted to Other land | | kha | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |

### *3) Carbon Stock Changes in Soils in "Land converted to Other land"*

In this category, carbon stock changes in mineral soils in forest land converted to other land were estimated.

- ***Estimation Method***

Carbon stock changes in mineral soils in this category were estimated as same as section 6.6.2.b)3.

- ***Parameters***

The parameters described in Table 6-11 were applied to estimating the carbon stock changes in mineral soils in forest land converted to other land.

- ***Activity Data (Area)***

The areas of forest land converted to other land within 20 years were calculated by summing the annually converted areas during the past 20 years. The areas were shown in Table 6-50.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

The uncertainties of the parameters and the activity data for living biomass and dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 19% for the entire emission from the land converted to other land.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.6.2.b)1), the time-series consistency for this subcategory is basically ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

- ***Correction in accordance with revision of D area***

Since the D area, which is used for estimating the areas of Other land converted from forest were recalculated, carbon stock changes in living biomass, dead organic matter and carbon stock change in mineral soils in this category were recalculated for all years.

- ***Correction of carbon stocks of annual crops biomass in cropland before conversion***

Since carbon stocks of annual crops biomass in cropland were corrected, living biomass stock losses in land converted from cropland were estimated, and carbon stock changes of living biomass in other land converted from cropland were recalculated for all years.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

- ***Breakdown Analysis of Other Land and Reclassification into Other Land-Use Categories***

A further breakdown analysis of the other land is required, since it may still include some areas that are supposed to be classified into other land-use categories even after the reallocation carried out in this year.

- ***Carbon Stock Changes in Living Biomass in "Land converted to Other Land"***

The carbon stock changes in living biomass in land converted to other land were assumed to be zero because of a lack of reference information for other land. However, this assumption may differ from the actual situation. Therefore, the methods used to quantify the carbon stock are being examined.

- ***Estimation Method of Soil Carbon Stock Changes in "Forest land, Cropland and Grassland converted to Other Land"***

The estimation method will be considered when new data and information are obtained.

## 6.11. Harvested Wood Products (4.G)

Harvested Wood Products (HWP) that have been removed from forest through harvest, store these carbon substances while HWP has been used, such as housing materials and furniture. Eventually, $CO_2$ are emitted when it is discarded due to incineration or decayed.

This category deals with annual carbon stock changes in the HWP pool. The production approach is applied to the estimation. Methodologies according to Land Use, Land-Use Change and Forestry (LULUCF) reporting rules in the Kyoto Protocol is also applied to reporting of LULUCF under the Convention. Therefore, the HWP (such as sawn-wood, wooden board, plywood and, paper and paperboard) that are produced from domestic HWP from "ikusei-rin forest", which forest management practices are implemented in forest land, is subject to estimation. The changes in carbon stock associated with use or disposal are estimated. The carbon stock changes in the HWP for imports were deducted

from the estimation. Also, the carbon stock changes in the HWP from deforestation land were accounted for on the basis of instantaneous oxidation and they were not estimated as HWP. The net removal (carbon stock changes) from this subcategory in FY2018 were 2,046 kt-$CO_2$; this represents an increase of 453.1% over the FY1990 value and an increase of 15.1% over the FY2017 value.

The main reasons for the removal fluctuation since FY1990 in the category were due to economic situation and effects of disaster.

In this section, the HWP is divided into three subcategories: “buildings”, “wood used for other than buildings” and “paper and paperboard”, these subcategories are described separately in the following subsections.

Table 6-51 $CO_2$ emissions and removals associated with carbon stock change in HWP pools

| Gas | Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | Total | | kt-$CO_2$ | -370 | 1,475 | 1,821 | 621 | 642 | 50 | 2,461 | 62 | 321 | -843 | -1,230 | -1,200 | -1,777 | -2,046 |
| | Buildings | Total | kt-$CO_2$ | -476 | -853 | -3 | -845 | -1,591 | -1,575 | 873 | -1,508 | -799 | -1,391 | -1,752 | -1,611 | -1,660 | -1,896 |
| | | Sawnwood | kt-$CO_2$ | -257 | -535 | 416 | -358 | -930 | -830 | 1,623 | -761 | 34 | -567 | -873 | -667 | -750 | -992 |
| | | Wooden board | kt-$CO_2$ | -209 | -324 | -435 | -377 | -317 | -330 | -386 | -314 | -312 | -372 | -357 | -395 | -394 | -396 |
| | | Plywood | kt-$CO_2$ | -11 | 6 | 17 | -109 | -344 | -414 | -364 | -432 | -521 | -452 | -522 | -549 | -516 | -509 |
| | Wood used for other than building | Total | kt-$CO_2$ | 639 | 1,155 | 1,395 | 1,257 | 1,173 | 989 | 942 | 898 | 746 | 507 | 345 | 124 | -198 | -284 |
| | | Sawnwood | kt-$CO_2$ | 954 | 1,295 | 1,478 | 1,485 | 1,481 | 1,421 | 1,227 | 1,313 | 1,235 | 1,171 | 1,095 | 1,089 | 1,055 | 960 |
| | | Wooden board | kt-$CO_2$ | -326 | -219 | -198 | -132 | 40 | 24 | 4 | -98 | -112 | -96 | -87 | -116 | -119 | -94 |
| | | Plywood | kt-$CO_2$ | 11 | 80 | 115 | -96 | -348 | -457 | -289 | -317 | -377 | -567 | -663 | -850 | -1,134 | -1,149 |
| | Paper and paperboard | | kt-$CO_2$ | -533 | 1,173 | 429 | 208 | 1,059 | 636 | 646 | 672 | 374 | 41 | 177 | 287 | 80 | 134 |

### 6.11.1. Buildings

#### *a) Category Description*

This category deals with annual change in carbon stock in sawnwood, wooden board, and plywood used in buildings. The net removal (carbon stock changes) from this subcategory in FY 2018 were 1,896 kt-$CO_2$; this represents an increase of 298.0% over the FY1990 value and an increase of 14.2% over the FY2017 value.

#### *b) Methodological Issues*

- ***Estimation Method***

Since sawn-wood, wooden board, and plywood are mainly used for buildings and their statistics related to the buildings have been compiled with a certain accuracy in Japan, the carbon stock changes in these pools are estimated by using country-specific stock inventory method (Tier 3). Carbon stock changes in sawn-wood, wooden board, and plywood that are used when buildings are constructed are recorded as inflow and released carbon when the buildings are demolished are recorded as outflow. The net carbon stock changes were estimated by summing inflow and outflow calculated separately. It means that the all carbon used in the buildings are immediately oxidized when the buildings are demolished. The estimation equation is as follows:

Sawn-wood, wooden board and plywood used in the buildings are reported in “Sawnwood”, “Wood panels”, and “Other solid wood products” under “Solid wood” in the CRF tables, respectively.

$$\Delta C_{j,i} = Inflow_{j,i} - Outflow_{j,i}$$

$j$ : Subcategories (sawnwood, wooden board, plywood)

$i$ : Year

$Inflow_{j,i}$ : Inflow to the HWP pools of subcategory j during year i [t-C/year]

$Outflow_{j,i}$ : Outflow from the HWP pools of subcategory j during year i [t-C/year]

$\Delta C_{j,i}$ : Carbon stock change in the HWP pools of subcategory j during year i [t-C/year]

Regarding the carbon stock (inflow) in sawnwood, wooden board, and plywood that are used when buildings are constructed, and released carbon (outflow) when the buildings are demolished, were calculated by the following equations.

- ***Inflow***

As for the inflow, the calculation steps are as follows. First, the total amount of domestic wood used for buildings was estimated by multiplying constructed floor area, amount of wood used per unit constructed floor area (hereafter constructed unit), rate of domestic logs to total logs used for construction. Second, the carbon content of wood input to building (Inflow) was calculated by multiplying amount of domestic wood input to building, by density of wood and carbon fraction (See estimation equation below).

$$Inflow_{j,i} = \left\{ S_{P_{st,i}} \times v_{DP_{j,st,i}} \times f_{DP_{j,i}} - V_{IM_i} \right\} \times D_j \times CF_j$$

- ***Outflow***

As for the outflow, the calculation steps are as follows. First, amount of domestic wood used for the building demolished was estimated by multiplying floor area of building demolished, by amount of wood input per unit floor area in the year in which the demolished buildings were constructed, rate of domestic logs for demolished building. Second, the amount of domestic wood input into the building demolished was calculated by subtracting the amount of wood in imported houses, from amount of domestic wood used for building demolished. Third, carbon content from HWP (outflow) was calculated by multiplying amount of domestic wood input of the building demolished, by density of wood and carbon fraction (See estimation equation below).

Note that decay function as referred to in the *2019 Refinements* was not applied for calculating the outflow and the outflow is obtained directly from the amount of building demolished in Japan.

$$Outflow_{j,i} = \left\{ S_{W_{st,i}} \times v_{DW_{j,st,i}} \times f_{DW_{j,i}} - V_{IM_i} \right\} \times D_j \times CF_j$$

Since the amount of wood used per unit floor area and the rate of domestic logs for demolished building change over time, to reflect the changes over time, the amount of wood input per unit floor area in the demolished building ($v_{DW_{j,st,i}}$) and rate of domestic log for demolished building ($f_{DW\,j,i}$) were calculated by using proportion of the floor area built in n years of the demolished floor area in i year to the area demolished in i year respectively (see estimation equation below).

$$v_{DW\,i} = \sum_n \left( \frac{S_{w\,i\,(n)}}{S_{w\,i}} \times v_{DP\,i\,(n)} \right)$$

$$f_{DW\,i} = \sum_n \left( \frac{S_{w\,i\,(n)}}{S_{w\,i}} \times f_{DP\,i\,(n)} \right)$$

In addition, floor area demolished in i year ($S_{W\,i}$) are calculated by subtracting the difference between the floor area stock in i year and constructed floor area in i-1 year, from floor area stock in i-1 year (see estimation equation below). Since the floor area data of the buildings demolished after extension were reflected in the floor area stock for i-1 and i year and constructed floor area respectively. Also, the floor area of building demolished includes the floor area of buildings that has been demolished after extension.

However, the renovated building without increase or decrease in floor area was not included in the calculating for "Building (Tier3)". The demolished renovation area is reflected in "Wood used for other than buildings (Tier 2)" calculation.

$$S_{W_{St,i}} = S_{S_{st,i-1}} - \left(S_{S_{st,i}} - S_{P_{st,i}}\right)$$

| | |
|---|---|
| $j$ | : Subcategories (sawnwood, wooden board, plywood) |
| $i$ | : Year |
| $st$ | : Uses and structure type of buildings (residential or nonresidential) |
| $n$ | : Year of construction |
| $Inflow_{j,i}$ | : Annual carbon inflow to the HWP pools of subcategory j during year i [t-C/year] |
| $Outflow_{j,i}$ | : Outflow from the HWP pools of subcategory j during year i [t-C/year] |
| $S_{P\ st,i}$ | : Constructed floor area by uses (residential or nonresidential) and by structure type during year i including extension area [$m^2$/year] |
| $S_{W\ st,i}$ | : Floor area of demolished by uses (residential or nonresidential) and by structure including demolished area after extension [$m^2$/year] |
| $S_{W\ i,(n)}$ | : Floor area of the building constructed in year n out of the floor area of the building demolished in year i [$m^2$] |
| $S_{S\ st,i}$ | : Floor area stock by use (residential or nonresidential building) and by structure in each year including constructed floor area in i year and extension area [$m^2$/year] |
| $v_{DP\ j,st,i}$ | : Wood input amount per unit floor area of subcategory j [$m^3/m^2$] |
| $v_{DP\ i,(n)}$ | : Wood input amount per unit floor area of the building constructed in year n out of the wood input amount per unit floor area of building demolished in year i [$m^3/m^2$] |
| $v_{DW\ i}$ | : Wood input per unit floor area in the year in which the demolished buildings were constructed [$m^3/m^2$] |
| $f_{DP\ j,i}$ | : Rate of domestic logs to total logs used for construction of subcategory j in each year [%] |
| $f_{DP\ i\ (n)}$ | : Rate of domestic logs used in building constructed in year n out of the rate of domestic logs used in building demolished in year i [%] |
| $f_{DW\ i}$ | : Rate of domestic logs for demolished building of subcategory j in each year [%] |
| $V_{IM\ i}$ | : Amount of wood used for imported houses in each year [$m^3$] |
| $D_j$ | : Density of subcategory j [t-d.m./$m^3$] |
| $CF_j$ | : Carbon fraction of subcategory j [t-C/t-d.m.] |

- ***Parameters***

➢ ***Wood input per unit floor area ($m^3/m^2$)***

- ***Sawnwood***

As for wooden residential building, amount of wood per unit floor area from FY1991 to FY2011 were identified by *Survey on Actual Demand of Construction Labor and Materials* (MLIT). As for non-wood residential building, the values of FY2013 are obtained from the survey which was implemented newly because only data until FY1991 in the *Survey on Actual Demand of Construction Labor and Materials* (MLIT) above was available. The same values of FY 2013 were applied from FY2014 onwards. The values of FY1992 to FY2012 were calculated by linear interpolation.

- ***Wooden board***

The amount of wooden board by types and uses was calculated by multiplying the ratio of the amount

of shipped wooden board by uses to total shipment, by the types in *Yearbook of Current Production Statistics, Mineral Resources and Petroleum Products, Ceramics and building materials Statistics* (METI). The wood input per unit area were estimated by dividing the amount of wood calculated above, by the floor areas of constructed buildings.

- ***Plywood***

The values obtained from the *Survey on Actual Demand of Construction Labor and Materials* (MLIT) were applied. As for the years that data are missing, the values were calculated by linear interpolation.

➢ ***Rate of domestic logs***

- ***Sawnwood***

The rate of domestic logs for sawnwood by conifer and non-conifer was calculated by dividing shipment quantity of domestic sawnwood for buildings, by the total amount of shipment quantity of sawnwood for buildings and imported sawnwood.

- ***Wooden board***

Amount of shipped wooden board (domestic logs) for buildings by raw material were calculated by multiplying proportion of raw materials in particle board and fiberboard, and the ratio of domestic logs for each raw material (logs, wood residue in mills and forestry practices and scrap wood). The ratio of domestic logs for each raw material were estimated from production of domestic wood chips, imported wood chips, and quantity of arrival logs for wood chips (domestic logs and imported logs). The ratio of domestic logs for each wooden board type were estimated by dividing the amount of shipped wooden board (domestic logs) above, by the sum of the amount of shipped wooden board for buildings and amount of imported wooden board for buildings.

- ***Plywood***

The ratio of domestic logs for plywood constructed buildings was calculated by multiplying ratio of production of plywood to the sum of plywood production and imports, by the ratio of domestic logs for plywood.

➢ ***Density and Carbon fraction***

The default values (Table 2.8.1) described in the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (hereafter *KP Supplement*) were applied.

Table 6-52 Default values of density and carbon fraction for the HWP categories

| HWP categories | | Density [Mg/m$^3$] | Carbon fraction [Mg-C/Mg-d. m.] |
|---|---|---|---|
| Sawnwood | Coniferous sawnwood | 0.45 | 0.5 |
| | Non-coniferous sawnwood | 0.56 | 0.5 |
| Wood panels (wooden board) | Particle board (PB) | 0.596 | 0.451 |
| | Hardboard (HDF) | 0.788 | 0.425 |
| | Medium-density fireboard (MDF) | 0.691 | 0.427 |
| | Insulating board (other board, low density fiber) | 0.159 | 0.474 |
| Wood panels (plywood) | | 0.542 | 0.493 |

Reference: the *KP Supplement*, Table 2.8.1)

Table 6-53 Data used for parameters (Buildings)

| | Variable | Reference | Note |
|---|---|---|---|
| 1 | Shipment quantity of sawlogs (for building) (domestic logs) | *Report on Supply and Demand of Lumber* (MAFF) | |
| 2 | Shipment quantity of sawlogs (for building) (imported logs) | *Report on Supply and Demand of Lumber* (MAFF) | |
| 3 | Received quantity of logs for sawlogs | *Report on Supply and Demand of Lumber (the Survey on Lumber)* (MAFF) | |
| 4 | Imports of lumber (coniferous tree) | *Trade Statistics of Japan* (MOF) | Softwood (coniferous tree) is assumed as building materials because imports for building structures cannot be obtained in the statistics. |
| 5 | Shipment quantity of wooden board | *Yearbook of Current Production Statistics, Mineral Resources and Petroleum Products, Ceramics and building materials Statistics* (METI) | Including own-use |
| 6 | Imports of wooden board | *Trade Statistics of Japan* (MOF) | |
| 7 | Imported wood chips | *Trade Statistics of Japan* (MOF) | |
| 8 | Production of domestic wood chips | *Report on Supply and Demand of Lumber* (MAFF) | |
| 9 | Quantity of arrival logs for wood chips (domestic logs) | *Report on Supply and Demand of Lumber* (MAFF) | |
| 10 | Quantity of arrival of logs for wood chips (imported logs) | *Report on Supply and Demand of Lumber* (MAFF) | |
| 11 | Shipment quantity of wooden board by use | *Shipments of wood-based board production* by Japan Fiberboard and Particleboard Manufacturers Association | |
| 12 | Production of plywood | *Report on Supply and Demand of Lumber* (MAFF) | |
| 13 | Imports of veneer for plywood | *Trade Statistics of Japan* (MOF) | Calculated by multiplying rate of veneer for plywood to imports of veneer, by imports of veneer obtained from FAOSTAT |
| 14 | Imports of plywood | *FAOSTAT* (FAO)<br>*Trade Statistics of Japan* (MOF) | Calculated by subtracting bonded wood and bamboo of plywood by *Trade Statistics of Japan* from bonded wood by *FAOSTAT* |
| 15 | Received quantity of logs for plywood (domestic logs) | *Report on Supply and Demand of Lumber* (MAFF) | |
| 16 | Received quantity of logs for plywood (imported logs) | *Report on Supply and Demand of Lumber* (MAFF) | |

MIC: Ministry of Internal Affairs and Communications; METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

- ***Activity Data***

Activity data were floor area of construction (inflow) and demolition (outflow). Floor area of construction by uses (residential or nonresidential) and by structures in *Construction Statistics for Housing* and *Construction Statistics for Building* by MLIT was applied, and floor area stock in *Fixed Property Tax Division, Local Tax Bureau (Houses)* by MIC was applied. The floor area of demolition was calculated by subtracting the difference between the floor area stock in i year and constructed floor area in i-1 year, from floor area stock in i-1 year. The floor area of building demolished includes the floor area of buildings that has been demolished after extension. These values were based on statistics, and this method considered economic recessions and natural disasters.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

The uncertainties of carbon stock changes of buildings were assessed based on the uncertainties of the

default factors provided in the *KP Supplement* and the uncertainties of exiting statistical data. The uncertainty was estimated as 30% for the carbon stock changes in buildings.

- ***Time-series Consistency***

Since wood input per unit area were obtained from the *Survey on Actual Demand of Construction Labor and Materials* by the MLIT which is implemented every three years, the data for missing years were calculated by interpolation by means of linear expression. The time-series consistency for this subcategory is ensured.

#### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

#### *e) Category-specific Recalculations*

With update of wood supply and demand statistics for FY2017, carbon stock changes for FY2017 were recalculated. The outflow values were also recalculated for all years due to the correction of the equation for calculating the domestic wood rate in demolition materials and input amount of demolition material per unit area. According to the change of the domestic wood rate in demolition materials, the inflow values of wood boards were also recalculated for all years.

See Chapter 10 for impact on trend.

#### *f) Category-specific Planned Improvements*

Due to increasing use of wood for building material caused by the revision of Building Code Act and spread of Cross Laminated Timber (CLT), there is a possibility that the wood input per unit area will be changed in the future.

### 6.11.2. Wood used for other than buildings

#### *a) Category Description*

This category deals with carbon stock changes in sawnwood, wooden board, and plywood used in other than buildings. The net emissions from this subcategory in the FY1990 were 639 kt-$CO_2$; the net removals (carbon stock changes) from this subcategory in FY2017 were 198 kt-$CO_2$; the net removals in FY2018 were 284 kt-$CO_2$.

#### *b) Methodological Issues*

- ***Estimation Method***

The carbon stock change in the HWP pool of this category were estimated from the difference between the HWP pool in reference year and prior year by using the Tier 2 method by the first-order decay (FOD) function described in the *KP Supplement.* Inflow to the HWP pool during one year were estimated by multiplying amount of wood used in other than buildings, rate of domestic logs of each subcategory (sawnwood, wooden board and plywood), by carbon conversion factor. The estimation equations are as follows.

In the CRF tables, “Sawnwood” are reported as “Sawnwood for non-buildings”, “Wooden board” as

"Wooden board for non-buildings", and "Plywood" as "Plywood for non-buildings" under "Other (please specify)", respectively.

$$C_{j,i+1} = e^{-k_j} \times C_{j,i} + \left[\frac{\left(1 - e^{-k_j}\right)}{k_j}\right] \times Inflow_{j,i}$$

$$\Delta C_{j,i} = C_{j,i+1} - C_{j,i}$$

$i$ : Year
$j$ : Subcategories (sawnwood, wooden board and plywood)
$C_{j,i}$ : Carbon stock of the HWP pool in the beginning of year i [t-C]
$Inflow_{j,i}$ : Inflow to the HWP pool during year i [t-C/year]
$k_j$ : Decay constant of FOD for each HWP category, $k_j = \ln(2) / HLj$
HL$j$: half-life of the HWP pool in years
$\Delta C_{j,i}$ : Carbon stock change in the HWP category during year $i$ [t-C/year]
$C_{j,(1900)}$ : Carbon stock in 1900 was assumed to be zero

$$Inflow_{j,i} = V_{p\ j,i} \times f_{DPj,i} \times D_j \times CF_j$$

$i$ : Year
$j$ : Subcategories (sawnwood, wooden board and plywood)
$V_{Pj,i}$ : Amount of wood used in other than buildings [$m^3$/year]
$f_{DPj,i}$ : Rate of domestic logs used in other than buildings during year i [%]
$D_j$ : Density [t-d.m./$m^3$]
$CF_j$ : Carbon fraction [t-C/t-d.m]

- ***Parameters***

➢ ***Rate of domestic logs***

- ***Sawnwood***

The ratio of domestic logs for sawnwood used for other than buildings were calculated by dividing the amount of shipped sawnwood from domestic logs by tree species, by the amount of shipment.

- ***Wooden board***

The ratio of domestic logs for wooden board production were estimated by multiplying proportion of raw materials used for practical board and fiber board, by the ratio of domestic logs for each raw material (logs, wood residue in mills and forestry practices, and scrap wood). The rate of domestic logs for each raw material were estimated from production of domestic wood chips, imported wood chips, and quantity of arrival logs for wood chips (domestic logs and imported logs).

- ***Plywood***

The ratio of domestic logs in plywood used for other than buildings, were calculated by dividing the amount of received materials from domestic logs for plywood for other than buildings by sum of the amount of received materials for plywood and imported veneers for plywood (converted to roundwood).

➢ ***Default Half-lives***

The default half-lives (sawnwood: 35 year, wood panels: 25 year) described in *the KP Supplement* were

applied (Table 2.8.2). The default half-lives of wood panels are used for wooden board and plywood.

➢ ***Density and Carbon fraction***

The default values used are the same as section 6.11.1 "Building" (See Table 6-52 for the details).

Table 6-54 Data used for parameters (wood used for other than buildings)

| | Variable | Reference | Note |
|---|---|---|---|
| 1 | Shipment quantity of lumber (for other than domestic logs and building lumber) | *Report on Supply and Demand of Lumber* (MAFF) | |
| 2 | Shipment quantity of wooden board | *Yearbook of Current Production Statistics, Mineral Resources and petroleum products, Ceramics and building materials Statistics* (METI) | Including own-use |
| 3 | Imported wood chips | *Trade Statistics of Japan* (MOF) | |
| 4 | Production of domestic wood chips | *Report on Supply and Demand of Lumber* (MAFF) | |
| 5 | Domestic wood chips (for pulp) | *Trends in Pulp Collection* by Japan Paper Association | |
| 6 | Received quantity of logs for wood chips (domestic logs) | *Report on Supply and Demand of Lumber* (MAFF) | |
| 7 | Received quantity of logs for wood chips (imported logs) | *Report on Supply and Demand of Lumber* (MAFF) | |
| 8 | Imports of plywood (veneer) | *Trade Statistics of Japan* (MOF) | Calculated by multiplying rate of veneer for plywood to imports of veneer, by imports of veneer obtained from FAOSTAT |
| 9 | Received quantity of logs for plywood (domestic logs) | *Report on Supply and Demand of Lumber* (MAFF) | |
| 10 | Received quantity of logs for plywood (imported logs) | *Report on Supply and Demand of Lumber* (MAFF) | |

METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

● ***Activity Data***

Activity data were input of lumber, volume of wooden board, and production of plywood. Input of lumber were estimated by subtracting lumber for building material from sold shipment quantity of lumber in *Report on Supply and Demand of Lumber* (MAFF). The amount of wooden board were estimated by (1) calculating the volume from sale area of each PB, HB, MDF, and LDF in *Yearbook of Current Production Statistics, Mineral Resources and Petroleum Products, Ceramics and Building Materials* (METI); (2) subtracting the volume of sold wooden board for buildings from volumes calculated at (1). Production of plywood were used in *Report on Supply and Demand of Lumber (the Survey on Lumber)* (MAFF).

➢ ***Method of tracing back up to 1900***

As for wood used for other than buildings, they were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in *the 2006 IPCC Guidelines*. For the estimated annual rate for industrial round wood production (U), default value of Asia between 1900 and 1961 (0.0217) was used (*2006 IPCC Guidelines*, Table 12.3).

$$V_t = V_{1961} \times e^{[U \times (t-1961)]}$$

$V_t$ : Annual production for other wood use [kt- C/year]
$t$ : Year
$V_{1961}$ : Annual production for other wood use for the year 1961 [kt- C/year]
$U$ : Estimated continuous rate of change in industrial roundwood consumption for the region that includes the reporting country between 1900 and 1961

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

The uncertainties of carbon stock changes of wood use other than buildings were assessed based on the uncertainties of the default factors in provided in the *KP Supplement* and the uncertainties of statistical data. The uncertainty was estimated as 30% for the carbon stock changes in wood used for other than buildings.

- ***Time-series Consistency***

The data before 1961 were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in *the 2006 IPCC Guidelines*, the time-series consistency for this subcategory is ensured. The activity data and any parameter after 1962 were used consistent statistics.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

With update of wood supply and demand statistics for FY2017, carbon stock changes for FY2017 were recalculated. The outflow values were also recalculated for all years due to the correction of the equation for calculating the domestic wood rate in demolition materials and input amount of demolition material per unit area. According to the change of the domestic wood rate in demolition materials, the inflow values of wood boards were also recalculated for all years.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

Wood which is used mainly in roundwood form in civil engineering and construction field, are not estimated at present.

## 6.11.3. Paper and paperboard

### *a) Category Description*

This category deals with carbon stock changes in paper and paperboard (including waste paper). The net removal (carbon stock changes) from this subcategory in FY1990 were 533 kt-$CO_2$, the net emissions in FY2017 were 80 kt-$CO_2$, in FY2018 were 134 kt-$CO_2$.

### *b) Methodological Issues*

- ***Estimation Method***

The carbon stocks change in the HWP pool in paper and paperboard were estimated from the difference between the HWP pool in reference year and prior year in the same way as wood for other use by using the Tier 2 method by the first order decay (FOD) function described in the *KP Supplement*. Inflow to the HWP pool during one year were estimated by multiplying amount of production of paper and paperboard, rate of domestic logs for paper and paperboard, by carbon conversion factor. The estimation equations are as follows.

$$C_{j,i+1} = e^{-k_j} \times C_{j,i} + \left[\frac{\left(1 - e^{-k_j}\right)}{k_j}\right] \times Inflow_{j,i}$$

$$\Delta C_{j,i} = C_{j,i+1} - C_{j,i}$$

| | |
|---|---|
| $i$ | : year |
| $j$ | : Subcategories (paper and paperboard) |
| $C_{j,i}$ | : Carbon stock in HWP pool in the beginning of year i [t-C] |
| $Inflow_{j,i}$ | : Inflow to the HWP pool during year i [t-C/year] |
| $k_j$ | : Decay constant of FOD for paper products, $k_j = \ln(2)/HLj$ |
| | HL*j*: half-life of the HWP pool: two years |
| $\Delta C_{j,i}$ | : Carbon stock change of the HWP category during year i [t-C/year] |
| $C_{j,(1900)}$ | : Carbon stock in 1900 was assumed to be zero |

$$Inflow_{j,i} = PP_{p\ j,i} \times f_{DPj,i} \times D_j \times CF_j$$

| | |
|---|---|
| $i$ | : year |
| $j$ | : Subcategories (paper and paperboard) |
| $PP_{Pj,i}$ | : Production of paper and paperboard during year i [t] |
| $f_{DPj,i}$ | : Rate of domestic logs for paper and paperboard during year i [%] |
| $D_j$ | : Density (oven dry mass over air dry mass) |
| $CF_j$ | : Carbon fraction [t-C/t-d.m.] |

- ***Parameters***

➢ ***Ratio of domestic logs***

Ratio of domestic logs of paper and paperboard was estimated by dividing consumption of domestic production of paper and paperboard, by total amount of domestic production of paper and paper pulp, waste paper and waste paper pulp that were produced from domestic logs. Domestic production of paper pulp, waste paper and waste paper pulp that were made from domestic logs were estimated, respectively.

Ratio of domestic logs of paper pulp were estimated by dividing domestic and imported consumption by made from raw woods and chips, by total consumption of raw materials in *Yearbook of current production statistics, Paper, printing, plastic products and rubber products*(METI). But, domestic chips included chips which were made from imported logs in domestic industries, the ratio of domestic logs in paper pulp were estimated by subtracting chips which were made from imported logs, using input of domestic and imported raw materials for chips, and the ratio of domestic logs in buildings.

Ratio of domestic logs of waste paper and waste paper pulp were estimated domestic amount of supply from production of waste paper in *Yearbook of current production statistics Paper, printing, plastic products and rubber products* by METI and import and export amount of waste paper in *Trade Statistics of Japan* by MOF.

Table 6-55 Data used for parameters (Paper and paperboard)

| | Variable | Reference | Note |
|---|---|---|---|
| 1 | Consumption of raw materials for pulp products<br>Made from domestic logs<br>Raw woods<br>Chips<br>Chips made from imported logs | *Yearbook of Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics Current Survey of Production* (METI) | Used for calculating rate of domestic logs |
| 2 | Production of waste paper | *Yearbook of Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products* (METI) | FAOSTAT (Recovered paper) |
| 3 | Imports and Exports of waste paper | *Trade Statistics of Japan* (MOF) | FAOSTAT (Recovered paper) |
| 4 | Imports and Exports of paper and paperboard | *Trade Statistics of Japan* (MOF) | FAOSTAT (Recovered paper) |
| 5 | Rate of production of wood chips | *Report on Supply and Demand of Lumber* (MAFF) | Used for estimating the ratio of domestic logs for pulp production chips |
| 6 | Received quantity of logs for wood chips (domestic logs) | *Report on Supply and Demand of Lumber* (MAFF) | |
| 7 | Received quantity of logs for wood chips (imported logs) | *Report on Supply and Demand of Lumber* (MAFF) | |

METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

➢ ***Half-life***

Default half-life of paper and paperboard (2 year) described in the *KP Supplement* (Tables 2.8.2) was used.

➢ ***Default conversion factors for Paper and paperboard***

Default parameters (oven dry mass over air dry mass: 0.9 t-d.m./t, carbon fraction: 0.386 t-C/t-d.m.) for paper and paperboard described in the *KP Supplement* (Tables 2.8.2) were used.

● ***Activity Data***

➢ ***Method since 1961***

Amount of production of paper, paperboard and domestic logs (Pulpwood and Chips) were used in *Yearbook of Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products* (METI). These are same with production amount of Paper and Paperboard in FAOSTAT.

➢ ***Method of tracing back up to 1900***

For paper and paperboard, the estimation method is the same as wood used for other than buildings. For detailed information on the equation and the parameters, see section 6.11.2.

***c) Uncertainties and Time-series Consistency***

● ***Uncertainty Assessment***

The uncertainties of carbon stock changes of paper and paperboard were assessed based on the uncertainties of the default factors provided in the *KP Supplement* and the uncertainties of exiting statistical data.

The uncertainty was estimated as 30% for carbon stock changes in paper and paperboard.

- ***Time-series Consistency***

The data before 1961 were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in *the 2006 IPCC Guidelines*, the time-series consistency for this subcategory is ensured. The activity data and any parameter after 1962 were used consistent statistics.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

The inflow values of consumption of raw materials for pulp products were recalculated for all years due to the correction of the domestic wood rate in demolition materials. Because of the inflow recalculation, the outflow values which are calculated based on first order decay function were also recalculated.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

None.

## 6.12. Direct $N_2O$ emissions from N inputs to managed soils (4. (I))

### *a) Category Description*

This category deals with direct $N_2O$ emissions from N fertilization in land other than cropland and grassland. The direct $N_2O$ emissions from N fertilization in forest land were estimated but in wetlands and settlements were reported as "IE" because those are included in the Agriculture sector. The emissions by this subcategory in FY2018 were 0.51 kt-$CO_2$ eq. This represents a decrease of 38.7% below the FY1990 value.

Table 6-56 Direct $N_2O$ emissions from N fertilization (Inorganic N fertilizers)

| Gas | Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_2O$ | Total | kt-$N_2O$ | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| | | kt-$CO_2$ eq. | 0.84 | 0.72 | 0.67 | 0.64 | 0.48 | 0.56 | 0.53 | 0.54 | 0.56 | 0.54 | 0.51 | 0.51 | 0.51 | 0.51 |
| | Forest land | kt-$N_2O$ | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| | Forest land remaining Forest land | kt-$N_2O$ | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| | Land converted to Forest land | kt-$N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Wetlands | kt-$N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Wetlands remaining Wetlands | kt-$N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Land converted to Wetlands | kt-$N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Settlements | kt-$N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Settlements land remaining Settlements | kt-$N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Land converted to Settlements | kt-$N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Other | kt-$N_2O$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

### b) Methodological Issues

- ***Estimation Method***

The direct $N_2O$ emissions from N fertilization in forest land were estimated by applying Tier 2 estimation method based on decision tree described in the *2006 IPCC Guidelines* because country specific emission factors can be used. The estimation equation was the same as the Agriculture sector.

- ***Parameters***

➢ ***Emission factor***

The emission factor (0.62% [kg-$N_2O$-N/kg-N[12]]), which was applied to the estimation of $N_2O$ emissions resulting from application of synthetic fertilizer to agricultural soils, was also applied to the estimation of $N_2O$ emissions from N fertilization to soils in forest land. For detailed information on the emission factor, see section 5.5.1.1.b) in chapter 5 in this NIR.

- ***Activity Data***

Results of surveys from 2006 to 2008 on fertilizer application to soils in forest land by the Forestry Agency of Japan are applied to activity data. The amount of synthetic fertilizer applied to soils in forest land in the years in which the surveyed data did not exist was estimated by multiplying the total amount of synthetic fertilizer application in *Yearbook of Fertilizer Statistics (Pocket Edition)* by the average percentage of synthetic fertilizer application to soils in forest land in the period from 2006 to 2008.

The average percentage is 0.047% of the total amount of synthetic fertilizer application. With respect to kinds of fertilizer applied to soils in forest land, most of them are synthetic fertilizer according to the surveys by the Forestry Agency of Japan. Hence, the fertilizer applied to soils in forest land is regarded as synthetic fertilizer.

Since the application of crop residues to forest land and the grazing in the forest land have not been carried out, the amount of crop residues applied to soils in forest land and, grazing land, and paddock were zero.

### c) Uncertainties and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty estimates of $N_2O$ emissions from N fertilization were 31% by applying the same value as the estimation of the $N_2O$ emissions from N fertilization in the Agriculture sector.

- ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are multiplied by same ratio throughout the time series. Time-series consistency for this category is ensured.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

[12] Akiyama et al. (2006)

### *e) Category-specific Recalculations*

Statistic data of synthetic fertilizer without nitrification inhibitor after FY2015 and the data of synthetic fertilizer with nitrification inhibitor after FY2016 were revised. Therefore, emissions after FY2015 were recalculated.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

None.

## 6.13. Emissions and Removals from Drainage and Rewetting and Other Management of Organic and Mineral soils (4.(II))

### *a) Category Description*

Regarding the non-$CO_2$ emissions from drainage and rewetting and other management of organic and mineral soils, the emissions from drainage of organic soils were estimated in Japan. $CH_4$ emission from drainage of organic soils in upland fields and pasture land were estimated in this subcategory ($CH_4$ emissions from drainage of organic soils in rice fields were reported in the Agriculture sector). In addition, $CH_4$ and $N_2O$ emissions from organic soil drainage activities in settlements converted from other land use categories were estimated. Regarding the rewetted organic soils and coastal wetlands that methodology is described in the *Wetlands Guidelines,* the estimation method has not been applied. Hence, the emissions were reported as "NA".

Regarding the emissions from soil drainage activities in forest land, the non-$CO_2$ emissions did not occur, because soil drainage activities are not carried out in general in Japan. $CH_4$ and $N_2O$ emissions from drainage of organic soils in forest land are reported as "NO". As explained in section 4.D.1, peatland classified as wetlands was reported as "NE" because it can be considered insignificant in terms of overall level and trend in national emissions. Flooded land and other wetlands were reported as "NA" because the estimation method was not applied.

The emissions by this subcategory in FY2018 were 44.0 kt-$CO_2$ eq. This represents a decrease of 16.9% below the FY1990 value, and an increase of 0.3 % over the FY2017 value.

Table 6-57 $CH_4$ emission from drainage of organic soils

| Gas | Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All | Total | kt-$CO_2$ eq. | 53.0 | 51.2 | 50.0 | 48.4 | 47.4 | 46.3 | 46.3 | 45.9 | 45.2 | 45.3 | 45.1 | 44.0 | 43.9 | 44.0 |
| $CH_4$ | Total | kt-$CH_4$ | 2.09 | 2.02 | 1.97 | 1.91 | 1.87 | 1.83 | 1.83 | 1.82 | 1.79 | 1.79 | 1.79 | 1.74 | 1.74 | 1.75 |
| | | kt-$CO_2$ eq. | 52.1 | 50.4 | 49.3 | 47.8 | 46.8 | 45.8 | 45.8 | 45.4 | 44.8 | 44.9 | 44.7 | 43.6 | 43.5 | 43.6 |
| | Forest land | kt-$CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Cropland | kt-$CH_4$ | 1.44 | 1.42 | 1.41 | 1.40 | 1.40 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.40 | 1.41 |
| | Grassland | kt-$CH_4$ | 0.09 | 0.09 | 0.09 | 0.09 | 0.11 | 0.09 | 0.11 | 0.11 | 0.10 | 0.12 | 0.12 | 0.09 | 0.09 | 0.09 |
| | Wetlands | kt-$CH_4$ | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA |
| | Peat land | kt-$CH_4$ | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| | Flooded land | kt-$CH_4$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Other wetlands | kt-$CH_4$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Other (Organic soil in settlements converted from other land-use categories) | kt-$CH_4$ | 0.6 | 0.5 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 |
| $N_2O$ | Total | kt-$N_2O$ | 0.003 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | | kt-$CO_2$ eq. | 0.8 | 0.8 | 0.7 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| | Forest land | kt-$N_2O$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Wetlands | kt-$N_2O$ | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA |
| | Peat land | kt-$N_2O$ | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| | Flooded land | kt-$N_2O$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Other wetlands | kt-$N_2O$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Other (Organic soil in settlements converted from other land-use categories) | kt-$N_2O$ | 0.003 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

### *b) Methodological Issues*

- ***Estimation Method***

As for upland fields, grassland and settlements converted from other land use categories, $CH_4$ emissions from drained inland organic soils were estimated by using Tier 1 method described in section 2.2.2.1 in the *Wetlands Guidelines*. The estimation equation is as follows:

$$CH_{4-organic} = \sum \{A \times [(1 - Frac_{ditch}) \times EF_{CH4_{land}} + Frac_{ditch} \times EF_{CH4_{ditch}}]\}$$

$CH_{4\text{-}organic}$ : Annual $CH_4$ loss from drained organic soils [kg-$CH_4$]
$A$ : Land area of drained organic soils [ha]
$EF_{CH4\_land}$ : Emission factors for direct $CH_4$ from drained organic soil [kg-$CH_4$/ha]
$EF_{CH4\_ditch}$ : Emission factors for $CH_4$ emissions from drainage ditches [kg-$CH_4$/ha]
$Frac_{ditch}$ : Fraction of the total area of drained organic soil which is occupied by ditches

$N_2O$ emissions from drained organic soil in settlements converted from other land use categories were estimated by using Tier 2 method described in section 2.2.2.1 in the *Wetlands Guidelines*. The estimation equation is as follows.

$$N_2O_{-Nos} = A \times EF_2$$

$N_2O_{\text{-}Nos}$ : $N_2O$ emissions from drained organic soil [t-$N_2O$/yr]
$A$ : Area of organic soil in settlements converted from other land use categories [kha]
$EF_2$ : $N_2O$ emission factor form drained organic soil [kg-$N_2O$-N/ha/yr]

- ***Parameters***

As for upland fields and grassland, the following emission factors for $CH_4$ from drained organic soil, emission factors for $CH_4$ from drainage ditches, and the proportion of ditches to the total area of drained

organic soil which were provided by the *Wetlands Guidelines* Table 2.3 and Table 2.4, were applied to the estimation. Regarding to settlements converted from other land use categories, since default emission factors for settlements have not been provided in the *2006 IPCC Guidelines* and the *Wetlands Guidelines*, considering that conversion to settlements mainly occurs in rice fields in Japan, country specific emission factor for rice field was applied.

Table 6-58 $CH_4$ and $N_2O$ emission factors for drained organic soils (land surface)

| Land-use category | Emission factor | Unit | Climate/ vegetation zones |
|---|---|---|---|
| Cropland, drained | 0 | $kgCH_4/ha/yr$ | Cropland, temperate |
| Grassland, deep-drained, nutrient-rich | 16 | $kgCH_4/ha/yr$ | Grassland, deep-drained, nutrient rich, temperate |
| Rice field | 0.297 | $kgN_2O\text{-}N/ha/yr$ | Country specific data (Actual measurement in Hokkaido) |

Reference: the *Wetlands Guidelines*: Table 2.3

Table 6-59 Default $CH_4$ emission factors for drained organic ditches

| Land-use category | Emission factor | Unit | $Frac_{ditch}$ (indicative values) | Climate/ vegetation zones |
|---|---|---|---|---|
| Deep-drained Grassland, Cropland | 1165 | $kgCH_4/ha/yr$ | 0.05 | Boreal/ Temperate |

Reference: the *Wetlands Guidelines*: Table 2.4

- ***Activity Data***

For detailed information on the methods of determining the areas of organic soils in upland fields, grassland and settlements converted from other land use categories, see section 6.6.1 and section 6.7.1.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

The uncertainties for parameters were assessed on the basis of default values described in the *Wetlands Guidelines.* As a result, the uncertainty estimates for the $CH_4$ emissions from drained inland organic soils were 67%.

- ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

- ***Correction in accordance with revision of D area***

Since area of deforestation (D area) were revised, the emissions for all years were recalculated.

- ***New estimating for $CH_4$ and $N_2O$ emissions associated with drainage of organic soils in settlements converted from other land use categories***

Since $CH_4$ and $N_2O$ emissions from organic soils drainage activities in settlements converted from other

land use categories were estimated from this submission, $CH_4$ and $N_2O$ from this category were recalculated for all years.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

None.

## 6.14. Direct $N_2O$ emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils (4.(III))

### *a) Category Description*

This category deals with direct $N_2O$ emissions from N mineralization resulting from change of land use or management of mineral soils. Therefore, according to the *2006 IPCC Guidelines*, N immobilization associated with gain of soil carbon on mineral soils is not considered, only $N_2O$ emissions from mineralization associated with loss of soil organic matter were estimated.

The direct $N_2O$ emissions in forest land remaining forest land and land converted to other land were estimated by using Tier 1 method according to N mineralization associated with loss of soil organic matter. The $N_2O$ emissions in land converted to cropland and grassland were estimated with the same country specific emission factors as for the Agriculture sector. Carbon stock change in soil organic matter only for pasture land among 3 sub-categories of grassland were estimated. Thus, the estimation in this category was implemented only for pasture land subcategory as well. For land-use categories other than those categories described above, $N_2O$ emissions were reported as “NA” because the loss of soil carbon does not occur (Only for wetlands converted from land was reported as “NE” because the methodology is not provided in the *2006 IPCC Guidelines*). The emissions from this subcategory in FY2018 were 137.4 kt-$CO_2$ eq. This represents a decrease of 10.6 % below the FY1990 value, and an increase of 1.6 % over the FY2017 value.

Table 6-60 $N_2O$ emissions from N mineralization resulting from change of land use or management of mineral soils

| Gas | Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_2O$ | Total | kt-$N_2O$ | 0.52 | 0.50 | 0.48 | 0.46 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.45 | 0.45 | 0.45 | 0.46 |
| | | kt-$CO_2$ eq. | 153.7 | 148.2 | 142.4 | 135.6 | 131.4 | 130.3 | 130.2 | 131.3 | 131.4 | 132.2 | 133.0 | 133.9 | 135.3 | 137.4 |
| | Forest land | kt-$N_2O$ | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.41 | 0.41 | 0.42 | 0.42 | 0.43 | 0.43 |
| | Forest land remaining Forest land | kt-$N_2O$ | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.41 | 0.41 | 0.42 | 0.42 | 0.43 | 0.43 |
| | Land converted to Forest land | kt-$N_2O$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Cropland | kt-$N_2O$ | 0.08 | 0.06 | 0.04 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| | Land converted to Cropland | kt-$N_2O$ | 0.08 | 0.06 | 0.04 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| | Graassland | kt-$N_2O$ | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | Grassland remaining Grassland | kt-$N_2O$ | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | Land converted to Graassland | kt-$N_2O$ | IE | | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | Wetlands | kt-$N_2O$ | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA | NE,NA |
| | Wetlands remaining Wetlands | kt-$N_2O$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Land converted to Wetlands | kt-$N_2O$ | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| | Settlements | kt-$N_2O$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Settlements remaining Settlements | kt-$N_2O$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Land converted to Settlements | kt-$N_2O$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | Other land | kt-$N_2O$ | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

### *b) Methodological Issues*

- ***Estimation Method***

The Tier 1 method described in the *2006 IPCC Guidelines* is used for forest land remaining forest land and other land. The estimation equation is as follows. Equation 2.25 described Session 2.3.3.1 in the *2006 IPCC Guidelines* is used for loss of soil organic matter.

$$N_2O_{direct-}N_{Mineral} = F_{SOM} \times EF_1$$

$$F_{SOM} = \sum_{LU}\left[\left(\Delta C_{Mineral,LU} \times \frac{1}{R}\right) \times 1000\right]$$

| | |
|---|---|
| $N_2O_{direct}$-$N_{Mineral}$ | : Annual direct $N_2O$-N emissions produced from N mineralization [kg-$N_2O$-N] |
| $F_{SOM}$ | : Net amount of N mineralized in mineral soil [kg-N] |
| $EF_1$ | : Emission factor [kg-$N_2O$-N/kg-N input] |
| $\Delta C_{Mineral,LU}$ | : Average annual loss of soil carbon for each land-use type [t-C] |
| $R$ | : C:N ratio for the soil organic matter |

For land converted to cropland and grassland, annual amount of loss of soil carbon due to N mineralization in mineral soils cannot be obtained, when using the estimation method described in the *2006 IPCC Guidelines*. Therefore, $N_2O$ emissions from land converted to cropland and grassland were estimated by using country specific method, by multiplying the area of mineral soils in cropland converted from other land use and in grassland, by the $N_2O$ emission per unit area in cropland. Carbon stock change of soil organic matter only for pasture land among 3 sub-categories of grassland was estimated. Thus, the estimation in this category was implemented only for pasture land subcategory as well and the estimations from grazed meadow and wild land are excluded. For a detailed description of the calculation methods, see the Agriculture sector.

$$N_2O_{direct} - N_{Mineral_{CG}} = \sum_i A_i \times EF_{1_{CG}}$$

| | |
|---|---|
| $N_2O_{direct}$-$N_{Mineral\_C,G}$ | : Annual direct $N_2O$-N emissions produced from N mineralization [kg-$N_2O$-N] |
| $A$ | : The cumulative total mineral soil area of land converted to cropland and grassland [ha] |
| $EF_{1\_C,G}$ | : $N_2O$ emission from N mineralization per unit area of mineral soil [kg-$N_2O$-N/ha] |
| $i$ | : Type of land use |

- ***Parameters***

➢ ***CN ratio for soils***

Country specific data of 11.3 established by MOE(2006) was applied.

➢ ***N-$N_2O$ emission factor for soils***

For forest land and other land, default value [0.01 kg- $N_2O$-N/kg- N] described in the *2006 IPCC Guidelines* was used. For cropland and grassland, the value used in the Agriculture sector [0.23 kg-$N_2O$-N/ha] was applied. (For detailed information, see section 5.5.1.5.b).

- ***Activity Data***

For amount of N mineralized in mineral soil in forest land remaining forest land and in other land,

annual loss of soil carbon in mineral soil for estimating carbon stock changes in mineral soils was used (see Chapter 6.5.2. and Chapter 6.10.2. ). The area of mineral soil in land converted to cropland, which are calculated by subtracting the area of organic soil from the total area of land converted to cropland, are used for the estimation as activity data (see Chapter 6.6.1. b) 2)). The area of mineral soil in land cropland converted from other land use categories reported in the CRF "Table 4(III) Sectoral background data for land use, land-use change and forestry－Direct nitrous oxide (N2O) emissions from nitrogen (N) mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils" is same as the value reported in the CRF "Table 4.B".

The area of mineral soil in grassland was calculated by multiplying the area of pasture land obtained from existing statistics by the ratio of mineral soil area to the area of pasture land and renewal ratio (see section 6.7.1.) of pasture land (see Chapter 6.7.1. ).

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

The uncertainties of emission/removal for forest land and other land were assessed on the basis of carbon stock change in soil and C:N ratio for the soil organic matter. The uncertainties of parameters described in the *2006 IPCC Guidelines* were used. For the uncertainty assessment for cropland and grassland converted from other land-use category, 31% which is the same value of the uncertainties for the emissions in the Agriculture sector was applied. As a result, the uncertainties in the $N_2O$ emissions from N mineralization associated with loss of soil organic matter were -70%~+189%.

- ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since area of afforestation and reforestation (AR area) and area of deforestation (D area) were revised, the emissions from N mineralization associated with loss of soil organic matter in forest land, cropland, grassland and other land from FY1990 to FY2017 were recalculated.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

None.

## 6.15. Indirect nitrous oxide ($N_2O$) emissions from managed soils (4.(IV))

### *a) Category Description*

This category deals with indirect $N_2O$ emissions from managed soils. The indirect $N_2O$ emissions

include, $N_2O$ emissions from N volatilization as $NH_3$ and $NO_x$ and deposition of these gases and their products $NH_4^+$ and $NO_3^-$ onto soils and the surface of lakes and other waters, and $N_2O$ emissions from leaching and runoff in regions where these events occur. In Japan, the indirect $N_2O$ emissions from N fertilization in forest land and the indirect $N_2O$ emissions from N mineralization associated with loss of soil organic matter were estimated.

The emissions from this category in FY2018 were 33.0 kt-$CO_2$ eq. This represents a decrease of 19.8% below FY1990 value, and an increase of 2.2% over FY2017 value.

Table 6-61 Indirect $N_2O$ emissions from managed soils

| Gas | Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $NO_2$ | Total | | kt-$N_2O$ | 0.14 | 0.13 | 0.12 | 0.11 | 0.10 | 0.10 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| | | | kt-$CO_2$ eq. | 41.2 | 37.6 | 34.7 | 32.4 | 31.1 | 30.8 | 30.7 | 31.3 | 31.4 | 31.6 | 31.7 | 31.8 | 32.3 | 33.0 |
| | | Atmospheric deposition | kt-$N_2O$ | 0.0005 | 0.0004 | 0.0004 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| | | Nitrogen leaching and run-off | kt-$N_2O$ | 0.14 | 0.13 | 0.12 | 0.11 | 0.10 | 0.10 | 0.10 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |

### *b) Methodological Issues*

#### *1) $N_2O$ emission from atmospheric deposition of N volatilized*

- ***Estimation Method***

The Tier 1 method described in section 11.2.1.1 in the *2006 IPCC Guidelines* is used.

$$N_2O_{(ATD)} - N = \left[(F_{SN} \times Frac_{GASF}) + \left((F_{ON} + F_{PRP}) \times Frac_{GASM}\right)\right] \times EF_4$$

| | |
|---|---|
| $N_2O_{(ATD)}$-$N$ | : Annual amount of $N_2O$–N produced from atmospheric deposition of N volatilized [kg $N_2O$-N] |
| $F_{SN}$ | : Annual amount of synthetic fertilizer N applied to forest land [kg-N] |
| $F_{ON}$ | : Annual amount of organic N additions applied to forest land [kg-N] |
| $F_{PRP}$ | : Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock [kg-N] |
| $Frac_{GASF}$ | : Fraction of synthetic fertilizer N that volatilized as $NH_3$ and $NO_X$ [kg-$NH_3$-N + $NO_X$-N/kg-N applied] |
| $Frac_{GASM}$ | : Fraction of applied organic N fertilizer ($F_{ON}$) and of urine and dung N deposited by grazing animals ($F_{PRP}$) that volatilizes as $NH_3$ and NOx [kg-$NH_3$-N + $NO_X$-N/kg-N] |
| $EF_4$ | : Emission factor for $N_2O$ emissions from atmospheric deposition of N on soils and water surfaces [kg-$N_2O$-N/kg-$NH_3$-N+$NO_X$-N] |

- ***Parameters***

➢ ***Fraction of synthetic fertilizer N that volatilized as $NH_3$ and $NO_X$***

0.1 [kg $NH_3$-N +NOx-N/kg N applied] (Table 11.3 in Vol.4 of the *2006 IPCC Guidelines*)

➢ ***Emission factor (N volatilization and re-deposition)***

0.01 [kg $N_2O$-N/kg $NH_3$-N +NOx-N volatilized] (Table 11.3 in Vol.4 of the *2006 IPCC Guidelines*)

- ***Activity Data***

For amount of N fertilizer applied to forest land, see section 6.12 in this NIR.

#### *2) $N_2O$ emission from leaching/runoff*

- ***Estimation Method***

The Tier 1 method described in section 11.2.2.1 in the *2006 IPCC Guidelines* is used.

$$N_2O_{(L)} - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH-(H)} \times EF_5$$

| | |
|---|---|
| $N_2O_{(L)}$ -N | : Annual amount of $N_2O$–N produced from leaching and runoff of N additions [kg $N_2O$-N] |
| $F_{CR}$ | : Amount of N in crop residues [kg-N] |
| $F_{SOM}$ | : Annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter [kg-N] |
| $Frac_{LEACH-(H)}$ | : Fraction of all N mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff [kg-N/kg-N] |
| $EF_5$ | : Emission factor for $N_2O$ emissions from N leaching and runoff [kg-$N_2O$-N] |

- ***Parameters***

➢ ***Fraction of all N mineralized in managed soils***

0.3 [kg N/kg nitrogen of fertilizer] (Table 11.3 in Vol.4 of the *2006 IPCC Guidelines*)

➢ ***Emission factor (N leaching and runoff)***

0.0075 [kg $N_2O$-N/(kg N leaching/runoff)] (Table 11.3 in Vol.4 of the *2006 IPCC Guidelines*)

- ***Activity Data***

For amount of N fertilizer applied to forest land, see section 6.12 in this NIR. For amount of N mineralization associated with loss of soil organic matter, see section 6.13 in this NIR.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty Assessment***

The uncertainty of indirect $N_2O$ emissions from N fertilizer was assessed based on the uncertainty of the emission factor (see the *2006 IPCC Guidelines*, p.11.24) and that of the amount of fertilizer. The uncertainty of indirect $N_2O$ emissions from N mineralization associated with loss of soil organic matter was 288%, which is the same value with the uncertainty of in direct $N_2O$ emissions from N mineralization associated with loss of soil organic matter. Consequently, the uncertainty of indirect $N_2O$ emissions from this category was assessed as -107%~+360%.

- ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Following the revision of AR area and D area , the indirect $N_2O$ emissions from managed soils were recalculated for all years (see section 6.14). In addition, since statistic data of synthetic fertilizer without nitrification inhibitor after FY2015 and the data of synthetic fertilizer with nitrification inhibitor after FY2016 were revised (see section 6.12). Therefore, emissions after FY2015 were recalculated.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

None.

## 6.16. Biomass burning (4.(V))

### *a) Category Description*

This category deals with emissions of $CH_4$, CO, $N_2O$ and NOx from biomass burning. For the emissions of CO and $NO_X$, see Annex 3.

For forest land, the emissions resulting from wildfires in forest land remaining forest land and land converted to forest land are reported in a lump for wildfires in forest land remaining forest land, because the data in the statistics for forest fires include the wildfires occurred in both of the categories. Moreover, controlled burning activities in forests and land conversion from land-use categories other than forest land to forest land are not implemented in Japan because the activities are stringently restricted by the "Waste Management and Public Cleansing Act" and "Fire Service Act". Hence, the emissions resulting from controlled burning in forest land do not occur and are reported as "NO".

$CH_4$ and $N_2O$ emissions from controlled burning in cropland are estimated for woody biomass burning of pruned branches from orchard. One of the characteristics of Japan's cropland is intensive management. Under this management style, the occurrences of wildfire are regarded as negligible. $CH_4$ and $N_2O$ emissions from wildfires in cropland are reported as "NO". In addition, $CH_4$ and $N_2O$ emissions from controlled burning in grassland are estimated. $CH_4$ and $N_2O$ emissions from wildfires in grassland are reported as "NO" for the same reasons as cropland.

$CH_4$ and $N_2O$ emissions from wildfires in land other than forest land, cropland and grassland are reported as "NE" because information on wildfires is not enough. $CH_4$ and $N_2O$ emissions from biomass burning in Wetlands are reported as "NE" because it can be considered insignificant.

$CO_2$ emission is not included in this category because it was included in estimation of carbon stock changes.

The emissions by this subcategory in FY2018 were 49.6 kt-$CO_2$ eq. This represents a decrease of 28.5% below the FY1990 value and a decrease of 31.7% below the FY2017 value. These fluctuations are due to less amount of woody biomass burning of pruned branches from orchard over the long run, while, in the short run, inconsistencies of wild fire occurrences also effect it.

Table 6-62 Non-$CO_2$ emissions from biomass burning

| Gas | Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All | Total | | kt-$CO_2$ eq. | 69.4 | 66.8 | 63.0 | 62.9 | 60.9 | 54.9 | 56.1 | 51.0 | 53.0 | 73.1 | 54.7 | 49.2 | 72.6 | 49.6 |
| $CH_4$ | Total | | kt-$CH_4$ | 1.9 | 1.8 | 1.7 | 1.7 | 1.6 | 1.4 | 1.5 | 1.3 | 1.3 | 2.1 | 1.4 | 1.2 | 2.1 | 1.2 |
| | | | kt-$CO_2$ eq. | 47.2 | 45.3 | 42.2 | 42.4 | 40.8 | 35.3 | 36.5 | 31.8 | 33.7 | 52.3 | 35.3 | 30.3 | 52.0 | 30.8 |
| | | Forest land | kt-$CH_4$ | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.2 | 0.3 | 0.1 | 0.2 | 0.9 | 0.2 | 0.1 | 0.9 | 0.1 |
| | | Cropland | kt-$CH_4$ | 1.0 | 0.9 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 |
| | | Grassland | kt-$CH_4$ | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | | Wetlands | kt-$CH_4$ | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO |
| | | Settlements | kt-$CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | | Other land | kt-$CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | | Other | kt-$CH_4$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| $N_2O$ | Total | | kt-$N_2O$ | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.06 | 0.06 | 0.07 | 0.06 | 0.06 | 0.07 | 0.06 |
| | | | kt-$CO_2$ eq. | 22.1 | 21.5 | 20.8 | 20.5 | 20.1 | 19.6 | 19.7 | 19.2 | 19.3 | 20.8 | 19.4 | 18.9 | 20.6 | 18.8 |
| | | Forest land | kt-$N_2O$ | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.001 | 0.002 | 0.001 | 0.001 | 0.006 | 0.002 | 0.0004 | 0.006 | 0.001 |
| | | Cropland | kt-$N_2O$ | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | Grassland | kt-$N_2O$ | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | | Wetlands | kt-$N_2O$ | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO |
| | | Settlements | kt-$N_2O$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | | Other land | kt-$N_2O$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | | Other | kt-$N_2O$ | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

### b) Methodological Issues

#### 1) Non $CO_2$ gases from forest fires

- **Estimation Method**

For $CH_4$, and $N_2O$ emissions due to biomass burning from forest fires, the Tier 1 method is used in the *2006 IPCC Guidelines*.

➢ **Forest land**

- **$CH_4$**

$$bbGHG_f = L_{forest\ fires} \times ER$$

- **$N_2O$**

$$bbGHG_f = L_{forest\ fires} \times ER \times NC_{ratio}$$

$bbGHG_f$ : GHG emissions due to forest biomass burning
$L_{forest\ fires}$ : Carbon released due to forest fires [t-C/yr]
$ER$ : Emission ratio ($CH_4$ : 0.012, $N_2O$ : 0.007)
$NC_{ratio}$ : Nitrogen Carbon ratio of the biomass

- **Parameters**

➢ **Emission ratio**

The following values are applied to emission ratios for non-$CO_2$ gases due to biomass burning.

$CH_4$: 0.012, $N_2O$: 0.007

(Default value stated in the *GPG-LULUCF*, Table 3A.1.15)

➢ **NC ratio**

The following values are applied to NC ratio.

NC ratio: 0.01 (default value stated in the *GPG-LULUCF* p.3.50)

- **Activity Data**

➢ **Forest land**

As activity data in forest land, carbon loss due to forest fire is used. Carbon loss due to forest fire is estimated by the Tier 3 method in the *2006 IPCC Guidelines*. For each of the national forest land and private forest land, carbon loss are calculated from the fire-damaged timber volume multiplied by wood density, the biomass expansion factor and the carbon fraction of dry matter.

$$L_{forest\ fires} = \Delta C_n + \Delta C_p$$

$L_{forest\ fires}$ : carbon loss due to fire [t-C/yr]
$\Delta C_n$ : carbon loss due to fire in national forests [t-C/yr]
$\Delta C_P$ : carbon loss due to fire in private forests [t-C/yr]

Fire-damaged timber volume is separately estimated for national forests and private forests. With regard to national forests, the timber volume of standing trees damaged due to fires in national forests in the *Handbook of Forestry Statistics* is used. With regard to private forests, the damaged timber volume due to fires is estimated by using the actual damaged area and damaged timber volume by age class (inquiry

survey by Forestry Agency). Damaged timber volume for age classes equal to or under 4 is calculated by multiplying the stand volume per unit area of age class equal to or under 4 estimated by the Forestry Status Survey and the NFRDB by loss ratio (ratio of damaged timber volume to stand volume) of damaged timber volumes whose age classes equal to or over 5 in private forests. The loss ratio is assumed to be constant regardless of age classes.

- ***National forest, Private forest***

$$\Delta C_{n,p} = Vf_{n,p} \times D_{n,p} \times BET_{n,p} \times CF_{n,p}$$

$\Delta C_{fn,p}$ : Carbon loss due to fire in national forests and private forest [t-C/yr]
$Vf_{fn,p}$ : Damaged timber volume due to fire in national forests and private forest [$m^3$/yr]
$D_{n,p}$ : Wood density in national forests and private forest [t-d.m./$m^3$]
$BEF_{n,p}$ : Biomass expansion factor for national forests and private forest
$CF$ : Carbon fraction of dry matter [t-C/t-d.m.]

The values for wood density and biomass expansion factors for national and private forest land are determined as weighted averages using the ratios of intensively managed forests and semi-natural forests.

Table 6-63 Wood density and biomass expansion factors for national and private forests

| Type | Wood density [t-d.m./$m^3$] | Biomass expansion factor |
|---|---|---|
| National forest | 0.49 | 1.61 |
| Private forest | 0.46 | 1.61 |

Reference: Based on Forestry Agency data

Table 6-64 Damaged timber volume due to wild fire

| Category | | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Damaged timber volume due to disturbance in national fore | | | $m^3$ | 3,688 | 1,014 | 1,599 | 359 | 976 | 16,091 | 934 | 360 | 279 | 5,326 | 2,472 | 916 | 75 | 112 |
| Damaged timber volume due to disturbance in private fores | | | $m^3$ | 63,602 | 68,361 | 60,228 | 72,575 | 67,417 | 15,810 | 41,537 | 12,269 | 26,620 | 147,989 | 38,571 | 8,151 | 157,051 | 16,309 |
| | ≧5 | Actual damaged area | kha | 0.29 | 0.94 | 0.48 | 0.35 | 0.37 | 0.07 | 0.59 | 0.10 | 0.18 | 0.53 | 0.22 | 0.04 | 0.35 | 0.09 |
| | | Damaged timber volume | $m^3$ | 47,390 | 58,129 | 54,487 | 59,235 | 55,628 | 12,780 | 40,477 | 11,566 | 25,204 | 137,078 | 36,693 | 7,370 | 153,412 | 15,148 |
| | ≦4 | Actual damaged area | kha | 0.27 | 0.51 | 0.16 | 0.27 | 0.28 | 0.06 | 0.07 | 0.03 | 0.04 | 0.18 | 0.05 | 0.02 | 0.04 | 0.03 |
| | | Damaged timber volume | $m^3$ | 16,212 | 10,232 | 5,741 | 13,340 | 11,789 | 3,030 | 1,060 | 703 | 1,416 | 10,911 | 1,878 | 781 | 3,639 | 1,161 |

Reference: Based on *Handbook of Forestry Statistics* for national forest, and Forestry Agency data for private forest

- ***Note***

In Japan, emissions due to biomass burning are estimated separately for national forests and for private forests, because of different reporting procedures in regard to forest fire information. However, forest fires in Japan are covered by a set of data for both national forests and private forests, and the emissions are thus appropriately estimated.

### *2) Non $CO_2$ from burning of pruned branches from orchard trees*

- ***Estimation Method***

For $CH_4$ and $N_2O$ emissions due to biomass burning of pruned branches from orchard trees, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* was applied. The estimation equation is as follows:

$$L_{fire} = W_B \times C_f \times G_{ef} \times 10^{-6}$$

$L_{fire}$ : Amount of greenhouse gas emission from fire [kt- GHG]
$W_B$ : Amount burnt [t-d.m.]
$C_f$ : Combustion factor
$G_{ef}$ : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor, a value of 0.9 which has been used generally in field burning of crop residues in agriculture in Japan is applied. For emission factor, the default emission factors of "Agricultural residue" provided in the *2006 IPCC Guidelines* are used.

Table 6-65 Emission factors [t/kt-d.m.]

| Category | $CH_4$ | $N_2O$ |
|---|---|---|
| Agricultural residue | 2.7 | 0.07 |

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity Data (Amount burned)***

The amount burned data was calculated by multiplying the same the cultivation area of the orchard trees as used in the calculation of carbon stock change in 4.B., by the MAFF by dry matter residue weight per unit area (400kg/10a) from the domestic field survey National Institute of Resources (1982), and ratio of burning of pruned branches in field (25%) from the survey result in 2008.

$$W_B = \sum_i (A_i \times E \times 10) \times R$$

$W_B$ : Amount of burning pruned branches from orchard trees [kg-d.m.]
$A$ : Cultivation area of orchard tress [ha]
$E$ : Dry matter residue weight per unit area [kg-d.m./10a]
$R$ : Combustion ratio of pruned branches from orchard trees
$i$ : Type of orchard tree

### *3) Non $CO_2$ from biomass burning in Grassland*

- ***Estimation method***

For $CH_4$ and $N_2O$ emissions due to biomass burning from grassland, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* was applied. The estimation equation is as follows:

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-6}$$

$L_{fire}$ : Amount of greenhouse gas emission from fire [kt- GHG]
$A$ : Area burnt [ha]
$M_B$ : Mass of available fuel for combustion [t-d.m/ha]
$C_f$ : Combustion factor
$G_{ef}$ : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor, value of 0.9 is applied according to expert judgment that considering survey data on burning of grassland in Japan. For emission factor, the default emission factors of "Savanna and

grassland" provided in the *2006 IPCC Guidelines* are used.

Table 6-66 Emission factors [t/kt-d.m.]

| Category | $CH_4$ | $N_2O$ |
|---|---|---|
| Savanna and grassland | 2.3 | 0.21 |

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity data***

The total mass of fuel available for combustion in grassland is calculated by multiplying area burnt of grassland, by the average amount of dry mass per unit area. There is no comprehensive statistical information or official data relating to burnt area of grassland. However, the area of controlled large-scale burning events on grassland which may affect national GHG emissions is limited in Japan. The area burnt for this estimation is estimated based on the five controlled large-scale burning events exceeding 1,000 ha: Aso, Higashi-Fuji exercise area, Kita-Fuji exercise area, Watarase flood control basin, and Akiyoshidai. The total planned burnt areas of these five events of 24,400ha are used as activity data uniformly over the whole year. For the amount burnt per area unit, value of 10 t-d.m./ha is applied according to expert judgment that considering survey data on burning of grassland in Japan.

### *4) Non $CO_2$ from biomass burning in Wetlands*

Controlled burning and wildfire occur only at riverside in Wetlands in Japan.

The emissions from biomass burning in Wetland were estimated with Tier 1 methodology（the *2006 IPCC Guidelines*, Equation2.27) with Default EF of All savanna and grassland on Table 2.5 in the *2006 IPCC Guidelines*. 'MB・Cf' was applied 10.0 t-d.m./ha of All savanna grasslands (mid/late dry season burns) on table 2.4 in the *2006 IPCC Guidelines*. (i.e. 1.2 t-$CO_2$ eq./ha)

From the fire and disaster statistics, 5,500-8,000 wild fire occurred on non-forest, agriculture and settlement area per year which included wild fire at riverside. Under the assumption that all these wild fires occurred at riverside, if area burned per a wild fire accounts for more than 11 ha, total emission from this category is classified as "significant" in LULUCF sector in Committee for GHG Emissions Estimation Methods in Japan.

Area of wild fire in forest land in Japan reaches some hundreds ha at the most. Over 10 ha wild fire is regarded as massive fire in Japan. In the view of these facts and uncertainty of parameters, emission in this category was judged as insignificant. Furthermore, the emissions from biomass burning along downstream of Arakawa River at which data on wild fire is available was about 300 t-$CO_2$ eq. This value applied to estimate the upper limit of applicability of "NE" for being considered insignificant.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainly Assessment***

The uncertainties for parameters and activity data related to forest fires were individually assessed on the basis of field studies, expert judgment, or default values described in the *2006 IPCC Guidelines*. Regarding the uncertainties for parameters and activity data related to biomass burning for pruned branches from orchard trees, the uncertainties ($CH_4$: 296%, $N_2O$: 300%) for crop residues burning in the Agriculture sector were substituted. For the uncertainty for biomass burning from grassland, the uncertainties for parameters and activity data were assessed on the basis of field studies, and default values described in the *2006 IPCC Guidelines* ($CH_4$: 56%, $N_2O$: 63%). As a result, the uncertainty estimates for the emissions resulting from biomass burning were 81% for $CH_4$ and 48% for $N_2O$,

respectively.

- ***Time-series Consistency***

Time-series consistency for biomass burning in forest land remaining forest land is ensured by using the same data sources (*Handbook of Forestry Statistics* compiled by the Forestry Agency, and the data provided by the Agency) and the same methodology from 1990 to 2013. Time-series consistency for biomass burning for pruned branches from orchard trees and for grassland is ensured by using the same data sources (*Statistics of Cultivated and Planted Area* by the MAFF.)

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Since cultivation area for orchard trees for FY2016 were published, $CH_4$ and $N_2O$ emissions from burning of pruned branches from orchard trees after FY2016 were recalculated.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

None.

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# Chapter 7. Waste (CRF sector 5)

## 7.1. Overview of Sector

### 7.1.1. Overview of Waste Management and Estimation Category

In the waste sector, greenhouse gas emissions from treatment and disposal of waste are estimated for solid waste disposal (5.A.), biological treatment of solid waste (5.B.), incineration and open burning of waste (5.C.), wastewater treatment and discharge (5.D.), and other (5.E.)[1] in accordance with treatment processes. Figure 7-1 and Figure 7-2 show the estimation categories of waste/wastewater treatment system and/or waste classification in Japan.

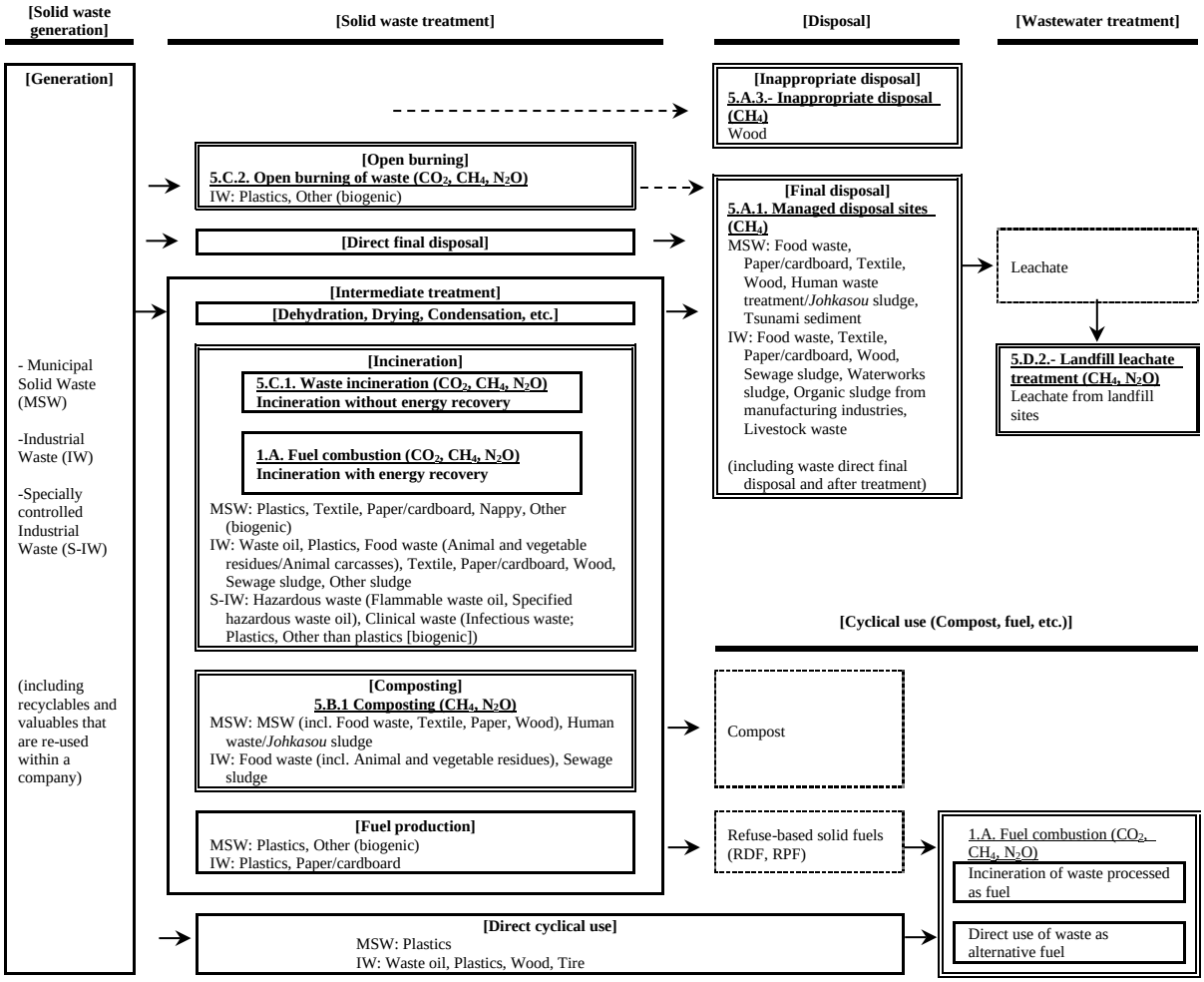


Figure 7-1 Flow chart of solid waste managements and the estimation categories

[1] Data for some emission source categories in the waste sector are complemented by estimation, when statistical data or related data are not available. The methodologies for this estimation are not described in this chapter. For details, refer to the website of MOE, *Committee for the Greenhouse Gases Emissions Estimation Methods* (http://www.env.go.jp/earth/ondanka/ghg-mrv/committee/).

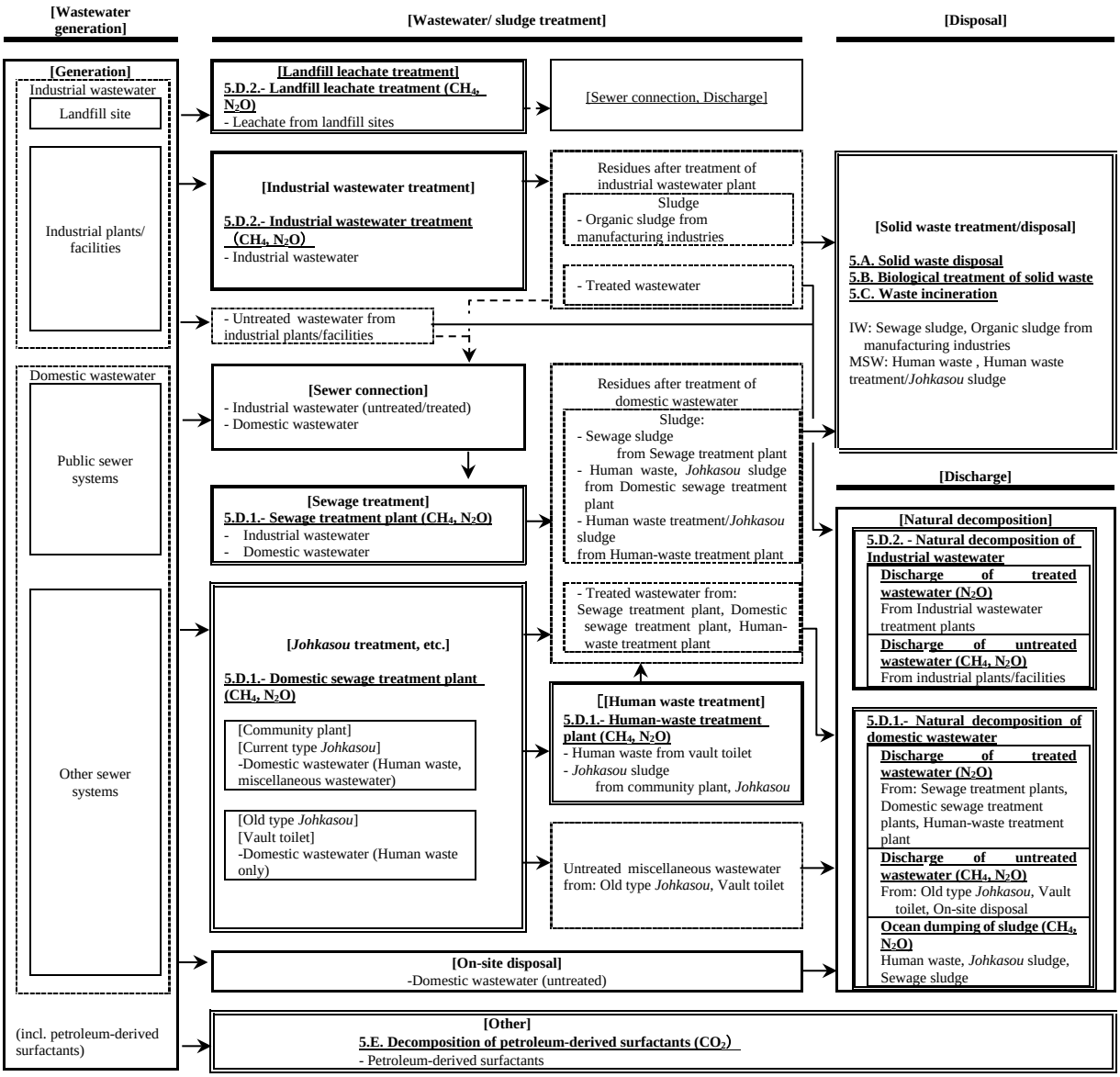


Figure 7-2 Flow chart of wastewater/sludge treatments and the estimation categories

"Waste" to be covered in this sector is the waste as defined in the *2006 IPCC Guidelines*. In the case of Japan, the waste does not only include municipal waste and industrial waste as defined by the Waste Management and Public Cleansing Act, but also include recyclables and valuables that are re-used within a company, and reported in category "7.3.1. Composting (5.B.1)", "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)", and "7.4.3.3. Incineration of Waste Processed as Fuel (1.A.)",. Since waste statistics are compiled separately for municipal waste and industrial waste in Japan, estimation methodologies for many of emission sources in the waste sector are discussed respectively for municipal waste and industrial waste. Emissions from the treatment of disaster waste caused by the Great East Japan Earthquake, which occurred on 11th March, 2011, are reported in this sector.

### 7.1.2. Overview of Greenhouse Gas Emissions on Waste Sector

In FY2018, emissions from the Waste sector resulted in 19,267 kt-$CO_2$ eq. and accounted for 1.6% of Japan's total greenhouse gas emissions (excluding LULUCF). Total emissions had decreased by 35.2%

compared to those of FY1990 and decreased by 3.0% compared to those of FY2017. Breakdown of FY2018 emissions of the Waste sector by category shows that the largest contributor to the emissions is Incineration and Open Burning of Waste (5.C.) (excluding emissions from waste incineration and energy use reported on the energy sector) accounting for 60.6% (a decrease by 16.0% from FY1990) followed by the Wastewater Treatment and Discharge (5.D.) accounting for 18.7% (a decrease by 32.4% compared to FY1990), Solid Waste Disposal (5.A.) accounting for 15.2% (a decrease by 69.4% from FY1990), Other (5.E.) accounting for 3.5% (a decrease by 4.2% from FY1990) , and Biological Treatment of Solid Waste (5.B.) accounting for 2.0% (an increase by 64.0% from FY1990). Breakdown of the emissions of the Waste sector by gas shows that the largest contributor to the emissions is $CO_2$ emissions associated with the incineration/open burning of petroleum-derived waste such as waste plastic and waste oil accounting for 53%, followed by $CH_4$ emissions from solid waste disposal on land accounting for 15%, $N_2O$ emissions from wastewater treatment and discharge accounting for 10%.

The changes in greenhouse gas emissions from the Waste sector since FY1990 show a trend in a decrease in $CH_4$ emissions from the solid waste disposal on land associated with a decrease in the amount of disposal of biodegradable waste due to the improvement in recycling rate since the enactment of the Basic Law for Establishing the Recycling-based Society and other recycling laws. Note that while the recycling rate of waste in Japan has increased in FY2016 (15.4%) in comparison with FY1990 (7.4%), the total disposal amount has reduced in FY2016 (14 Mt/year) in comparison with FY1990 (109 Mt/year) (Ministry of the Environment: MOE, 2019).On the other hand, emissions from the incineration of petroleum-derived waste with energy recovery, emissions from the direct use of petroleum-derived waste as alternative fuel, and emissions from the incineration of petroleum-derived waste processed as fuel, which are accounted for in the Energy sector, have increased along with an increase of waste recycling rate (an increase by 63.9% from FY1990).

### 7.1.3. General Description for Methodological Issues on the Waste Sector

- ***Estimation Method and Emission Factors***

Japan generally employs country specific methodologies and emission factors in GHG emission estimations on the waste sector. For the category on which sufficient views are not obtained from domestic survey, default methodologies and emission factors in the *2006 IPCC Guidelines* are partially applied. For details, see articles "*b) Methodological Issues*" in each category's section.

Table 7-1 Summary for methods and emission factors used on waste sector

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES | $CO_2$ | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| **5. Waste** | CS | CS | CS, D, T2, T3 | CS, D | CS, D, T2 | CS, D |
| A. Solid waste disposal | NA | NA | T3 | CS | | |
| B. Biological treatment of solid waste | | | T2 | CS | T2 | CS |
| C. Incineration and open burning of waste | CS | CS | CS, T2 | CS, D | CS, T2 | CS, D |
| D. Wastewater treatment and discharge | | | CS, D | CS, D | CS, D | CS, D |
| E. Other | CS | CS | NA | NA | NA | NA |

Note:
D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country specific method or EF

- ***Activity Data***

As activity data in the methodologies on the waste sector, the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes – Volume on Cyclical Use* (Environmental

Regeneration and Material Cycles Bureau of MOE) (hereinafter referred to as the *Cyclical Use of Waste Report*), the *Waste Treatment in Japan* (the same agency of MOE), and the *annual editions of Sewage Statistics – Admin. Ed.* (Japan Sewage Works Association: JSWA) (hereinafter referred to as the *Sewage Statistics*) are mainly referred. Also, various other statistics related on the waste management and provided data from relevant agencies and bodies are used. For details, see articles "*b) Methodological Issues*" in each category's section.

Note that treatment and disposal amount of disaster wastes since FY2011, when the Great East Japan Earthquake occurred, are surveyed by Environmental Regeneration and Material Cycles Bureau of MOE, and are considered in the activity data to estimate GHG emissions from these sources.

### 7.1.4. General Assessment Procedure for the Uncertainty on the Waste Sector

The uncertainty of GHG emissions on the waste sector is assessed based on the *2006 IPCC Guidelines* and MOE (2013a). The general assessment procedures are indicated below. For details, see articles "*c) Uncertainties and Time-series Consistency*" in each category's section.

- ***Emission factors***

The uncertainties in emission factors are assessed by using the 95% confidence interval obtained from actual measurement, or by expert judgment. When emission factor is derived from formulas using parameters, the uncertainty is assessed by combining the uncertainties of these parameters.

- ***Activity data***

Regarding the uncertainty for activity data, due to the lack of information on statistical error in quoted references, it is difficult to assess uncertainties based on concrete evidence. Therefore, it is assessed by expert judgment as indicated in the Table 7-2.

Table 7-2 Uncertainty for statistics used for activity data on waste sector

| Statistics used for activity data | Range of uncertainty | | Justification for assessing the uncertainty |
|---|---|---|---|
| | ( - ) | ( + ) | |
| Municipal waste (Domestic wastewater excl. sewage) | -10% | +10% | In the uncertainty which is provided as default value in the *2006 IPCC Guidelines*, the value (±10%) in the case where waste weight is measured by truck scale is adopted based on expert judgment. |
| Industrial waste (Industrial wastewater) | -30% | +30% | In the uncertainty which is provided as default value in the *2006 IPCC Guidelines*, the value (±30%) "in the case where amount of generated waste is regularly collected" is adopted based on expert judgment. |
| Specially-controlled industrial waste | -60% | +60% | The twofold higher uncertainty than the value in industrial waste statistics is adopted based on expert judgment. |
| Valuables (valuable waste) | -30% | +30% | In the uncertainty which is provided as default value in the *2006 IPCC Guidelines*, the value (±30%) "in the case where amount of generated waste is regularly collected" is adopted based on expert judgment. |
| Sewage | -5% | +5% | Since the data has collected through complete survey for whole sewage treatment plants in Japan, it is considered that data is accurate enough to reflect the current status. Therefore, the uncertainty is evaluated at 5% based on expert judgment. |
| Water works | -5% | +10% | Sampling error in the statistics is evaluated at 5% based on expert judgment as well as sewage statistics. However, water works statistics target only water company and supplier of city water which have more than 5001 official water supplied population; sludge generated from small-sized filter plants by private water-supply system is not identified. Therefore, an additional 5% to the upper limit of uncertainty is added since the population of private water-supply system account for 5% of the total. |

- ***Emissions***

Since emissions are calculated by formulas, the uncertainty is assessed by combining the uncertainties of emission factors and activity data.

### 7.1.5. General Recalculations for Emissions from Waste Sector

Most of statistics in Japan are compiled on the basis of Japan's fiscal year (starting on April 1 of the year and ending on March 31 of the following year). Therefore, some process of statistical compilation for the latest fiscal year, which is referred in waste sector inventory, does not complete in time for an inventory compilation.

In such a case, the activity data of previous fiscal year are generally adopted for the latest fiscal year in accordance with the *2006 IPCC Guidelines*, but adoptions of more appropriate estimations are desirable for data of latest fiscal year for main categories. To obtain such better activity data related to solid waste to be quoted from the *Cyclical Use of Waste Report* as main statistics, "the Committee for improvement of the research on cyclical use of waste" organized by Environmental Regeneration and Material Cycles Bureau of MOE, annually prepares preliminary data for the latest year estimated by using economic indexes such as volume/value of shipment of products to be finally disposed of (*Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics*, MOE). Thus, GHG emissions for latest fiscal year on the waste sector are estimated by using this preliminary activity data. Consequently, every year, these preliminary data are updated with definite data, and emissions are recalculated in the inventory of its next annual submission.

## 7.2. Solid Waste Disposal (5.A.)

This category covers $CH_4$ emissions from solid waste disposal on land. For this emission source category, estimation methodologies are discussed separately for municipal waste and industrial waste in

accordance with Japan's waste classification system, and emissions are estimated for the sources presented in Table 7-3.

Table 7-3 Categories whose emissions are estimated for solid waste disposal (5.A.)

| Category | Waste type | | | Disposal type | | $CO_2$ | $CH_4$ |
|---|---|---|---|---|---|---|---|
| 5.A.1. (7.2.1) | Municipal solid waste | Food waste | | Managed disposal sites | Anaerobic/ Semi-aerobic landfill | NO | ○ |
| | | Paper/cardboard | | | | | ○ |
| | | Wood | | | | | ○ |
| | | Textiles | Natural fiber [1)] | | | | ○ |
| | | Sludge | Human waste treatment/*Johkasou* sludge | | | | ○ |
| | | | Tsunami sediment [2)] | | Anaerobic landfill[7)] | NO | ○ |
| | Industrial waste | Food waste [3)] | Animal and vegetable residues, Animal carcasses | | Anaerobic/ Semi-aerobic landfill | NO | ○ |
| | | Paper/cardboard | | | | | ○ |
| | | Wood | | | | | ○ |
| | | Textiles | Natural fiber [1)] | | | | ○ |
| | | Sludge | Sewage sludge: Digested sewage sludge [4)] | | | | ○ |
| | | | Sewage sludge: Other sewage sludge | | | | ○ |
| | | | Waterworks sludge | | | | ○ |
| | | | Organic sludge from manufacturing industries | | | | ○ |
| | | | Livestock waste [5)] | | | | ○ |
| 5.A.2. (7.2.2) | - | | | Unmanaged disposal sites | | NO | NO |
| 5.A.3. (7.2.3) | Industrial waste | Wood | | Inappropriate disposal [6)] (Anaerobic landfill) | | NE | ○ |

Note:

1) Only natural fiber textiles are included in the estimation under the assumption that synthetic fiber waste is not biologically decomposed in landfills.
2) Part of tsunami sediment generated by the Great East Japan Earthquake, which occurred on 11th March, 2011, is disposed of finally. Since disposed tsunami sediment includes organic matters, $CH_4$ emissions from this source are estimated using the emission factor for wood by expert judgment.
3) Japan's industrial waste classifications of "Animal and vegetable residues" and "Animal carcasses" are aggregated as food waste.
4) "Digested sewage sludge" includes sewage sludge landfilled after digested and dehydrated. Because digestion treatment reduces the amount of carbon content biodegraded in sludge decreases, $CH_4$ emissions are estimated separately by landfilled sewage sludge with and without digestion treatment.
5) Although livestock waste is not classified as "sludge" under Japanese law, the emissions from the waste are estimated within the category of sludge since both properties are similar.
6) The emissions from wood are currently considered as inappropriate disposal of waste containing biodegradable carbon.
7) Since the disposal type for tsunami sediment have not been identified, it is conservatively assumed as anaerobic landfill (MCF=1.0) which derives larger emissions.

Table 7-4 GHG emissions from solid waste disposal (5.A.)

| Gas | Category | | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 5.A.1. Managed waste disposal saites | a. Anaerobic landfill | | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | | b. Semiaerobic landfill | | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 5.A.2. Unmanaged waste disposal sites | | | kt-$CO_2$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 5.A.3. Uncategorized waste disposal sites | Inappropriate disposal | | kt-$CO_2$ | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| | Total | | | kt-$CO_2$ | NO,NE | NO,NE | NO,NE | NO,NE | NO,NE | NO,NE | NO,NE | NO,NE | NO,NE | NO,NE | NO,NE | NO,NE | NO,NE | NO,NE |
| $CH_4$ | 5.A.1. Managed waste disposal saites | a. Anaerobic landfill | MSW | kt-$CH_4$ | 218.0 | 187.2 | 145.3 | 110.2 | 85.6 | 79.8 | 74.8 | 70.2 | 65.8 | 62.1 | 58.1 | 54.3 | 51.3 | 48.2 |
| | | | ISW | kt-$CH_4$ | 141.5 | 135.7 | 111.9 | 83.1 | 63.1 | 58.9 | 55.7 | 52.8 | 49.9 | 47.1 | 44.7 | 42.7 | 40.9 | 39.2 |
| | | b. Semiaerobic landfill | MSW | kt-$CH_4$ | 18.7 | 28.0 | 31.8 | 34.6 | 30.6 | 28.8 | 27.4 | 26.3 | 25.6 | 24.0 | 23.2 | 21.4 | 20.6 | 19.3 |
| | | | ISW | kt-$CH_4$ | 4.2 | 7.7 | 11.3 | 13.2 | 11.8 | 11.0 | 10.8 | 10.8 | 10.8 | 10.3 | 10.0 | 9.5 | 9.3 | 9.0 |
| | 5.A.2. Unmanaged waste disposal sites | | | kt-$CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | 5.A.3. Uncategorized waste disposal sites | Inappropriate disposal | | kt-$CH_4$ | 0.3 | 0.8 | 2.5 | 2.4 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 1.9 | 1.8 | 1.9 | 1.8 | 1.6 |
| | Total | | | kt-$CH_4$ | 382.8 | 359.4 | 302.8 | 243.6 | 193.4 | 180.8 | 170.9 | 162.3 | 154.2 | 145.4 | 137.8 | 129.9 | 123.7 | 117.2 |
| | | | | kt-$CO_2$ eq. | 9,570 | 8,985 | 7,570 | 6,090 | 4,835 | 4,521 | 4,272 | 4,058 | 3,855 | 3,635 | 3,444 | 3,247 | 3,093 | 2,930 |
| Total | | | | kt-$CO_2$ eq | 9,570 | 8,985 | 7,570 | 6,090 | 4,835 | 4,521 | 4,272 | 4,058 | 3,855 | 3,635 | 3,444 | 3,247 | 3,093 | 2,930 |

Estimated greenhouse gas emissions from solid waste disposal on land are shown in Table 7-4. In FY2018, greenhouse gas emissions from this source category are 2,930 kt-$CO_2$ eq. and accounted for

0.2% of the national total emissions (excluding LULUCF). Emissions from this category decreased by 69.4% compared to the emissions in FY1990. This $CH_4$ emissions decrease is the result of decrease in the amount of biodegradable waste landfilled due to the increase in the practice of waste incineration to reduce waste volume in Japan.

For the category "managed disposal sites", while trend in the disposal amount of biodegradable waste has steadily decreased since FY1990, trend in the estimations of $CH_4$ generated from degradation of waste has relatively slowly decrease due to the time lags derived from long half-lives of waste in the FOD method (e.g. 7 years for half-life of paper/cardboard). Hence trend in the implied emission factors (IEFs) has increased since FY1990. For the category "uncategorized waste disposal sites (inappropriate disposal)", while trend in the disposal amount irregularly fluctuate year by year since the estimations should consider only disposal amount for revealed matters, trend in $CH_4$ emissions estimated by FOD method is relatively stable. Hence trend in the IEFs also tend to irregularly fluctuate year by year.

### 7.2.1. Managed Disposal Sites (5.A.1.)

#### *a) Category Description*

In Japan, part of food waste, paper/cardboard, textiles, wood, and sludge in municipal solid waste (MSW) and industrial waste (IW) is landfilled without incineration; therefore, $CH_4$ is generated as a result of biodegradation of organic materials from the landfill sites. Because Japanese landfill sites are appropriately managed pursuant to the Waste Management and Public Cleansing Act, the amount of $CH_4$ emitted from there is reported under this category "Managed Disposal Sites (5.A.1.)". Emissions of $CO_2$ from waste incineration at the managed disposal sites are reported as NO, because waste incineration is not implemented at that site in Japan.

#### *b) Methodological Issues*

- ***Estimation Method***

The revised first order decay (FOD) method given in the *2006 IPCC Guidelines* is applied for its emission estimates since this method assumes the delay time from the deposition of waste to the generation of $CH_4$. According to the decision tree indicated in the said guidelines, the revised FOD method with country-specific parameters (Tier 3) is used to estimate emissions from this source.

In Japan, emission factor is defined as "$CH_4$ emissions from biodegradable waste", and activity data are defined as "the amount of waste biodegraded within the reporting fiscal year".

$$E = \left\{ \sum_{i,j} \left( EF_{i,j} \times A_{i,j} \right) - R \right\} \times (1 - OX)$$

Where：

| | |
|---|---|
| $E$ | : $CH_4$ emissions from landfill sites [kg-$CH_4$] |
| $EF_{i,j}$ | : Emission factor for a biodegradable waste *i* (dry basis) that is damped into a landfill site *j* without incineration [kg-$CH_4$/t] |
| $A_{i,j}$ | : Amount of a biodegradable waste *i* (dry basis) that is damped into a landfill site j without incineration and is biodegraded within an inventory year) [t] |
| $R$ | : Recovered $CH_4$ in an inventory year [kg-$CH_4$] |
| $OX$ | : Oxidation factor of $CH_4$ related to soil cover |

- ***Emission Factors***

Emission factors are defined as the amount of $CH_4$ [kg] generated through decomposition of one ton of biodegradable landfill wastes (dry basis) without incineration. They are established by the type of biodegradable waste (i.e., food waste, paper/cardboard, natural fibers, wood, sewage sludge, human

waste, waterworks sludge, organic sludge from manufacturing industries and livestock waste) and by the type of landfill site (i.e., anaerobic or semi-aerobic landfill). Emission factors are estimated as indicated below.

$$EF = DOC_i \times DOCF \times MCF_j \times F \times 1000 \times \frac{16}{12}$$

$DOC_i$ : Fraction of carbon content in a biodegradable waste *i*
$DOCF$ : Fraction of degradable organic carbon dissimilated
$MCF_j$ : Methane correction factor in a landfill site *j*
$F$ : Percentages of $CH_4$ in landfill gas

➢ ***Carbon Content (DOC: Per Dry Weight)***

Carbon content per dry weight, which is used as uniform value every year because the property of each waste type does not vary significantly over time, is determined based on MOE (2006b) and MOE (2010) as indicated in Table 7-5 below.

Table 7-5 Carbon content of waste disposed of in managed landfill sites (dry basis)

| Item | Carbon Content | Data source |
|---|---|---|
| Food waste | 43.4 % | MSW: Calculated by taking the averages of carbon contents of MSW provided by Tokyo, Yokohama, Kawasaki, Kobe, and Fukuoka (FY1990-2004)<br>IW: Substituted the carbon content of MSW for IW because its properties are similar to those of MSW (MOE, 2006b) |
| Paper/cardboard | 40.9 % | |
| Wood | 45.2 % | |
| Textiles (natural fiber) | 45.0 % | Calculated by taking a weighted average of carbon content estimated based on the constituent of each natural fiber type (cotton, wool, silk, linen, and recycled textiles) by the domestic demand of natural fibers (FY1990-2004) (MOE, 2006b) |
| Human waste treatment /*Johkasou* sludge | 40.0 % | Substituted the value for "Other sewage sludge" |
| Tsunami sediment | 4.5 % | Calculated by multiplying the fraction of organic matter in tsunami sediment by the fraction of carbon contents in the organic matter; assuming the fraction of organic matter in tsunami sediment finally disposed of is 10%, and 45.2% of fraction of carbon content for wood is substituted for tsunami sediment by expert judgment |
| Digested sewage sludge | 30.0 % | Expert judgment based on Fujimoto (2000), Fujishima, et al. (2004), Oshima, et al. (1986) and Tanaka, et al. (1980) |
| Other sewage sludge | 40.0 % | Expert judgment based on domestic researches (MOE, 2006b) |
| Waterworks sludge | 6.0 % | Average values of survey results conducted at 23 water purification plants (MOE, 2010) |
| Organic sludge from manufacturing | 45.0 % | Value for paper industry is substituted because it generates the largest amount of organic sludge finally disposed of. Estimated based on the carbon content of cellulose because the main constituent of organic sludge generated is paper sludge (MOE, 2006b) |
| Livestock waste | 40.0 % | Substituted the value for "Other sewage sludge" |

➢ ***Fraction of degradable organic carbon dissimilated (DOCF)***

Fraction of degradable organic carbon dissimilated for the biodegradable waste is set at 50% based on Ito (1992).

➢ ***Methane Correction Factor (MCF)***

- ***Anaerobic landfill sites***

For Methane Correction Factor of anaerobic landfill sites ($MCF_{an}$), default values of 1.0 given in the *2006 IPCC Guidelines* is used.

- ***Semi-aerobic landfill sites***

For Methane Correction Factor of semi-aerobic landfill sites in ideal condition ($MCF_{semi}$) default values of 0.5 given in the *2006 IPCC Guidelines* is used. However, semi-aerobic landfill site in Japan is in an anaerobic condition when the outflow port of leachate collection system is swamped, the system is full

of water, it holds retaining of leachate, or leachate collection/gas extraction system is not properly extend. Considering these inappropriate management conditions of the leachate collection system at landfill sites, a country-specific parameter is defined as "percentage of open outflow port of leachate collection system" and used for the estimation; the methane correction factor of semi-aerobic landfill site in actual condition ($MCF_{semi,act}$) is estimated for municipal solid waste disposal sites and industrial waste disposal sites, respectively, as follows:

$$MCF_{semi,act} = \{P \times MCF_{semi} + (1 - P) \times MCF_{an}\}$$

$MCF_{semi,act}$ : Methane correction factor of semi-aerobic landfill sites in actual condition
$MCF_{semi}$ : Methane correction factor of semi-aerobic landfill sites in ideal condition (0.5)
$MCF_{an}$ : Methane correction factor of anaerobic landfill sites (1.0)
$P$ : Percentage of open outflow port of leachate collection system

Where,

$$P = W'/W$$

$W'$ : Disposal amount in a reporting year at semi-aerobic landfill sites in ideal condition, where open outflow port of leachate collection system [for municipal solid waste: t, for industrial waste: $m^3$]
$W$ : Disposal amount in a reporting year at whole semi-aerobic landfill sites [for municipal solid waste: t, for industrial waste: $m^3$]

To evaluate W' and W for municipal solid waste, the condition of open outflow port and disposal amount in each semi-aerobic landfill sites provided in the *state of municipal waste treatment survey* are used. For industrial waste, those data in each semi-aerobic landfill sites indicated in a result of questionnaire survey by Environmental Regeneration and Material Cycles Bureau of MOE, are used.

Table 7-6 Percentage of open outflow port of leachate collection system at semi-aerobic landfill sites for municipal solid waste and industrial waste

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Municipal solid waste | % | 64.7 | 64.7 | 64.7 | 64.7 | 66.7 | 69.1 | 71.2 | 71.2 | 69.7 | 71.9 | 70.3 | 73.2 | 71.2 | 71.2 |
| Industrial solid waste | % | 57.9 | 57.9 | 57.9 | 57.9 | 57.9 | 55.9 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 | 57.2 |

- ***Proportions of $CH_4$ in Generated Gas (F)***

Default value (50%) given in the *2006 IPCC Guidelines* is used.

- ***Emission Factor (EF)***

Emission factors calculated by methodologies above are shown in Table 7-7.

Table 7-7 Emission factors by type of biodegradable waste and by treatment

| Item | Anaerobic landfill [kg-$CH_4$/t] | Semi-aerobic landfill [1)] [kg-$CH_4$/t] |
|---|---|---|
| Food waste | 145 | 72 |
| Paper/cardboard | 136 | 68 |
| Textiles (natural fiber) | 150 | 75 |
| Wood | 151 | 75 |
| Human waste treatment/*Johkasou* sludge | 133 | 67 |
| Tsunami sediment | 15 | NA |
| Digested sewage sludge | 100 | 50 |
| Other sewage sludge | 133 | 67 |
| Waterworks sludge | 20 | 10 |
| Organic sludge from manufacturing | 150 | 75 |
| Livestock waste | 133 | 67 |

Note:
1) Each emission factor indicated in the table are the values in the ideal condition of semi-aerobic landfill. (MCF=0.5).

- ***Activity Data***

Out of the amount of waste landfilled without incineration (dry basis), the amount of waste degraded within the reporting year is calculated by multiplying the amount of waste remaining in landfills at the end of the previous reporting year by the methane generation rate constant for waste landfilled. The amount of biodegradable MSW and IW are determined by type of waste and landfill site.

The amount of waste landfilled in each fiscal year is calculated by multiplying the amount of biodegradable waste landfilled (wet basis) by the percentage of landfill site by the type of site (wet basis), and subtracting the water content by each type of waste. Activity data are estimated going back as far as FY1954, when the Public Cleansing Law (now the Waste Management and Public Cleansing Act) was enforced.

$$A_{\mathrm{i,j}}(T) = W_{i,j}(T-1) \times (1 - e^{-k_i})$$
$$W_{i,j}(T) = W_{i,j}(T-1) \times e^{-k_i} + w_{i,j}(T)$$

$A_{i,j}(T)$ : Amount of waste *i* degraded in site *j* in the calculated year (year T) (activity data: dry basis) [t (dry)]
$W_{i,j}(T)$ : Amount of waste *i* remaining in site *j* in year T (dry basis) [t (dry)]
$w_{i,j}(T)$ : Amount of waste *i* landfilled into site *j* in year T (dry basis) [t (dry)]
$k_i$ : Methane generation rate constant of waste *i* [1/year]

Where,

$$w_{i,j}(T) = w_{i,wet}(T) \times S_j \times (1 - u_i)$$
$$k_i = \ln(2)/\mathrm{H_i}$$

$w_{i,wet}(T)$ : Amount of waste *i* landfilled in year T (wet basis) [t (wet)]
$S_j$ : Percentage of landfill site structure type *j* [%]
$u_i$ : Percentage of water content in waste *i* [%]
$H_i$ : Decomposition half-life of waste *i* (the time taken by landfilled waste *i* to reduce in amount by half) [year]

- ***Amount of Biodegradable Waste Disposed of in Landfills***

Table 7-8 shows the annual amount of biodegradable waste landfilled (dry basis) in Japan.

Table 7-8 Annual amount of biodegradable waste disposed of in landfills
(Total amount of anaerobic and semi-aerobic landfilling)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSW | | | | | | | | | | | | | | | |
| Food waste | kt / year (dry) | 424 | 272 | 196 | 78 | 30 | 30 | 27 | 22 | 21 | 18 | 16 | 13 | 13 | 13 |
| Paper/ cardboad | kt / year (dry) | 1,140 | 859 | 698 | 492 | 300 | 311 | 294 | 260 | 226 | 182 | 142 | 125 | 97 | 95 |
| Textiles (natural fiber) | kt / year (dry) | 59 | 46 | 34 | 67 | 4 | 3 | 5 | 4 | 3 | 3 | 3 | 2 | 1 | 1 |
| Wood | kt / year (dry) | 363 | 200 | 155 | 81 | 42 | 40 | 36 | 31 | 65 | 27 | 22 | 21 | 18 | 19 |
| Human waste treatment/ *Jokasou* sludge | kt / year (dry) | 78 | 51 | 46 | 47 | 17 | 20 | 14 | 15 | 10 | 8 | 7 | 8 | 9 | 12 |
| Ttsunami sediment[1)] | kt / year (dry) | NO | NO | NO | NO | NO | NO | 9 | 10 | 29 | NO | NO | NO | NO | NO |
| ISW | | | | | | | | | | | | | | | |
| Food waste | kt / year (dry) | 65 | 177 | 109 | 45 | 22 | 22 | 23 | 30 | 11 | 15 | 12 | 13 | 14 | 14 |
| Paper/ cardboad | kt / year (dry) | 102 | 125 | 137 | 89 | 44 | 31 | 37 | 32 | 16 | 17 | 12 | 15 | 11 | 11 |
| Textiles (natural fiber) | kt / year (dry) | 4 | 16 | 15 | 17 | 6 | 7 | 10 | 7 | 6 | 10 | 11 | 11 | 9 | 10 |
| Wood | kt / year (dry) | 465 | 490 | 235 | 230 | 125 | 145 | 149 | 106 | 111 | 116 | 124 | 110 | 129 | 129 |
| Digested sewage sludge | kt / year (dry) | 59 | 50 | 31 | 11 | 3 | 3 | 5 | 5 | 4 | 5 | 3 | 3 | 3 | 3 |
| Other sewage sludge | kt / year (dry) | 219 | 185 | 114 | 42 | 17 | 17 | 34 | 22 | 11 | 12 | 12 | 12 | 10 | 10 |
| Waterworks sludge | kt / year (dry) | 199 | 166 | 146 | 66 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 |
| Organic sludge from manufacturing industry | kt / year (dry) | 345 | 157 | 69 | 48 | 22 | 31 | 39 | 27 | 17 | 14 | 13 | 11 | 12 | 11 |
| Livestock waste | kt / year (dry) | 12 | 12 | 11 | 11 | 14 | 11 | 11 | 9 | 12 | 13 | 13 | 13 | 12 | 12 |

Note:

1) Disposal amount of tsunami sediment has increased in FY2013 compared to FY2012, since disaster waste by the 2011 earthquake has massively treated in FY2013 due to the activation of disaster restoration service. The final disposal of this tsunami sediment has finished in FY2013; therefore, the amount is accounted as 0 kt/year from FY2014 onward.

As indicated in Table 7-9, for the data sources for the amount of biodegradable waste landfilled by waste type, the *Cyclical Use of Waste Report*, and the *Sewage Statistics* are used.

The amount of biodegradable waste landfilled is estimated going back as far as FY1954, when the Public Cleansing Law (now the Waste Management and Public Cleansing Act) was enforced. The statistical survey of landfilling began in 1980s, and in the case that historical data on the amount of biodegradable waste landfilled are unavailable (primarily prior to FY1980), the data of the most current year available (primarily the data of FY1980) are applied. For the years where the data are unavailable even after FY1980, interpolated values are applied. For details, see Table 7-9.

Table 7-9 Overview of data for the amount of biodegradable waste disposed of in landfill

| Waste type | | | Data source | Detail | Historical data |
|---|---|---|---|---|---|
| Municipal solid waste | Food waste | | *Cyclical Use of Waste Report* (MOE) | - Amount directly landfilled<br>- Amount landfilled after intermediate treatment.<br><br>* For fraction of natural fiber in textiles for each year, see also the description for synthetic fiber in " 7.4.1.1. Municipal Solid Waste (5.C.1.-)". | - Estimated by interpolation for some fiscal years,<br>- Substituted FY1980 value for the years prior to FY1980 |
| | Paper/cardboard | | | | |
| | Wood | | | | |
| | Textiles (natural fiber) * | | | | |
| | Human waste treatment/*Johkasou* sludge | (Direct final disposal) | *Waste Management in Japan* (MOE) | Calculated by multiplying the amount of human waste sludge in "other treatment" (volume basis) by the weight-conversion factor (1.0 kg/L) | Substituted FY1978 value for the years prior to FY1978 |
| | | (Final disposal after treatment) | *Cyclical Use of Waste Report* (MOE) | Amount landfilled after intermediate treatment, excluding ash after incineration | For the years prior to FY1998, estimated by using the amount of direct final disposal human waste sludge |
| | Tsunami sediment | | *Waste Treatment in Japan* (MOE) | Direct final disposal of "Tsunami sediment" | Disposed from FY2011 |
| Industrial waste | Food waste (Animal and vegetable residues, Animal carcasses) | | *Cyclical Use of Waste Report* (MOE) | - Amount directly landfilled<br>- Amount landfilled after intermediate treatment, excluding ash after incineration by using reference data<br><br>* All textiles in industrial waste are considered to consist of natural fiber due to the Waste Management and Public Cleansing Act | - Estimated by interpolation for some fiscal years,<br>- Substituted FY1980 value for the years prior to FY1980 |
| | Paper/cardboard | | | | |
| | Wood | | | | |
| | Textiles (natural fiber) * | | | | |
| | Digested sewage sludge | | Data provided by MLIT | Compiled and provided by MLIT | - For some fiscal years, estimated by interpolation<br>- Substituted FY1985 value for the years prior to FY1985 |
| | Other sewage sludge | | *Sewage Statistics* (JSWA) | Total amount of sewage sludge excluding the amount of digested sewage sludge | |
| | Waterworks sludge | | *Waterworks Statistics* (Japan Water Works Association) | Estimated by "Total amount of soil disposed" and "landfilled percentage" of each purification plant | Substituted FY1980 value for the years prior to FY1980 |
| | Organic sludge from manufacturing | Paper industry | Data provided by Japan Paper Association, Japan Technical Association of the Pulp and Paper Industry | Total amount of organic sludge landfilled for papermaking industry | Substituted FY1989 value for the years prior to FY1989 |
| | | Chemical industry | *Survey of generation status of industry - specific by-products (industrial waste and recyclable waste)* (METI), etc. | Total amount of organic sludge landfilled for chemicals industry and food manufacturing industry | - For some fiscal years, estimated by interpolation<br>-For the years from FY2015 onward, estimated with the data from *Follow-up Action Result of the Voluntary Action Plan on the Environment* (Japan Business Federation) and the *Report on the State of Industrial Waste Generation and Treatment Survey* (MoEJ)<br>-For the years prior to FY1998, estimated with the data from *Follow-up Action Result of the Voluntary Action Plan on the Environment* (Japan Business Federation)<br>- Substituted FY1990 value for the years prior to FY1990 |
| | | Food manufacturing industry | | | |
| | Livestock waste | | Survey conducted by MOE | | Substituted FY1980 value for the years prior to FY1980 |

- ***Percentage of Water Content in Waste***

In Japan, activity data are estimated on a dry basis because the carbon content of waste can be identified more precisely. The percentages of water content by each type of waste to estimate activity data on a

dry basis and their sources are given in Table 7-10. In order to estimate the $CO_2$ emissions for the category "7.4.

Incineration and Open Burning of Waste (5.C.)" as well as this source category, dry basis activity are used for the same reason.

Table 7-10 Percentage of water content in waste disposed of in managed landfill sites

| Items | | | Intermediate treatment | Water content | Source |
|---|---|---|---|---|---|
| Municipal solid waste | Food waste | | Untreated | 75% | Water percentage of food waste in the *Cyclical Use of Waste Report* |
| | | | Treated | 30% | Specified by considering material flow |
| | Paper/cardboard | | (Unseparated) | 20% | Expert judgment |
| | Wood | | (Unseparated) | 45% | Expert judgment |
| | Textiles (natural fiber) | | (Unseparated) | 20% | Expert judgment |
| | Human waste treatment/*Johkasou* sludge | | Untreated | 85% | Moisture content standard of landfill standard (sludge) specified by enforcement ordinance of the Waste Management and Public Cleansing Act |
| | | | Treated | 70% | Expert judgment |
| | Tsunami sediment | | (Unseparated) | 45% | Substituted the value for wood by expert judgment |
| Industrial solid waste | Food waste | | Untreated | 75% | Water percentage of food waste in "*Cyclical Use of Waste Report*" |
| | | | Treated | Specific to each FY | Specified by considering material flow |
| | Paper/cardboard | | (Unseparated) | 15% | Expert judgment |
| | Wood | | (Unseparated) | 45% | Expert judgment |
| | Textiles (natural fiber) | | (Unseparated) | 15% | Expert judgment |
| | Sewage sludge | Digested sewage sludge | (Unseparated) | Specific to each disposal site | Average water content of "delivered or final disposal sludge" in the *Sewage Statistics* (JSWA) |
| | | Other sewage sludge | (Unseparated) | | |
| | Waterworks Sludge | | (Unseparated) | Not specified | Activity data on a dry basis are provided by the data sources |
| | Organic sludge from manufacturing industries | Paper industries | (Unseparated) | Not specified | |
| | | Chemical industries | (Unseparated) | 57% | Reference of Clean Japan Center Survey |
| | | Food manufacturing | (Unseparated) | 77% | |
| | Livestock waste | | Untreated | 83.1% | Japan Livestock Technology Association (2002) |
| | | | Treated | 70% | Expert judgment |

➢ ***Percentages of Landfill Sites by Site Structure Type***

- ***Percentages of MSW Landfill Sites by Site Structure Type***

Among the Japan's MSW disposal sites listed in the section "Facility by Type (Final Disposal Sites)" of the *Annual editions of Results of Study on Municipal Solid Waste Disposal* (Environmental Regeneration and Material Cycles Bureau of MOE) (hereinafter referred to as the *Results of Study on MSW Disposal*), landfill sites which have leachate treatment facilities and subsurface containment structures are regarded as semi-aerobic landfill sites, and the percentage of their total landfill capacity [$m^3$] is defined as the percentage of semi-aerobic landfill disposal volume.

Since the percentages of semi-aerobic landfill sites for the period FY1996 and before are not available, they are determined as indicated below:

- For the period FY1997 and after, they are determined based on actual data.
- For the period FY1977 and before, all the landfill sites including all the sea area landfills are considered to be anaerobic landfill sites since semi-aerobic landfill technology started in FY1977.
- For the period FY1977-1996, they are estimated by linear interpolation using actual data of FY1997 based on expert judgment.

- ***Percentages of IW Landfill Sites by Site Structure Type***

The percentages of landfill sites by site structure type for IW are determined as follows:

- For the period FY2008 and after, they are determined based on the *Survey of Industrial Waste Treatment Facilities* (MOE).
- For the period FY1977 and before, all the landfill sites including all the sea area landfills are considered to be anaerobic landfill sites since semi-aerobic landfill technology started in FY1977.
- For the period FY1990 -2007, they are estimated by using the total amount of waste landfilled and the actual data of waste deposited of in semi-aerobic landfill sites in FY2008.
- For the period FY1977-1989, they are estimated by linear interpolation using the data of FY1990 based on expert judgment.

Table 7-11 Percentages of landfill sites by site structure

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Municipal solid waste | | | | | | | | | | | | | | | |
| Anaerobic landfill | % | 74.2 | 64.2 | 54.4 | 43.5 | 36.5 | 36.1 | 38.7 | 33.1 | 39.9 | 28.4 | 29.0 | 29.6 | 36.6 | 36.6 |
| Semi-aerobic landfill | % | 25.8 | 35.8 | 45.6 | 56.5 | 63.5 | 63.9 | 61.3 | 66.9 | 60.1 | 71.6 | 71.0 | 70.4 | 63.4 | 63.4 |
| Industrial solid waste | | | | | | | | | | | | | | | |
| Anaerobic landfill | % | 90.2 | 81.1 | 66.4 | 48.3 | 36.9 | 47.0 | 36.7 | 28.5 | 30.0 | 35.0 | 37.7 | 33.4 | 33.4 | 33.4 |
| Semi-aerobic landfill | % | 9.8 | 18.9 | 33.6 | 51.7 | 63.1 | 53.0 | 63.3 | 71.5 | 70.0 | 65.0 | 62.3 | 66.6 | 66.6 | 66.6 |

- ***Decomposition Half-life***

Decomposition half-life is the time taken for 50% of waste landfilled in a certain year to be degraded from its initial mass. Conducting several actual measurements at the Central Breakwater Landfill Site in metropolitan Tokyo, the largest managed landfill for MSW in Japan at the time, Ito (1992) obtained a set of half-lives. Assuming this research was on a representative managed disposal site in Japan for temperate/boreal wet climate, the half-lives in his research for food waste, paper/cardboard, textiles (natural fiber), and wood are applied as country specific parameters (3, 7, 7, and 36 years respectively). Because no relevant research have been obtained to identify a country specific half-life for the sludge, the default value of 3.7 years provided in the spreadsheets attached to the *2006 IPCC Guidelines* is applied. The half-life for wood is used for the half-life of tsunami sediment as a substitute by expert judgment.

Table 7-12 Decomposition half-life for biodegradable waste

| Item | | Half-life [year] | Data source |
|---|---|---|---|
| Food waste [1)] | | 3 | Ito (1992) |
| Paper/cardboard | | 7 | |
| Textiles (natural fiber) | | 7 | |
| Wood [2)] | | 36 | |
| Sludge | Tsunami sediment | 36 | The half-life of wood is applied by expert judgment. |
| | Human waste treatment/*Johkasou* sludge | 3.7 | *2006 IPCC Guidelines* |
| | Digested sewage sludge | | |
| | Other sewage sludge | | |
| | Waterworks sludge | | |
| | Organic sludge from manufacturing | | |
| | Livestock waste | | |
| | Digested sewage sludge [3)] | | |

Note:

1) Ito (1992) identified the half-life for food waste that is shorter than the default value (4 years) for temperate/wet climate zone of the *2006 IPCC Guidelines*. This is considered to be the reason for that food waste in Japan is more rapidly degraded than theoretical waste the IPCC guidelines assume, since Japan's climate is warmer and more humid than typical temperate/wet climate assumed by the IPCC guidelines (MOE, 2006b).

2) Ito (1992) identified the half-life for wood that is longer than the default value (23 years) for temperate/wet climate zone of the *2006 IPCC Guidelines*. This is considered to be the reason for that meanwhile the IPCC default value covers wood and straw waste, the Japan's country specific parameter does only wood (MOE, 2006b).
3) Although livestock waste is not sludge on the "Wastes Disposal and Public Cleansing Act", the IPCC default half-life for sewage sludge is adopted as that of livestock waste since livestock waste has similar property of sewage sludge.

- ***Delay Time***

Delay time is the time lag from when the waste is landfilled until when the decomposition actually occurs. As no knowledge is obtained for making it possible to set a delay time specific to Japan, the default value (6 months) given in the *2006 IPCC Guidelines* is used.

Table 7-13 Amount of biodegraded waste decomposed in each year (Activity data)

| Item | | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. Anaerobic landfill | Mumicipal solid waste | Food waste | kt / year (dry) | 358 | 278 | 172 | 99 | 53 | 44 | 37 | 32 | 27 | 23 | 19 | 16 | 14 | 12 |
| | | Paper/cardboard | kt / year (dry) | 1,042 | 913 | 724 | 545 | 423 | 393 | 367 | 343 | 319 | 297 | 274 | 252 | 232 | 213 |
| | | Textiles (natural fiber) | kt / year (dry) | 54 | 48 | 38 | 31 | 25 | 23 | 21 | 19 | 18 | 16 | 15 | 13 | 12 | 11 |
| | | Wood | kt / year (dry) | 186 | 186 | 179 | 167 | 157 | 155 | 152 | 149 | 147 | 144 | 142 | 139 | 137 | 134 |
| | | Human waste treatment/ *Jokasou* sludge | kt / year (dry) | 96 | 66 | 44 | 29 | 20 | 17 | 16 | 14 | 12 | 11 | 10 | 8 | 7 | 7 |
| | | Ttsunami sediment | kt / year (dry) | NO | NO | NO | NO | NO | NO | NO | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| | Industrial solid waste | Food waste | kt / year (dry) | 69 | 102 | 117 | 74 | 38 | 32 | 28 | 24 | 21 | 17 | 15 | 12 | 11 | 10 |
| | | Paper/cardboard | kt / year (dry) | 137 | 138 | 121 | 99 | 80 | 74 | 68 | 63 | 58 | 53 | 49 | 44 | 41 | 37 |
| | | Textiles (natural fiber) | kt / year (dry) | 22 | 16 | 15 | 12 | 10 | 10 | 9 | 8 | 8 | 7 | 7 | 7 | 6 | 6 |
| | | Wood | kt / year (dry) | 224 | 261 | 258 | 247 | 235 | 232 | 228 | 225 | 221 | 218 | 214 | 211 | 208 | 205 |
| | | Digested sewage sludge | kt / year (dry) | 59 | 52 | 38 | 22 | 12 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 4 | 3 |
| | | Other sewage sludge | kt / year (dry) | 221 | 196 | 144 | 83 | 46 | 39 | 34 | 30 | 26 | 22 | 19 | 17 | 15 | 13 |
| | | Waterworks sludge | kt / year (dry) | 180 | 165 | 127 | 85 | 56 | 51 | 48 | 44 | 40 | 36 | 34 | 33 | 31 | 30 |
| | | Organic sludge from manufacturing industry | kt / year (dry) | 341 | 263 | 154 | 88 | 50 | 43 | 38 | 34 | 30 | 25 | 22 | 19 | 17 | 14 |
| | | Livestock waste | kt / year (dry) | 11 | 11 | 9 | 7 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| b. Semiaerobic landfill | Mumicipal solid waste | Food waste | kt / year (dry) | 70 | 94 | 90 | 81 | 51 | 45 | 39 | 35 | 31 | 27 | 24 | 21 | 19 | 17 |
| | | Paper/cardboard | kt / year (dry) | 119 | 191 | 232 | 262 | 254 | 248 | 243 | 237 | 231 | 222 | 214 | 203 | 192 | 180 |
| | | Textiles (natural fiber) | kt / year (dry) | 6 | 10 | 12 | 18 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| | | Woods | kt / year (dry) | 10 | 16 | 21 | 25 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 |
| | | Human waste treatment/ *Jokasou* sludge | kt / year (dry) | 14 | 18 | 20 | 22 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 10 | 10 | 9 |
| | Industrial solid waste | Food waste | kt / year (dry) | 4 | 15 | 36 | 39 | 26 | 23 | 21 | 19 | 20 | 17 | 16 | 14 | 13 | 12 |
| | | Paper/cardboard | kt / year (dry) | 6 | 12 | 21 | 31 | 35 | 35 | 33 | 32 | 31 | 29 | 28 | 26 | 24 | 23 |
| | | Textiles (natural fiber) | kt / year (dry) | 1 | 1 | 2 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | | Wood | kt / year (dry) | 6 | 15 | 20 | 27 | 33 | 34 | 35 | 36 | 37 | 37 | 38 | 39 | 39 | 40 |
| | | Digested sewage sludge | kt / year (dry) | 3 | 6 | 9 | 8 | 6 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 |
| | | Other sewage sludge | kt / year (dry) | 13 | 23 | 33 | 32 | 22 | 20 | 18 | 19 | 18 | 17 | 15 | 14 | 13 | 12 |
| | | Waterworks sludge | kt / year (dry) | 12 | 20 | 30 | 36 | 36 | 37 | 37 | 38 | 39 | 41 | 41 | 41 | 42 | 42 |
| | | Organic sludge from manufacturing industry | kt / year (dry) | 21 | 28 | 29 | 31 | 24 | 22 | 21 | 22 | 22 | 20 | 18 | 16 | 15 | 14 |
| | | Livestock waste | kt / year (dry) | 1 | 1 | 2 | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 7 | 7 | 7 | 7 |

Note: The declining trend in the amount of biodegraded waste is affected by the improvement of waste reduction that causes the decrease of landfilled waste.

- ***Amount of $CH_4$ recovered from Landfills***

In order to reduce the amount of organic matter content and $CH_4$ emissions at landfill sites, certain intermediate treatments and landfill methods have been conducted; $CH_4$ recovery from landfills is not very common practice in Japan. $CH_4$ recovery from landfilled MSW for the purpose of electric power generation implemented at the Tokyo Metropolitan Inner Landfill Site for the Central Breakwater Landfill Site is the sole practice example in Japan. For IW, there is no practice of $CH_4$ recovery from landfills implemented in Japan. Because $CO_2$ emitted from the combustion of recovered $CH_4$ is of biogenic-origin, it is not included in the total emissions.

$$R = r \times f \times 16/22.4/1000$$

Where:

*R* : Amount of $CH_4$ recovered in landfill [g]

*r* : Amount of recovered landfill gas used for electric power generation [$m^3$ N]

*f* : Ratio of $CH_4$ to recovered gas [-]

- ***The amount of recovered landfill Gas used for electric power generation in the Central Breakwater Landfill Site***

The amount of recovered gas used for electric power generation is provided by the Waste Disposal Management Office of Tokyo.

- ***Fraction of $CH_4$ to the recovered gas***

The fraction of $CH_4$ to recovered landfill gas in the Central Breakwater Landfill Site has been annually provided since FY2005 by the Waste Disposal Management Office of Tokyo. The fraction for the years prior to FY2005 are determined based on the hearing conducted with the Waste Disposal Management Office of Tokyo: 60% for FY1987, when the recovery of landfill gas was started; 40% for FY1996; interpolated for FY1988 through FY1995; The FY1996 value is used for FY1997 through FY2004.

Table 7-14 Amount of $CH_4$ used at landfill sites in Japan

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amount of landfill gas use | $km^3$ N | 1,985 | 2,375 | 2,372 | 140 | 1,154 | 1,266 | 1,032 | 1,681 | 1,734 | 1,612 | 1,565 | 1,488 | NO | NO |
| $CH_4$ ratio | % | 53.3 | 42.2 | 40.0 | 48.5 | 40.0 | 43.8 | 51.2 | 49.5 | 44.9 | 41.0 | 39.2 | 40.2 | NA | NA |
| Amount of $CH_4$ use | $km^3$ N | 1,059 | 1,003 | 949 | 68 | 462 | 555 | 528 | 832 | 779 | 661 | 613 | 598 | NO | NO |
| $CH_4$ unit conversion | Gg-$CH_4$ | 0.76 | 0.72 | 0.68 | 0.05 | 0.33 | 0.40 | 0.38 | 0.59 | 0.56 | 0.47 | 0.44 | 0.43 | NO | NO |

Note: The trend of landfill gas use significantly depends on the operation of the only power plant at the Central Breakwater Landfill Site. The operation of the power plant has stopped since the beginning of CY2017.

- ***$CH_4$ Oxidation Factor Related by Landfill Cover Soil***

Based on law enforcement ordinances and local government ordinances, daily, intermediate and final soil coverings are practiced in the managed final disposal sites for MSW and IW in Japan. Therefore, the default oxidation factor for managed landfill sites (0.1) is used in accordance with the *2006 IPCC Guidelines*.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainties in emission factors for municipal solid waste and industrial waste on the category are assessed by combining the uncertainties in carbon content, fraction of degradable organic carbon dissimilated, percentages of $CH_4$ in landfill gas, methane correction factor (MCF), and oxidation factor evaluated by using the 95% confidence interval obtained from actual measurement, or by expert judgment.

Regarding the uncertainty for activity data for this sector, due to the lack of information on statistical error in quoted references, it is difficult to assess uncertainties based on concrete evidence. Therefore, it is assessed by expert judgment as indicated in the Table 7-2. Details of the uncertainty assessment on this category are shown in the Table 7-15.

Table 7-15 Uncertainty assessment by waste type on the category "managed disposal sites (5.A.1.)"

| Item | | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Municipal waste | Food waste | $CH_4$ | -47% | +47% | -10% | +10% | -48% | +48% | The uncertainties in emission factors are evaluated by combining the 95% confidence interval of actual measurement data of carbon content, the uncertainty in fraction of degradable organic carbon dissimilated and proportion of methane in generated gas based on expert judgment, and the uncertainty in default value of MCF and oxidation factor provided by the *2006 IPCC Guidelines*, by using the formula for propagation of errors. (Method 1) | The uncertainty in municipal waste statistics based on expert judgment is applied. | Combined by using the formula for propagation of errors |
| | Paper/cardboard | $CH_4$ | -47% | +47% | -10% | +10% | -48% | +48% | | | |
| | Textiles | $CH_4$ | -47% | +47% | -10% | +10% | -48% | +48% | | | |
| | Wood | $CH_4$ | -47% | +47% | -10% | +10% | -48% | +48% | | | |
| | Human waste treatment/ *Johkasou* sludge | $CH_4$ | -49% | +49% | -10% | +10% | -50% | +50% | | | |
| | Tsunami sediment | $CH_4$ | -47% | +47% | -10% | +10% | -48% | +48% | The uncertainty in emission factor for wood is substituted, since the substance of tsunami sediment for estimation is assumed to be wood. | | |
| Industrial waste | Food waste | $CH_4$ | -47% | +47% | -30% | +30% | -56% | +56% | The uncertainty is evaluated by using method 1. | The uncertainty in industrial waste statistics based on expert judgment is applied. | Combined by using the formula for propagation of errors |
| | Paper/cardboard | $CH_4$ | -47% | +47% | -30% | +30% | -56% | +56% | | | |
| | Textiles | $CH_4$ | -47% | +47% | -30% | +30% | -56% | +56% | | | |
| | Wood | $CH_4$ | -47% | +47% | -30% | +30% | -56% | +56% | | | |
| | Sewage sludge | $CH_4$ | -49% | +49% | -5% | +5% | -49% | +49% | The uncertainty in emission factor is evaluated by using method 1.The uncertainty of carbon content in the method is evaluated based on expert judgment. | The uncertainty in the sewage statistics based on expert judgment is applied. | |
| | Waterworks sludge | $CH_4$ | -51% | +51% | -5% | +10% | -51% | +52% | The uncertainty is evaluated by using method 1. | The uncertainty in the waterworks statistics based on expert judgment is applied. | |
| | Organic sludge from manufacturing industries | $CH_4$ | -58% | +58% | -30% | +30% | -65% | +65% | The uncertainty in emission factor is evaluated by using method 1.The uncertainty of carbon content in the method is evaluated by expert judgment. | The uncertainty in industrial waste statistics based on expert judgment is applied. | |
| | Livestock waste | $CH_4$ | -51% | +51% | -30% | +30% | -59% | +59% | The uncertainty in emission factors is evaluated by using method 1. For the carbon content in the method, the uncertainty provided by the *2006 IPCC Guidelines* as default value is applied. | | |
| Methane recovery | | $CH_4$ | -10% | +10% | -10% | +10% | -14% | +14% | The uncertainty of Methane concentration in recovered gas is evaluated based on expert judgment. | The uncertainty in municipal waste statistics based on expert judgment is applied. | Combined by using the formula for propagation of errors |

- ***Time-series Consistency***

Although some activity data in FY1990 and thereafter are not available, they are estimated by using the methods described in "Activity data" to develop consistent time-series data. The emissions are calculated in a consistent manner.

#### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

#### *e) Category-specific Recalculations*

By updating the statistical data, emissions were recalculated. For detail, see the section "7.1.5. General Recalculations for Emissions from Waste Sector". See Chapter 10 for impact on trend.

#### *f) Category-specific Planned Improvements*

For future inventories, long-term efforts on further scientific investigations will be made to identify country-specific parameters (e.g. fraction of degradable organic carbon dissimilated for each type of biodegradable waste and country-specific half-life for sludge at final disposal sites).

### 7.2.2. Unmanaged Waste Disposal Sites (5.A.2.)

#### *a) Category Description*

Because landfill sites in Japan are appropriately managed pursuant to the Waste Management and Public Cleansing Act, there are no unmanaged waste disposal sites in Japan. Therefore, the emissions from this source category are reported as "NO".

### 7.2.3. Uncategorized Waste Disposal Sites (5.A.3.)

### 7.2.3.1. Inappropriate Disposal (5.A.3.-)

#### *a) Category Description*

In Japan, the definition of "inappropriate disposal" is waste disposal violating the Waste Management and Public Cleansing Act (illegal dumping and other forms of improper disposal on lands or areas other than landfill sites). Activities in the category of inappropriate disposal are identified as 1) illegal dumping, and 2) revealed matter; both are irregular events. The ratio of the amount of inappropriate waste disposal is quite small comparing to the one of appropriate waste disposal. Although these inappropriate disposal lands or areas generally satisfy the conditions of managed disposal sites defined in the *2006 IPCC Guidelines*, $CH_4$ emissions from inappropriate disposal are reported under "Uncategorized waste disposal sites (5.A.3.)".

Very few fires are observed in inappropriate landfill sites, and they may be emitting fossil-fuel derived $CO_2$. However, since actual data are not available, the emissions from the fires at inappropriate landfill sites are reported as "NE".

#### *b) Methodological Issues*

- ***Estimation Method***

Wood and paper/cardboard are the wastes containing biodegradable carbon and being inappropriately disposed without incineration; however, only wood is the subject for the estimation, because the residual amount of paper/cardboard should be very small.

In a similar manner for the "Managed Disposal Sites (5.A.1.)", a FOD method with Japan's country-specific parameters is used for the estimation. Emissions are estimated by multiplying the amount of wood (dry basis) degraded in a reporting year by an emission factor. Since the condition of $CH_4$ emissions from inappropriate disposal is unidentified, it is regarded as almost the same as for the anaerobic landfill.

- ***Emission Factor***

Adopting 1.0 of methane correction factor for anaerobic decomposition and 45.2% of fraction of carbon content in wood, the same emission factor as shown in Table7-7 is used for the anaerobic disposal sites for "wood emissions from managed disposal sites".

- ***Activity Data***

Activity data (dry basis) is obtained by subtracting the water content from the residual amount of inappropriately disposed wood (wet basis) and multiplied by methane generation rate constant. The amount of inappropriately disposed wood is provided by "Wood (Construction and Demolition)" in the *Study on Residual Amounts of Industrial Waste from Illegal Dumping and other Sources* (Environmental Regeneration and Material Cycles Bureau, MOE). The percentage of water content and the methane generation rate constant used for estimating emissions from wood in managed disposal sites are also used for this source.

Table 7-16 Inappropriately disposed wood to be degraded in each estimation year (dry basis)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity data | kt (dry) | 2.3 | 5.5 | 16.3 | 16.3 | 14.7 | 14.7 | 14.5 | 14.4 | 13.6 | 12.7 | 12.2 | 12.3 | 11.9 | 10.3 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainties in emission factor and activity data are evaluated by using the same methods that are used for "Managed Disposal Sites (5.A.1.)". Details of the uncertainty assessment on this category are shown in the Table 7-17.

Table 7-17 Uncertainty assessment on the category "inappropriate disposal sites (5.A.3.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Inappropriately disposed waste | $CH_4$ | -42% | +41% | -60% | +60% | -74% | +73% | The uncertainty in emission factor for wood is substituted, since the source for estimation is assumed to be wood. | The twofold higher uncertainty than the value in industrial waste statistics is applied based on expert judgment. | Combined by using the formula for propagation of errors |

- ***Time Series Consistency***

Because data on inappropriate disposal are available only since FY2002, activity data prior to FY2002 are estimated. The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Due to the removals of inappropriate disposal, revelations of past inappropriate disposal, and etc., the amount of identified inappropriate disposal in the past has been updated annually. Due to the changes in the amount of inappropriate disposal, emissions were recalculated. See chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

For future inventories, long-term efforts on further scientific investigations will be made to identify country-specific parameters.

## 7.3. Biological Treatment of Solid Waste (5.B.)

In this category, $CH_4$ and $N_2O$ emissions from biological treatment of solid waste are calculated. The target categories are shown in Table 7-18.

Table 7-18 Categories whose emissions are estimated for biological treatment of solid waste (5.B.)

| Category | Waste type | | Category to be allocated to CRF | Treatment type | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|
| 5.B.1. (7.3.1) | Municipal solid waste | Food waste | Municipal solid waste (excl. human waste) | Composting | ○ | ○ |
| | | Paper/cardboard | | | | |
| | | Textile | | | | |
| | | Wood (garden and park waste) | | | ○ | ○ |
| | | Human waste/*Johkasou* sludge | Human waste | | ○ | ○ |
| | Industrial waste | Food waste (animal and vegetable residues, other food waste) | Food waste (industrial waste) | | ○ | ○ |
| | | Sewage sludge | Sewage sludge | | ○ | ○ |
| 5.B.2. (7.3.2) | - | | - | Anaerobic digestion | NE | NO |

Estimated greenhouse gas emissions from this category are shown in Table 7-19. In FY2018, emissions from this source category are 385 kt-$CO_2$ eq. and accounted for 0.03% of the national total emissions (excluding LULUCF). The emissions from this source category had increased by 64.0% compared to those in FY1990. This emission increase is primarily due to the enhancement of effective utilization of waste as recycled resources. While Japan adopts country-specific emission factors (wet basis) in this category, due to low variation in time series of waste composition for composting, the IEFs for whole category are stable (approximately 2.8 kg-$CH_4$/t [dry] and 0.78-0.79 kg-$N_2O$/t [dry]).

Table 7-19 GHG emissions from biological treatment of solid waste (5.B.)

| Gas | Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 5.B.1. Composting | Municipal solid waste (excl. human waste) | kt-$CH_4$ | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |
| | | Human waste | kt-$CH_4$ | NO | NO | NO | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Food waste (industrial waste) | kt-$CH_4$ | 2.0 | 2.0 | 2.0 | 3.6 | 3.9 | 3.4 | 3.8 | 3.8 | 3.7 | 3.7 | 3.8 | 3.8 | 3.3 | 3.3 |
| | | Sewage sludge | kt-$CH_4$ | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 5.B.2. Anaerobic digestion at biogas facilities | | kt-$CH_4$ | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| | Total | | kt-$CH_4$ | 2.2 | 2.1 | 2.2 | 3.8 | 4.2 | 3.7 | 4.1 | 4.1 | 4.0 | 4.0 | 4.1 | 4.1 | 3.6 | 3.6 |
| | | | kt-$CO_2$ eq. | 54 | 53 | 54 | 95 | 106 | 93 | 102 | 101 | 100 | 100 | 102 | 103 | 90 | 89 |
| $N_2O$ | 5.B.1. Composting | Municipal solid waste (excl. human waste) | kt-$N_2O$ | 0.02 | 0.01 | 0.01 | 0.02 | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 |
| | | Human waste | kt-$N_2O$ | NO | NO | NO | 0.00 | 0.02 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | Food waste (industrial waste) | kt-$N_2O$ | 0.56 | 0.56 | 0.56 | 1.01 | 1.09 | 0.96 | 1.06 | 1.06 | 1.05 | 1.04 | 1.06 | 1.07 | 0.93 | 0.92 |
| | | Sewage sludge | kt-$N_2O$ | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.04 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |
| | 5.B.2. Anaerobic digestion at biogas facilities | | kt-$N_2O$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Total | | kt-$N_2O$ | 0.61 | 0.60 | 0.61 | 1.07 | 1.19 | 1.04 | 1.15 | 1.14 | 1.12 | 1.12 | 1.14 | 1.15 | 1.00 | 0.99 |
| | | | kt-$CO_2$ eq. | 181 | 179 | 181 | 319 | 354 | 309 | 342 | 338 | 335 | 333 | 340 | 343 | 298 | 296 |
| Total | | | kt-$CO_2$ eq. | 235 | 233 | 235 | 414 | 460 | 402 | 444 | 440 | 435 | 433 | 441 | 446 | 388 | 385 |

### 7.3.1. Composting (5.B.1)

#### *a) Category Description*

Part of the MSW and industrial waste generated in Japan is composted, and $CH_4$ and $N_2O$ generated in that process are emitted from composting facilities. Emissions from composting of livestock waste are reported under "5.3. Manure management (3.B)" in the agriculture sector.

#### *b) Methodological Issues*

- ***Estimation Method***

Emissions are calculated by taking the amount of organic waste composted, which is obtained from the statistical information available in Japan, and multiplying it by country-specific emission factors. The calculation method is the same for both $CH_4$ and $N_2O$ emissions.

$$E = \sum_i EF_i \times A_i$$

$E$ : Amount of $CH_4$ or $N_2O$ emissions generated by composting organic waste [kg-$CH_4$], [kg-$N_2O$]

$EF_i$ : Emission factor for organic waste i (wet basis) [kg-$CH_4$/t], [kg-$N_2O$/t]

$A_i$ : Amount of composted organic waste i (wet basis) [t]

- ***Emission Factor***

Country-specific emission factors obtained from actual measurements at 9 facilities in summer and winter by MOE (2018a) are adopted (MOE, 2018b).

Table 7-20 GHG emission factors for composting (5.B.1) (wet basis)

| Waste type | | $CH_4$ emission factor [kg-$CH_4$/t] | $N_2O$ emission factor [kg-$N_2O$/t] | Note |
|---|---|---|---|---|
| MSW | Wood (garden and park waste) | 0.35 | 0.0015 | Low compostable |
| | Food waste | 0.96 | 0.27 | High compostable |
| | Paper/cardboard | | | |
| | Textile | | | |
| | Human waste/*Johkasou* sludge | | | |
| ISW | Food waste (animal and vegetable residues, other food waste) | | | |
| | Sewage sludge | | | |

Note: Since management practice in Japanese composting facilities includes turning over compost regularly or blowing air into the lower part of fermentation tanks to keep aerobic conditions, the country-specific $CH_4$ emission factors are lower than the default value in the 2006 *IPCC Guidelines*. Also, since wood (garden and park waste) has a lower biodegradability than sludge or food waste etc., the emission factors of both $CH_4$ and $N_2O$ for wood are lower.

- ***Activity Data***

Activity data for the category composting (5.B.1) are obtained from the data sources shown on the Table 7-21.

Table 7-21 Sources of activity data for composting (5.B.1)

| Waste type | | Data source | Note |
|---|---|---|---|
| MSW | Food waste | - *Waste Treatment in Japan* (MOE)<br>- *Cyclical Use of Waste Report* (MOE) | Amount of MSW treated at waste composting facilities indicated in the *Waste Treatment in Japan*, is disaggregated by using MSW composition treated at high-rate composting facilities provided in the *Cyclical Use of Waste Report*. |
| | Paper/cardboard | | |
| | Textile | | |
| | Wood (garden and park waste) | | |
| | Human waste/*Johkasou* sludge | *Waste Treatment in Japan* (MOE) | |
| ISW | Food waste (animal and vegetable residues, other food waste) | *Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics* (MOE) | This category includes;<br>- Animal and vegetable residues generated by food and beverage manufacturing.<br>- Food waste including valuables other than the above: although under the Waste Management and Public Cleansing Act, they fall under the category of industrial waste, it is included in industrial waste because of its source and properties. |
| | Additives (e.g. wood, etc.) | Expert judgment | Estimated by using additive ratio of 30% in food waste, derived from expert judgment referring to the *Cyclical Use of Waste Report*. |
| | Sewage sludge | *Sewage Statistics* (JSWA) | |
| | Additives (e.g. wood, etc.) | Data provided by MLIT | |

Activity data (wet basis) obtained is shown on the Table 7-22. As for the activity data (dry basis) reported on the CRF tables is calculated by using percentages of water content shown on the Table 7-10; in case the ratio is separated, percentages for untreated waste are applied.

Table 7-22 Amounts of composted waste (wet basis)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Municipal solid waste | | | | | | | | | | | | | | | |
| Food waste | kt (wet) | 35 | 20 | 29 | 66 | 108 | 117 | 143 | 120 | 121 | 115 | 122 | 134 | 141 | 132 |
| Paper/cardboard | kt (wet) | 28 | 16 | 23 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Textile | kt (wet) | 3 | 2 | 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Wood (garden and park waste) | kt (wet) | 8 | 5 | 4 | 33 | 44 | 48 | 41 | 40 | 45 | 60 | 60 | 85 | 84 | 80 |
| Human waste/*Johkasou* sludge | kt (wet) | NO | NO | NO | 4 | 58 | 17 | 15 | 21 | 19 | 25 | 35 | 30 | 21 | 21 |
| Industrial solid waste | | | | | | | | | | | | | | | |
| Food waste (incl. additive) | kt (wet) | 2,063 | 2,063 | 2,063 | 3,747 | 4,051 | 3,564 | 3,923 | 3,920 | 3,883 | 3,861 | 3,923 | 3,973 | 3,439 | 3,421 |
| Sewage sludge (incl. additive) | kt (wet) | 118 | 126 | 135 | 147 | 186 | 144 | 168 | 145 | 136 | 139 | 140 | 129 | 105 | 105 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainty in emission factors are evaluated according to the survey for EFs (MOE, 2018a). As for the uncertainty in activity data, since valuables account for much of activity data in biological treatment, the uncertainty for valuables indicated in Table 7-2 is adopted for activity data based on expert judgment. Details of the uncertainty assessment on this category are indicated in the Table 7-23.

Table 7-23 Uncertainty assessment on the category "composting (5.B.1.)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Composting | $CH_4$ | -79% | +79% | -30% | +30% | -84% | +84% | The uncertainty is evaluated according to the survey for the EFs (MOE, 2018a) | The uncertainty in valuables based on expert judgment is applied since AD mostly consists of valuables. | Combined by using the formula for propagation of errors |
| | $N_2O$ | -167% | +167% | -30% | +30% | -170% | +170% | | | |

- ***Time-series Consistency***

Since the amount of composted animal and plant residues generated by food manufacturing and food waste other than those for FY1990-2000 are unavailable, the data for FY2001 are used for those years. Since the data of the amount of additives (e.g. wood, etc.) to be added to sewage sludge treated at composting facilities for FY1990-1995 are unavailable, those data are estimated by multiplying the sewage sludge for FY1990-1995 by the ratio of additives for FY1996; thus, time series consistency in emission estimates has been ensured.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By updating the statistical data, emissions were recalculated. For detail, see the section "7.1.5. General Recalculations for Emissions from Waste Sector". See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

The implementation of emission estimates from domestic and commercial composting machine will be further considered. Because this kind of research could not be completed in a short period of time, a long-term effort on scientific investigations will be necessary.

## 7.3.2. Anaerobic Digestion at Biogas Facilities (5.B.2.)

### *a) Category Description*

- ***Biogas facilities in Japan***

As biogas facilities to be considered in this category, anaerobic digestion equipment at sewage treatment plants, biogas facilities for municipal waste, and biogas facilities for industrial waste are operated in Japan.

- ***Anaerobic digestion equipment for sewage sludge at sewage treatment plants***

JSWA (2009) states that, digestion tanks for sludge at sewage treatment plants should be kept air tight to prohibit explosions and odors caused by biogas leakage. It also states that unutilized digestion gas from these equipment should be combusted in views of safety and climate change mitigation. In addition, Japan estimates $CH_4$ and $N_2O$ emissions from sludge thickening tank and dehydration room by using

emission factors considering whole treatment system including these processes; $CH_4$ and $N_2O$ emissions from this source stated in the *2006 IPCC Guidelines* are included in "5.D.1. domestic wastewater".

- ***Biogas facilities for municipal waste***

MOE (2008) states that fermentation equipment at biogas facilities for municipal waste should be kept air tight. It also states that biogas from these equipment should be combusted by the excess gas combustion system and discharged safely when the facilities cannot supply biogas to consumers in emergencies or maintenances.

- ***Biogas facilities for industrial waste***

Although biogas facilities for industrial waste are not controlled by the guidelines such as for these for municipal waste, operators ought to keep air tight at the facilities in their installations as a safety measure.

- ***Emission estimates***

Biogas facilities in Japan for municipal waste and industrial waste are leaking small amounts of $CH_4$. By assuming 2% of the leakage fraction of biogas produced in a facility (a consideration of actual situation of the $CH_4$ emission) and 60% of the $CH_4$ concentration in biogas (the *JARUS Reference System for Information of Biomass Recycling Technology*, The Japan Association of Rural Resource Recycling Solutions), the $CH_4$ emissions from this source category were tentatively estimated as 1.4 [kt-$CO_2$ eq. per year] at a maximum. Hence the emissions from this source category are reported as "NE" which stands for "considered insignificant" guided by the decision tree on the Figure A5-2 of Annex 5.

Assumed to be negligible in accordance with the *2006 IPCC Guidelines*, $N_2O$ emission from this source category are reported as "NO".

## 7.4. Incineration and Open Burning of Waste (5.C.)

In Japan, waste disposed of has been reduced in volume primarily by incineration. Emissions from waste incineration are categorized as shown in Table 7-24. $CO_2$, $CH_4$, $N_2O$ emissions from "7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)" and "7.4.2. Open Burning of Waste (5.C.2.)" are reported under this category.

Table 7-24 Categories whose emissions are estimated for waste incineration and open burning (5.C.)

| Category | Waste type | | | Category to be allocated to CRF | Treatment type | | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|
| 5.C.1 (7.4.1) | Municipal solid waste (7.4.1.1) | Plastics | Fossil-fuel derived plastics | Non-biogenic/MSW | Incineration without energy recovery | Incinerator -continuous -semi-continuous -batch type<br>Gasification melting furnace | ○ | ○[2)] | ○[2)] |
| | | | Biomass-based plastics | Biogenic/MSW | | | NA[1)] | | |
| | | Paper/ cardboard | Fossil-fuel derived fraction | Non-biogenic/MSW | | | ○ | | |
| | | | Biogenic fraction | Biogenic/MSW | | | NA[1)] | | |
| | | Nappy (Fossil-fuel derived fraction) | | Non-biogenic/MSW | | | ○ | | |
| | | Textiles | Synthetic textile | Non-biogenic/MSW | | | ○ | | |
| | | | Natural fiber | Biogenic/MSW | | | NA[1)] | | |
| | | Other (Biogenic) | | Biogenic/MSW | | | NA[1] | | |
| | Industrial waste (7.4.1.2) | Waste oil | Fossil-fuel derived oil | Non-biogenic/ Fossil liquid waste | | Incinerator | ○ | ○ | ○ |
| | | | Animal and vegetable oil | Biogenic/ Non- fossil liquid waste | | | NA[1)] | ○ | ○ |
| | | Plastics | Fossil-fuel derived plastics | Non-biogenic/ISW | | | ○ | ○ | ○ |
| | | | Biomass-based plastics | Biogenic/ISW | | | NA[1)] | IE[3)] | IE[3)] |
| | | Food waste [Animal and vegetable residues/animal carcasses] | | Biogenic/ISW | | | NA[1)] | ○ | ○ |
| | | Paper/ cardboard | Fossil-fuel derived fraction | Non-biogenic/ISW | | | ○ | IE[4)] | IE[4)] |
| | | | Biogenic fraction | Biogenic/ISW | | | NA[1)] | ○ | ○ |
| | | Wood | | Biogenic/ISW | | | NA[1)] | ○ | ○ |
| | | Textile | Synthetic textile | - | | | IE[3)] | IE[3)] | IE[3)] |
| | | | Natural fiber | Biogenic/ISW | | | NA[1)] | ○ | ○ |
| | | Sludge | Sewage sludge | Biogenic/Sludge | | Various types of incinerations [5)] | NA[1)] | ○ | ○ |
| | | | Other than sewage sludge | Biogenic/Sludge | | Incinerator | NA[1)] | ○ | ○ |
| | Specially controlled industrial waste (7.4.1.3) | Waste oil | Flammable waste oil | Non-biogenic/ Hazardous waste | | | ○ | ○ | ○ |
| | | | Specified hazardous waste oil | Non-biogenic/ Hazardous waste | | | ○ | ○ | ○ |
| | | Infectious waste | Plastics (Fossil-fuel derived) | Non-biogenic/ Clinical waste | | | ○ | ○ | ○ |
| | | | Other (except plastics) | Biogenic/ Clinical waste | | | NA[1)] | ○ | ○ |
| 5.C.2 (7.4.2) | Municipal solid waste (7.4.2.1) | | | - | Open burning | | NO | NO | NO |
| | Industrial waste (7.4.2.2) | Plastics (Fossil-fuel derived) | | Non-biogenic/ISW | | | ○ | ○ | ○ |
| | | Other (Biogenic) | | Biogenic/ISW | | | NA[1)] | IE[6)] | IE[6)] |

Note:

1) $CO_2$ emissions from the incineration of biomass-derived waste are not included in the total emissions in accordance with the *2006 IPCC Guidelines*; instead it is estimated as a reference value and reported under "Biogenic" in Table 5.C of the CRF.
2) $CH_4$ and $N_2O$ emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported under "Non-biogenic/MSW" in Table 5.C of the CRF.
3) Included in fossil-fuel derived plastics in industrial solid waste (ISW)
4) Included in biogenic fraction of paper/cardboard
5) For details of incineration types for sewage sludge, see section 7.4.1.2.
6) $CH_4$ and $N_2O$ emissions from open burning of industrial solid waste in bulk are reported under "Non-biogenic/ISW".

Also, waste incineration includes the following practices of waste used as raw material or fuel:

- Waste Incineration with Energy Recovery (1.A.) (See section 7.4.3.1. )
- Direct Use of Waste as Alternative Fuel (1.A.) (See section 7.4.3.2. )
- Incineration of Waste Processed as Fuel (1.A.) (See section 7.4.3.3. )

In accordance with the *2006 IPCC Guidelines*, estimated emissions from the sources listed above are allocated to Energy sector (Category 1) as "7.4.3. Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)". For details of reporting category on energy sector, see Table 7-26.

In order to avoid double-counting or any other confusion, emissions from the categories indicated in Table 7-24, Table 7-25 and Table 7-26 with or without energy use are estimated collectively under the waste sector, thus the estimation methodology for these categories are provided in this section.

Table 7-25 Waste types whose emissions are estimated for "Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)"

| Category | Waste type | | | Fuel type on energy sector to be allocated to CRF | Treatment type | | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|
| 1.A.1. (7.4.3.1) [7] | Municipal solid waste | Plastics | Fossil-fuel derived plastics | Other fossil fuels | Incineration with energy recovery | ・Incinerator -continuous, -semi-continuous -batch type<br>・Gasification melting furnace | ○ | ○[2] | ○[2] |
| | | | Biomass-based plastics | Biomass[8] | | | NA[1] | | |
| | | Paper/ cardboard | Fossil-fuel derived fraction | Other fossil fuels[9] | | | ○ | | |
| | | | Biogenic fraction | Biomass | | | NA[1] | | |
| | | Nappy (Fossil-fuel derived fraction) | | Other fossil fuels | | | ○ | | |
| | | Textiles | Synthetic textile | Other fossil fuels | | | ○ | | |
| | | | Natural fiber | Biomass | | | NA[1] | | |
| | | Other (biogenic) | | Biomass | | | NA[1] | | |
| | Industrial waste | Waste oil | Fossil-fuel derived oil | Other fossil fuels | | Incinerator | ○ | ○ | ○ |
| | | | Animal and vegetable oil | Biomass | | | NA[1] | ○ | ○ |
| | | Plastics | Fossil-fuel derived plastics | Other fossil fuels | | | ○ | ○ | ○ |
| | | | Biomass-based plastics | Biomass[8] | | | NA[1] | IE[3] | IE[3] |
| | | Food waste [Animal and vegetable residues/animal carcasses] | | Biomass | | | NA[1] | ○ | ○ |
| | | Paper/ cardboard | Fossil-fuel derived fraction | Other fossil fuels[9] | | | ○ | IE[4] | IE[4] |
| | | | Biogenic fraction | Biomass | | | NA[1] | ○ | ○ |
| | | Wood | | Biomass | | | NA[1] | ○ | ○ |
| | | Textile | Synthetic textile | - | | | IE[5] | IE[5] | IE[5] |
| | | | Natural fiber | Biomass | | | NA[1] | ○ | ○ |
| | | Sludge | Sewage sludge | - | | | NO | NO | NO |
| | | | Other than sewage sludge | Biomass | | | NA[1] | ○ | ○ |
| | Specially controlled industrial waste | | | - | | | IE[5] | IE[5] | IE[5] |
| 1.A.1/2 (7.4.3.2) [7] | Municipal solid waste | Plastics | Fossil-fuel derived plastics | Other fossil fuels | Direct use as alternative fuel | | ○ | ○ | ○ |
| | | | Biomass-based plastics | Biomass[8] | | | NA[1] | IE[3] | IE[3] |
| | Industrial waste | Waste oil | Fossil-fuel derived oil | Other fossil fuels | | | ○ | ○ | ○ |
| | | | Animal and vegetable oil | Biomass | | | NA[1] | ○ | ○ |
| | | Plastics | Fossil-fuel derived plastics | Other fossil fuels | | | ○ | ○ | ○ |
| | | | Biomass-based plastics | Biomass[8] | | | NA[1] | IE[3] | IE[3] |
| | | Wood | | Biomass | | | NA[1] | ○ | ○ |
| | Waste tire | | Fossil-fuel derived fraction | Other fossil fuels | | | ○ | ○ | ○ |
| | | | Biogenic fraction | Biomass[8] | | | NA[1] | IE[6] | IE[6] |
| 1.A.1/2 (7.4.3.3) [7] | Refuse Derived Fuel (RDF) | | Fossil-fuel derived fraction | Other fossil fuels | Incineration of waste processed as fuel | | ○ | ○ | ○ |
| | | | Biogenic fraction | Biomass[8] | | | NA[1] | IE[6] | IE[6] |
| | Refuse Paper and Plastic Fuel (RPF) | | Fossil-fuel derived fraction | Other fossil fuels | | | ○ | ○ | ○ |
| | | | Biogenic fraction | Biomass[8] | | | NA[1] | IE[6] | IE[6] |

Note:

1) $CO_2$ emissions from the incineration of biomass-derived waste are not included in the total emissions; instead it is estimated as a reference value and reported as "Biomass" fuel in the CRF tables.
2) $CH_4$ and $N_2O$ emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported as "Other fossil fuels" in the CRF tables.
3) Included in fossil-fuel derived plastics in ISW
4) Included in biogenic fraction of paper/cardboard
5) Included in "Specially-controlled industrial waste" incineration without energy recovery
6) Included in the fossil-fuel derived fraction
7) For details of categories to be reported in the CRF, see Table 7-26.
8) For the biomass fraction in solid waste, etc. such as plastics, waste tire, RPF and RDF, it is difficult to distinguish the activity data on calorie basis for energy sector from the fossil-fuel derived fraction since there are no appropriate way to decompose calorimetric data of mixed solid waste. Hence, the activity data is reported as "IE", and is included in "other fossil fuels".
9) For the fossil-fuel derived fraction in "paper/cardboard", it is difficult to distinguish the activity data on calorie basis for energy sector from the biogenic fraction. Hence, the activity data is reported as "IE", and is included in "biomass".

Table 7-26 Reporting categories for waste incineration and energy use emissions (reported in the energy sector) (1.A.)

| Treatment type | Waste type | | Application breakdown | Major application | Reporting category on the energy sector | $CO_2$[2)] | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|
| Waste incineration with energy recovery | MSW | | (Unclassified) | Waste incineration with energy recovery | 1.A.4.a. Commercial/institutional | ○ | ○ | ○ |
| | Industrial waste | | | | | ○ | ○ | ○ |
| Direct use of waste as alternative fuel | MSW | Plastics | Liquefaction | Fuel | 1.A.2.g. Other | ○ | ○ | ○ |
| | | | Blast furnace reducing agent | Reducing agent in blast furnace | 1.A.2.a. Iron & steel | ○ | NO[3)] | NO[3)] |
| | | | Coke oven chemical feedstock | Raw material in coke oven | 1.A.1.c. Manufacture of solid fuels and other energy industries | ○ | IE[4)] | NO[5)] |
| | | | Gasification | Fuel | 1.A.2.g. Other | ○ | NE[6)] | NE[6)] |
| | Industrial waste | Waste oil | (Unclassified) | Fuel | 1.A.2.g. Other | ○ | ○ | ○ |
| | | Plastics | Blast furnace reducing agent | Blast furnace reducing agent | 1.A.2.a. Iron & steel | ○ | NO[3)] | NO[3)] |
| | | | Chemical industry | boiler fuel | 1.A.2.c. Chemicals | ○ | ○ | ○ |
| | | | Paper industry | boiler fuel | 1.A.2.d. Pulp, paper and print | ○ | ○ | ○ |
| | | | Cement burning | Cement burning | 1.A.2.f. Non-metallic minerals | ○ | ○ | ○ |
| | | | Automobile manufacturer | boiler fuel | 1.A.2.g. Other | ○ | ○ | ○ |
| | | | Liquefaction | Fuel | 1.A.2.g. Other | ○ | ○ | ○ |
| | | | Gasification | Fuel | 1.A.2.g. Other | ○ | NE[6)] | NE[6)] |
| | | Wood | (Unclassified) | Fuel | 1.A.2.g. Other | NA | ○ | ○ |
| | Waste tire | | Cement burning | Cement burning | 1.A.2.f. Non-metallic minerals | ○ | ○ | ○ |
| | | | Boiler | Fuel | 1.A.2.g. Other | ○ | ○ | ○ |
| | | | Iron manufacture | Raw materials in iron manufacturing | 1.A.2.a. Iron & steel | ○ | NO[3)] | NO[3)] |
| | | | Gasification | Fuel in iron manufacturing | 1.A.2.a. Iron & steel | ○ | ○ | ○ |
| | | | Metal refining | Fuel in metal refining | 1.A.2.b. Non-ferrous metals | ○ | ○ | ○ |
| | | | Tire manufacture | Fuel in tire manufacturing | 1.A.2.c. Chemicals | ○ | ○ | ○ |
| | | | Paper manufacture | Fuel in paper manufacturing | 1.A.2.d. Pulp, paper and print | ○ | ○ | ○ |
| | | | Power generation | Power generation | 1.A.4.a. Commercial/institutional | ○ | ○ | ○ |
| Incineration of waste processed as fuel | Refuse-derived fuel (RDF) | | (Unclassified) | Fuel use (including power generation) | 1.A.2.g. Other [1)] | ○ | ○ | ○ |
| | Refuse Paper and Plastic fuel (RPF) | | Petroleum product manufacturer | boiler fuel | 1.A.1.b. Petroleum refining | ○ | ○ | ○ |
| | | | Chemical industry | boiler fuel | 1.A.2.c. Chemicals | ○ | ○ | ○ |
| | | | Paper industry | Fuel use in paper manufacturing | 1.A.2.d. Pulp, paper and print | ○ | ○ | ○ |
| | | | Cement manufacturer | Cement burning | 1.A.2.f. Non-metallic minerals | ○ | ○ | ○ |

Note:

1) Emissions from power generation and heat supply excluding in-house use should be included in the category 1.A.4.a. However, they are reported in the category 1.A.2.g., because the actual circumstances are not understood at the moment.
2) $CO_2$ emissions from the incineration of biomass-derived fraction are not included in the total emissions; instead it is estimated as a reference value and reported as “Biomass” fuel in the CRF tables. For detail, see Table 7-25 .
3) Blast furnace gas generated from steel industry is entirely recovered.
4) These emissions are included in “solid fuels” in same category 1.A.1.c.
5) $N_2O$ is likely not produced since the atmosphere in coke oven is normally at least 1,000 degree Celsius, and reducing.
6) Considering that small fraction of these sources is combusted as alternative fuel but these are mostly used to obtain feedstock for ammonia productions, the emissions are not estimated.

Estimated greenhouse gas emissions from waste incineration (category 5.C.) are shown in Table 7-27. In FY2018, emissions from waste incineration are 11,678 kt-$CO_2$ eq. and accounted for 0.9% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 16.0% compared to those in FY1990. For the period FY1990-FY1997, $CO_2$ emissions increased as the practice of intermediate treatment by waste incineration increased in order to decrease the total volume of waste landfilled. From FY2001 onwards, as the use of waste as raw material or fuel has been replacing the incineration of fossil-origin waste for intermediate treatments, and these $CO_2$ emissions which used to be allocated to the waste sector is now allocated to the Energy sector, $CO_2$ emission estimates from

the waste sector decreased. The trend in the IEFs of $CO_2$ for this category is basically stable and range from 2.48 to 2.60 [t-$CO_2$/t-waste (wet)]. On the other hand, $N_2O$ emissions increased compared to FY1990 level due to the increase in sewage sludge incineration practice for the period FY1990 - FY1997. From FY2005 onward, $N_2O$ emissions from this source decreased because the practice of high temperature incineration of sewage sludge increased.

Table 7-27 GHG emissions from waste incineration (5.C.)

| Gas | Category | | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 5.C.1. Waste incineration | Munisipal solid waste | Plastics[1)] | kt-$CO_2$ | 5,092 | 5,082 | 5,275 | 3,091 | 2,399 | 2,109 | 2,429 | 2,601 | 2,721 | 2,293 | 2,504 | 1,661 | 1,641 | 1,628 |
| | | | Paper/cardboard[1)] | kt-$CO_2$ | 71 | 74 | 71 | 60 | 52 | 53 | 58 | 55 | 56 | 52 | 54 | 36 | 32 | 32 |
| | | | Nappy[1)] | kt-$CO_2$ | 32 | 38 | 34 | 39 | 46 | 49 | 52 | 52 | 58 | 59 | 73 | 48 | 44 | 44 |
| | | | Synthetic textiles[1)] | kt-$CO_2$ | 508 | 545 | 425 | 433 | 665 | 593 | 547 | 446 | 449 | 411 | 508 | 318 | 298 | 296 |
| | | Industrial waste | Waste oil[1)] | kt-$CO_2$ | 3,670 | 4,366 | 4,799 | 4,270 | 3,172 | 4,128 | 3,966 | 4,430 | 3,652 | 3,990 | 3,324 | 3,856 | 3,699 | 3,466 |
| | | | Plastics[1)] | kt-$CO_2$ | 2,131 | 4,539 | 4,380 | 4,332 | 3,474 | 3,785 | 3,185 | 3,450 | 3,947 | 3,397 | 3,777 | 3,715 | 3,884 | 3,770 |
| | | | Paper/cardboard[1)] | kt-$CO_2$ | 3 | 7 | 7 | 3 | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | Specially-controlled industrial waste | Waste oil (flammable)[1)] | kt-$CO_2$ | 698 | 1,036 | 1,526 | 1,402 | 1,845 | 1,143 | 815 | 784 | 796 | 782 | 692 | 816 | 561 | 482 |
| | | | Waste oil (specific hazardous)[1)] | kt-$CO_2$ | 19 | 28 | 41 | 38 | 39 | 42 | 44 | 25 | 55 | 124 | 149 | 131 | 127 | 127 |
| | | | Infectious waste (plastics)[1)] | kt-$CO_2$ | 199 | 328 | 428 | 435 | 366 | 395 | 452 | 336 | 341 | 452 | 426 | 411 | 395 | 393 |
| | 5.C.2. Open burning (Industrial waste plastics)[1)] | | | kt-$CO_2$ | 5 | 5 | 1 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.03 | 0.07 | 0.07 | 0.07 |
| | Total | | | kt-$CO_2$ | 12,429 | 16,046 | 16,988 | 14,103 | 12,062 | 12,300 | 11,549 | 12,183 | 12,076 | 11,561 | 11,508 | 10,992 | 10,682 | 10,239 |
| $CH_4$ | 5.C.1. Waste incineration | Munisipal solid waste[2)] | | kt-$CH_4$ | 0.5 | 0.4 | 0.4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| | | Industrial waste | Waste oil[2)] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | Plastics[2)] | kt-$CH_4$ | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | Food waste[3)] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | Paper/cardboard[2)] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | Wood[3)] | kt-$CH_4$ | 0.1 | 0.1 | 0.1 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 |
| | | | Natural fiber[3)] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | Sludge (sewage sludge/ other)[3)] | kt-$CH_4$ | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Specially-controlled industrial waste | Waste oil (flammable)[1)] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | Waste oil (specific hazardous)[1)] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | Infectious waste (plastics)[1)] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | Infectious waste (except plastics)[3)] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 5.C.2. Open burning (Industrial waste)[2)] | | | kt-$CH_4$ | 0.5 | 0.5 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | | | kt-$CH_4$ | 1.1 | 1.2 | 0.8 | 0.7 | 0.5 | 0.5 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| | | | | kt-$CO_2$ eq. | 28 | 29 | 21 | 18 | 13 | 12 | 11 | 11 | 12 | 10 | 10 | 9 | 10 | 10 |
| $N_2O$ | 5.C.1. Waste incineration | Munisipal solid waste[2)] | | kt-$N_2O$ | 1.03 | 1.05 | 0.98 | 0.52 | 0.48 | 0.46 | 0.49 | 0.46 | 0.47 | 0.43 | 0.47 | 0.30 | 0.28 | 0.28 |
| | | Industrial waste | Waste oil[2)] | kt-$N_2O$ | 0.02 | 0.02 | 0.02 | 0.10 | 0.07 | 0.09 | 0.09 | 0.10 | 0.08 | 0.09 | 0.08 | 0.09 | 0.08 | 0.08 |
| | | | Plastics[2)] | kt-$N_2O$ | 0.15 | 0.32 | 0.31 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | | Food waste[3)] | kt-$N_2O$ | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | | Paper/cardboard[2)] | kt-$N_2O$ | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | | Wood[3)] | kt-$N_2O$ | 0.06 | 0.10 | 0.06 | 0.14 | 0.09 | 0.08 | 0.07 | 0.08 | 0.10 | 0.08 | 0.08 | 0.07 | 0.09 | 0.09 |
| | | | Natural fiber[3)] | kt-$N_2O$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | Sewage sludge[3)] | kt-$N_2O$ | 2.65 | 3.94 | 4.86 | 5.48 | 4.30 | 4.16 | 4.17 | 4.22 | 4.25 | 3.92 | 4.16 | 3.69 | 4.07 | 4.11 |
| | | | Other sludge[3)] | kt-$N_2O$ | 0.89 | 0.92 | 0.94 | 0.22 | 0.20 | 0.19 | 0.19 | 0.16 | 0.18 | 0.17 | 0.16 | 0.16 | 0.18 | 0.17 |
| | | Specially-controlled industrial waste | Waste oil (flammable)[1)] | kt-$N_2O$ | 0.00 | 0.00 | 0.01 | 0.03 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 |
| | | | Waste oil (specific hazardous)[1)] | kt-$N_2O$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | | Infectious waste (plastics)[1)] | kt-$N_2O$ | 0.01 | 0.02 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | Infectious waste (except plastics)[3)] | kt-$N_2O$ | 0.00 | 0.00 | 0.00 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | 5.C.2. Open burning (Industrial waste)[2)] | | | kt-$N_2O$ | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | | | kt-$N_2O$ | 4.83 | 6.40 | 7.23 | 6.59 | 5.27 | 5.08 | 5.09 | 5.11 | 5.15 | 4.77 | 5.03 | 4.40 | 4.78 | 4.80 |
| | | | | kt-$CO_2$ eq. | 1,438 | 1,908 | 2,156 | 1,963 | 1,570 | 1,515 | 1,518 | 1,523 | 1,535 | 1,423 | 1,498 | 1,312 | 1,423 | 1,429 |
| Total | | | | kt-$CO_2$ eq. | 13,876 | 17,963 | 19,157 | 16,083 | 13,643 | 13,826 | 13,077 | 13,717 | 13,623 | 12,994 | 13,016 | 12,313 | 12,115 | 11,678 |

Note: 1) Include fossil-fuel derived component only
2) Include both fossil-fuel derived component and biogenic
3) Include biogenic component only

Note: $CO_2$ emissions from the incineration of biomass-derived waste (including biomass-based plastics and waste animal and vegetable oil) is not included in the total emissions in accordance with the *2006 IPCC Guidelines*; instead it is estimated as a reference value and reported under " Biogenic" in Table 5.C of the CRF.

For reference, the greenhouse gas emissions from waste incineration for energy purpose and with energy recovery are shown in Table 7-28. In FY2018, the emissions from waste incineration including these sources are 30,228 kt-$CO_2$, and it accounts for 2.4% of Japan's total greenhouse gas emissions (excluding LULUCF). The emissions from this source's category had increased by 19.9% compared to those in FY1990.

Table 7-28 Total GHG emissions from incineration of waste (reference value) including emissions from waste incineration for energy use and energy recovery

| Gas | Category | | | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 5.C. Waste Incineration and open burning (without energy recovery)[1] | | | | kt-$CO_2$ | 12,429 | 16,046 | 16,988 | 14,103 | 12,062 | 12,300 | 11,549 | 12,183 | 12,076 | 11,561 | 11,508 | 10,992 | 10,682 | 10,239 |
| | 1.A. Fuel combustion | Waste Incineration with Energy Recovery | MSW | Plastics[1] | kt-$CO_2$ | 5,916 | 6,373 | 8,270 | 6,677 | 4,687 | 4,267 | 4,545 | 5,458 | 5,388 | 4,826 | 4,644 | 5,435 | 5,909 | 5,865 |
| | | | | Paper/cardboard[1] | kt-$CO_2$ | 83 | 93 | 112 | 129 | 102 | 107 | 108 | 116 | 111 | 110 | 101 | 117 | 114 | 114 |
| | | | | Nappy[1] | kt-$CO_2$ | 38 | 48 | 53 | 83 | 90 | 99 | 98 | 109 | 114 | 125 | 135 | 156 | 160 | 160 |
| | | | | Synthetic textiles[1] | kt-$CO_2$ | 591 | 683 | 667 | 935 | 1,299 | 1,200 | 1,025 | 935 | 889 | 865 | 942 | 1,040 | 1,072 | 1,066 |
| | | | IW | Waste oil[1] | kt-$CO_2$ | 21 | 30 | 28 | 109 | 67 | 176 | 170 | 105 | 152 | 175 | 169 | 176 | 117 | 110 |
| | | | | Plastics[1] | kt-$CO_2$ | 31 | 66 | 188 | 307 | 351 | 581 | 688 | 732 | 608 | 679 | 899 | 838 | 830 | 805 |
| | | | | Paper/cardboard[1] | kt-$CO_2$ | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | Direct Use of Waste as Alternative Fuel | MSW | Plastics[1] | kt-$CO_2$ | NO | NO | 92 | 512 | 413 | 455 | 435 | 465 | 234 | 227 | 263 | 253 | 266 | 219 |
| | | | IW | Waste oil[1] | kt-$CO_2$ | 3,592 | 4,193 | 4,150 | 5,215 | 4,559 | 4,778 | 4,733 | 4,952 | 4,796 | 4,592 | 5,015 | 4,678 | 4,680 | 4,492 |
| | | | | Plastics[1] | kt-$CO_2$ | 55 | 59 | 450 | 1,238 | 1,707 | 1,835 | 1,741 | 1,820 | 1,892 | 2,184 | 2,098 | 2,244 | 2,366 | 2,483 |
| | | | Waste Tire[1] | | kt-$CO_2$ | 527 | 845 | 1,044 | 869 | 951 | 1,008 | 976 | 951 | 958 | 1,014 | 1,037 | 997 | 1,036 | 1,064 |
| | | Incineration of Waste Processed as Fuel | RDF[1] | | kt-$CO_2$ | 26 | 30 | 114 | 320 | 289 | 292 | 299 | 295 | 296 | 297 | 275 | 274 | 273 | 276 |
| | | | RPF[1] | | kt-$CO_2$ | NO | 11 | 46 | 683 | 1,114 | 1,093 | 1,148 | 1,196 | 1,265 | 1,237 | 1,262 | 1,357 | 1,376 | 1,387 |
| | Total | | | | kt-$CO_2$ | 23,307 | 28,477 | 32,202 | 31,180 | 27,692 | 28,190 | 27,512 | 29,316 | 28,779 | 27,891 | 28,349 | 28,557 | 28,881 | 28,279 |
| $CH_4$ | 5.C. Waste Incineration and open burning (without energy recovery)[2] | | | | kt-$CH_4$ | 1.1 | 1.2 | 0.8 | 0.7 | 0.5 | 0.5 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| | 1.A. Fuel combustion | Waste Incineration with Energy Recovery | MSW[2] | | kt-$CH_4$ | 0.5 | 0.5 | 0.6 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | | IW | Waste oil[2] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | Plastics[2] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | Food waste[3] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | Paper/cardboard[2] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | Wood[3] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | Natural Fiber[3] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | Sludge other than | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Direct Use of Waste as Alternative Fuel | MSW | Plastics[2] | kt-$CH_4$ | NO | NO | 0.0 | 0.0 | 0.0 | 0.0 | NO | NO | NO | NO | NO | NO | NO | NO |
| | | | IW | Waste oil[2] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | Plastics[2] | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| | | | | Wood[3] | kt-$CH_4$ | 1.8 | 1.8 | 2.2 | 2.9 | 4.2 | 4.2 | 4.4 | 4.5 | 4.8 | 5.2 | 5.0 | 4.9 | 5.2 | 5.3 |
| | | | Waste Tire[2] | | kt-$CH_4$ | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Incineration of Waste Processed as Fuel | RDF[2] | | kt-$CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | RPF[2] | | kt-$CH_4$ | NO | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | | | | kt-$CH_4$ | 3.5 | 3.6 | 3.8 | 4.0 | 5.1 | 5.0 | 5.2 | 5.3 | 5.6 | 6.1 | 5.8 | 5.7 | 6.1 | 6.2 |
| | | | | | kt-$CO_2$ eq. | 86 | 89 | 95 | 99 | 128 | 126 | 130 | 133 | 141 | 152 | 145 | 143 | 152 | 154 |
| $N_2O$ | 5.C. Waste Incineration and open burning (without energy recovery)[2] | | | | kt-$N_2O$ | 4.83 | 6.40 | 7.23 | 6.59 | 5.27 | 5.08 | 5.09 | 5.11 | 5.15 | 4.77 | 5.03 | 4.40 | 4.78 | 4.80 |
| | 1.A. Fuel combustion | Waste Incineration with Energy Recovery | MSW[2] | | kt-$N_2O$ | 1.19 | 1.32 | 1.53 | 1.13 | 0.95 | 0.93 | 0.91 | 0.97 | 0.93 | 0.91 | 0.86 | 0.99 | 1.00 | 1.00 |
| | | | IW | Waste oil[2] | kt-$N_2O$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | Plastics[2] | kt-$N_2O$ | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| | | | | Food waste[3] | kt-$N_2O$ | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | | | Paper/cardboard[2] | kt-$N_2O$ | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | | | Wood[3] | kt-$N_2O$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | Natural Fiber[3] | kt-$N_2O$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | Sludge other than | kt-$N_2O$ | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | Direct Use of Waste as Alternative Fuel | MSW | Plastics[2] | kt-$N_2O$ | NO | NO | 0.00 | 0.00 | 0.00 | 0.00 | NO | NO | NO | NO | NO | NO | NO | NO |
| | | | IW | Waste oil[2] | kt-$N_2O$ | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | | | Plastics[2] | kt-$N_2O$ | 0.03 | 0.02 | 0.03 | 0.02 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 |
| | | | | Wood[3] | kt-$N_2O$ | 0.02 | 0.02 | 0.03 | 0.03 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| | | | Waste Tire[2] | | kt-$N_2O$ | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | Incineration of Waste Processed as Fuel | RDF[2] | | kt-$N_2O$ | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | | RPF[2] | | kt-$N_2O$ | NO | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 |
| | Total | | | | kt-$N_2O$ | 6.11 | 7.81 | 8.89 | 7.87 | 6.41 | 6.21 | 6.20 | 6.28 | 6.28 | 5.91 | 6.11 | 5.61 | 6.00 | 6.02 |
| | | | | | kt-$CO_2$ eq. | 1,819 | 2,328 | 2,650 | 2,346 | 1,910 | 1,851 | 1,849 | 1,872 | 1,873 | 1,760 | 1,820 | 1,672 | 1,789 | 1,795 |
| Total | | | | | kt-$CO_2$ eq. | 25,213 | 30,894 | 34,947 | 33,625 | 29,730 | 30,167 | 29,491 | 31,321 | 30,793 | 29,804 | 30,315 | 30,372 | 30,822 | 30,228 |

Note: 1) Include fossil-fuel derived component only
2) Include both fossil-fuel derived component and biogenic
3) Include biogenic component only

## 7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)

### 7.4.1.1. Municipal Solid Waste (5.C.1.-)

#### *a) Category Description*

This category covers the emissions from incineration of municipal solid waste without energy recovery. Emissions of $CO_2$ are reported under either “Biogenic, Municipal solid waste (MSW)” or “Non-biogenic, Municipal solid waste” in accordance with the waste type as indicated in the Table 7-24. Emissions of $CH_4$ and $N_2O$ are estimated for each type of furnace. The data used for MSW incineration cannot distinguish wastes that are either biogenic-origin or non-biogenic origin. Therefore, total

emissions including biogenic-origin ones are reported altogether under “Non-biogenic, Municipal solid waste”.

***b) Methodological Issues***

***1) $CO_2$***

- ***Estimation Method***

Emissions of $CO_2$ from this emission source is calculated based on Japan’s country-specific emission factors, the volume of waste incinerated (dry basis) and the percentage of municipal waste incinerated at the municipal incineration facilities that is accompanied by energy recovery, in accordance with the decision tree in the *2006 IPCC Guidelines* (Volume 5, Page 5.9, Fig. 5.1). In order to estimate $CO_2$ emissions from the incineration of fossil-fuel derived waste[2], emissions from fossil-fuel derived plastics, synthetic textile and fossil-fuel derived fraction in paper/cardboard and nappy in municipal solid waste are estimated.

$$E = \sum_i EF_i \times A_i \times (1 - R)$$

$E$ : $CO_2$ Emissions from the incineration of municipal solid waste type $i$ [kg-$CO_2$]
$EF_i$ : Emission factor for the incineration of waste type $i$ (dry basis) [kg-$CO_2$/t]
$A_i$ : Volume of waste type $i$ incinerated (dry basis) [t]
$R$ : Percentage of municipal solid waste incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Equation***

In accordance with the *2006 IPCC Guidelines*, the emission factor is calculated as follows.

- ***Fossil-fuel derived plastics, synthetic textile***

$$EF_i = CF_i \times OF \times 44/12$$

$EF_i$ : Emission factor for the incineration of waste type $i$ (dry basis) [kg-$CO_2$/t]
$CF_i$ : Carbon content in waste type $i$ (dry basis) [%]
$OF$ : Oxidation factor [%]

- ***Paper/cardboard and nappy***

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

$EF_i$ : Emission factor for the incineration of waste type $i$ (dry basis) [kg-$CO_2$/t]
$CF_i$ : Carbon content in waste type $i$ (dry basis) [%]
$FCF_i$ : Fossil-fuel derived fraction in carbon in waste type $i$ [%]
$OF$ : Oxidation factor [%]

➢ ***Carbon Content***

The carbon content of plastics (fossil-fuel derived and biomass-derived waste) in MSW is estimated based on the averaged value of actual measured data for the period FY1990 - FY2008 provided by four

[2] $CO_2$ emissions from the incineration of food waste, biogenic fraction of paper/cardboard, natural fiber textiles, wood and biomass-based plastics are reported as the reference figures of biogenic municipal waste. Estimation methods for their emissions are the same as those for emissions from the incineration of fossil-fuel derived waste.

municipalities (Akita city, Kawasaki city, Kobe city and Osaka pref.) and applying it for the entire time-series (MOE, 2010).

For the carbon content of synthetic textile in MSW, the carbon content of the synthetic fibers in the textile products is used. It is set by taking a weighted average of carbon contents determined by the molecular formula of polymer for each type of synthetic textile based on the volume of synthetic textile consumption.

For the carbon content of paper/cardboard in MSW, the carbon content of default value in the *2006 IPCC Guidelines*, which is larger than country specific measured data (see Table 7-5) is conservatively applied.

For the carbon content of nappy in MSW, the carbon content of default value in the *2006 IPCC Guidelines* is used due to lack of domestic research in Japan.

Table 7-29 Carbon content of plastics and synthetic textile in MSW (dry basis)

| Item | Carbon content | Source |
|---|---|---|
| Plastics | 75.1 % | Averaged value of the data provided by four municipalities |
| Plastic bottles | 62.5% | (Reference value) Estimated from the molecular formula of polyethylene terephthalate<br>* Not adopted to estimate $CO_2$ emissions |
| Synthetic textile | 63.0 % | Weighted average of carbon content by each type of synthetic textile |
| Paper/cardboard | 46.0 % | *2006 IPCC Guidelines* |
| Nappy | 70.0 % | *2006 IPCC Guidelines* |

- ***Fossil-fuel derived fraction in carbon in waste***

For the fossil-fuel derived fraction in carbon in paper/cardboard and nappy in MSW, the default values in the *2006 IPCC Guidelines* are applied as indicated in the Table 7-30 due to lack of domestic research in Japan.

Table 7-30 Fossil-fuel derived fraction in carbon in paper/cardboard and nappy in MSW

| Item | Fossil-fuel derived fraction in carbon [%] | Source |
|---|---|---|
| Paper/cardboard | 1 | *2006 IPCC Guidelines* |
| Nappy | 10 | *2006 IPCC Guidelines* |

- ***Oxidation Factor***

Taking into account Japan's circumstances, the default value of 100% indicated in the *2006 IPCC Guidelines* is used.

- ***Emission Factor***

Emission factors calculated by methodologies above are shown in Table 7-31.

Table 7-31 Emission factors for plastics and synthetic textile in MSW (dry basis)

| Item | Unit | Emission factor |
|---|---|---|
| Plastics | kg-$CO_2$/t | 2,754 |
| Synthetic textile | kg-$CO_2$/t | 2,310 |
| Paper/cardboard (Fossil-fuel derived) | kg-$CO_2$/t | 17 |
| Nappy (Fossil-fuel derived) | kg-$CO_2$/t | 257 |

Table 7-32(Reference value) Emission factor for plastic bottles (dry basis)

| Item | Unit | Emission factor | Remarks |
|---|---|---|---|
| Plastic bottles | kg-$CO_2$/t | 2,292 | Not adopted to estimate $CO_2$ emissions |

- ***Activity Data***

As basic information to estimate activity data, the amount of plastic, plastic bottles distinguished from plastics, textiles and paper/cardboard incinerated are obtained from the *Cyclical Use of Wastes Report*. Note the reported amounts of plastic including plastic bottles potentially include biomass-based plastics. The details of activity data estimations are shown as follows.

➢ ***Fossil-fuel derived plastics***

The activity data for $CO_2$ emissions from the incineration of fossil-fuel derived plastics in MSW on a dry basis are calculated by subtracting water content from the amount of plastic incinerated (wet basis) and multiplying the fossil-fuel derived fraction of plastic incinerated in MSW.

$$A_{plastics} = MSW_{plastics} \times (1 - u_{plastics}) \times FPF_{msw}$$

$A_{plastics}$ : Activity data for fossil-fuel derived plastics (MSW) incinerated (dry basis) [t (dry)]
$MSW_{plastics}$ : Amount of MSW plastics incinerated (wet basis) [t (wet)]
$u_{plastics}$ : Percentage of water content in plastics [%]
$FPF_{msw}$ : Fossil-fuel derived fraction of MSW plastics [%]

In this method for MSW plastics, activity data is estimated separately as plastic bottles and the rest of plastics.

$$A_{plastics} = A_{plastic\ bottle} + A_{other\ plastics}$$

$A_{plastics}$ : Activity data for fossil-fuel derived plastics (MSW) incinerated
$A_{plastic\ bottle}$ : Activity data for fossil-fuel derived plastic bottles (MSW) incinerated
$A_{other\ plastics}$ : Activity data for fossil-fuel derived plastics (MSW) other than plastic bottle

- ***Percentage of water content in plastics***

The percentage of water content in plastic bottles/ plastics other than plastic bottles in MSW is defined as 20% provided by *Cyclical Use of Wastes Report*.

- ***Fossil-fuel derived fraction in plastic bottles/ plastics other than plastic bottles***

Fossil-fuel derived fraction in plastics is estimated as follows. For MSW, the parameters in this method are distinguished for plastic bottles and plastics other than plastic bottles, separately.

$$FPF_{msw}(T) = 1 - \frac{BPW_{\mathrm{msw}}(T)}{PW_{msw}(T)}$$

$FPF_{msw}(T)$ : Fossil-fuel derived fraction in MSW plastic in FY $T$ [%]
$BPW_{msw}(T)$ : Amount of biogenic fraction in MSW plastic in FY $T$ [t]
$PW_{msw}(T)$ : Amount of MSW plastic generation in FY $T$ [t]

MSW plastics (plastic bottles / plastics other than plastic bottles) generation in *FY T* ($PW_{msw}(T)$) are obtained from the *Cyclical Use of Wastes Report*. Amount of biogenic fraction in MSW plastics (plastic bottles / plastics other than plastic bottles) in *FY T* ($BPW_{msw}(T)$) are calculated by following equation.

$$BPW_{msw}(T) = \sum_{t}^{T} \sum_{i} (BP_{i,t} \times DP_{i,t} \times B_i \times W_{msw\ i,t}(T) \times DW_{msw}(T))$$

$BP_{i,t}$ : Amount of biomass-based plastic product *i* production in FY *t* [t]

$DP_{i,t}$ : Share of domestic shipments of biomass-based plastic product *i* in FY *t* [%]

$B_i$ : Biogenic fraction of biomass-based plastic product *i* [%]

$W_{msw\ i,t}(T)$ : Probability that biomass-based plastic product *i*, which was produced in FY *t*, is disposed of as MSW in FY *T* after use [%]

$DW_{msw}(T)$ : Fraction of MSW plastic treated domestically in FY *T* [%]

For the amount of biomass-based plastic products production ($BP_{i,t}$), the share of domestic shipments ($DP_{i,t}$), and the biogenic fraction ($B_i$) are obtained from a survey by the Japan Society of Biomass Industries and Japan BioPlastics Association. Note that the survey distinguishes final products made of bio-based resin by type (e.g. bio-PE, bio-PET, PLA, etc.) and by use (e.g. wrapping material, containers, daily use products, LCD, etc.).

The survey also provides the supplied amount of bio-based resin as intermediate products of bio-PE, bio-PET and PLA. By subtracting the amount of bio-based resin in final products identified above from the supplied amount of intermediate products by each bio-based resin type, unidentified amount of final products ($BP$) in the survey are also estimated as resin amounts. The shares of domestic shipments ($DP$) and the biogenic fractions ($B$) for those unidentified final products are given by an expert judgement.

A part of bio-PET resin in plastic bottles, one of a bio-based resin widely used in Japan, are recovered after use, materially recycled as final products such as bottle or other commodities, and disposed/incinerated finally. In such a circumstance, amount of biogenic fraction in MSW plastic ($BPW_{msw}(T)$) are identified by considering disposal amount of bio-based resin not only after first use in products but also after use in recycled products. The amount of recycled bio-PET resin in each product are estimated by considering data of material recycled plastics after bottle use provided by the *Annual Report on PET Bottle Recycling* (the Council for PET Bottle Recycling).

The probability that is disposed of as MSW ($W_{msw\ i,t}(T)$) is estimated by the expert judgement.

Fractions of MSW plastics other than plastic bottles treated domestically in *FY T* ($DW_{msw}(T)$) are assumed as 100% for plastics other than plastic bottles since the export status are not clear. The parameters for plastic bottles are obtained from *Annual report on PET bottle recycling* (Table 7-33).

Table 7-33 Fraction of waste plastic treated domestically (*DW*)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plastics in MSW (excl. plastic bottle) | % | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Plastic bottle in MSW | % | 48.6 | 48.6 | 48.6 | 48.6 | 47.4 | 47.5 | 50.5 | 50.9 | 51.6 | 57.1 | 52.0 | 54.4 | 59.6 | 61.7 |
| Plastics in IW | % | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Fossil-fuel derived fraction in plastic calculated by methodologies above are shown in Table 7-34.

Table 7-34 Fossil-fuel derived fraction in waste plastics (*FPF*)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plastics in MSW (excl. plastic bottle) | % | 100.0 | 100.0 | 100.0 | 100.0 | 99.7 | 99.5 | 99.5 | 99.5 | 99.3 | 99.1 | 98.8 | 98.7 | 98.7 | 98.7 |
| Plastic bottle in MSW | % | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.8 | 99.7 | 99.5 | 99.5 | 99.4 | 99.3 |
| Plastics in IW | % | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 99.8 | 99.8 | 99.8 | 99.8 | 99.8 | 99.8 | 99.8 | 99.8 |

➢ ***Synthetic textile***

The activity data of synthetic textile in MSW is estimated by multiplying the amount of textiles in MSW incinerated (wet basis) by the fraction of waste synthetic textile content in waste textile, and subtracting the water content in textiles (percentage of water content: 20%; see also Table 7-10).

$$A_{textiles} = MSW_{textiles} \times (1 - u_{textiles}) \times F_{synthetic}$$

$A_{textiles}$ : Activity data for incineration of synthetic textile (MSW) incinerated (dry basis) [t (dry)]
$MSW_{textiles}$ : Amount of textile incinerated (wet basis) [t (wet)]
$u_{textiles}$ : Percentage of water content in textiles [%]
$F_{synthetic}$ : Share of synthetic fiber content in textiles [%]

- ***Share of Synthetic Textile in Textiles***

Share of synthetic textile content in textiles contained in the MSW is calculated using the share of synthetic textile products in textile products, which is determined by taking the ratio of the annual domestic demand for synthetic textile to the one for all textiles indicated in the Textile Handbook and the Yearbook of Textiles and Consumer Goods Statistics.

Table 7-35 Share of synthetic textile and natural fiber in textiles

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Synthetic textile | % | 49.1 | 50.7 | 53.5 | 52.8 | 56.6 | 59.6 | 63.2 | 64.1 | 61.9 | 63.1 | 63.6 | 63.6 | 63.6 | 63.6 |
| Natural fiber | % | 50.9 | 49.3 | 46.5 | 47.2 | 43.4 | 40.4 | 36.8 | 35.9 | 38.1 | 36.9 | 36.4 | 36.4 | 36.4 | 36.4 |

➢ ***Paper/cardboard***

The activity data of paper/cardboard in MSW is estimated by subtracting the water content (percentage of water content: 20%; see also Table 7-10) in paper/cardboard from the amount of paper/cardboard in MSW incinerated (wet basis).

$$A_{paper} = MSW_{paper} \times \left(1 - u_{paper}\right)$$

$A_{paper}$ : Activity data for incineration of paper/cardboard (MSW) incinerated (dry basis) [t (dry)]
$MSW_{paper}$ : Amount of paper/cardboard incinerated [t (wet)]
$u_{paper}$ : Percentage of water content in paper/cardboard [%]

➢ ***Nappy***

Although nappy in Japan's municipal waste is generally classified into paper or textile, the incinerated amount is not clearly distinguished from these categories. Therefore, conservatively considering as the independent activity from paper/cardboard and textile incinerated, the amount of domestic production of nappies is applied as the activity data for nappy incinerated.

The amount of domestic production of nappies is derived from the reported amount of nappies for adult and infant (dry basis) on the *JHPIA news* published by Japan Hygiene Products Industry Association.

➢ ***Activity data***

Activity data calculated by methodologies above is shown in Table 7-36.

Table 7-36 Activity data to estimate $CO_2$ emissions from MSW incinerated (dry basis)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fossil-fuel derived plastics | kt / year (dry) | 3,998 | 4,160 | 4,919 | 3,547 | 2,573 | 2,316 | 2,533 | 2,927 | 2,945 | 2,585 | 2,596 | 2,577 | 2,742 | 2,721 |
| Synthetic textile | kt / year (dry) | 476 | 531 | 473 | 592 | 850 | 776 | 681 | 598 | 579 | 552 | 628 | 588 | 593 | 590 |
| Paper/cardboad | kt / year (dry) | 9,157 | 9,916 | 10,863 | 11,193 | 9,150 | 9,447 | 9,796 | 10,187 | 9,881 | 9,617 | 9,186 | 9,078 | 8,652 | 8,634 |
| Nappy | kt / year (dry) | 272 | 333 | 340 | 475 | 531 | 576 | 584 | 627 | 670 | 716 | 811 | 795 | 795 | 795 |

- ***Percentage of Municipal Waste Incinerated at Municipal Incineration Facilities for Energy Recovery***

Percentage of municipal waste that is incinerated at municipal incineration facilities with energy recovery stands for the one being incinerated at the facilities actually supply electricity or heat outside of them. These values are obtained from the *State of Municipal Waste Treatment Survey* (MOE).

Table 7-37 Percentage of municipal solid waste incinerated at incineration facilities with energy recovery

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| With off-field power generation or heat utilization | % | 53.7 | 55.6 | 61.1 | 68.4 | 66.1 | 66.9 | 65.2 | 67.7 | 66.4 | 67.8 | 65.0 | 76.6 | 78.3 | 78.3 |
| Without off-field power generation or heat utilization | % | 46.3 | 44.4 | 38.9 | 31.6 | 33.9 | 33.1 | 34.8 | 32.3 | 33.6 | 32.2 | 35.0 | 23.4 | 21.7 | 21.7 |

### *2) $CH_4$*

- ***Estimation Method***

$CH_4$ emissions from incinerator are estimated by multiplying the amount of MSW (wet basis) by incinerator method by each emission factor. $CH_4$ emissions from gasification melting furnace are estimated by multiplying the amount of MSW (wet basis) incinerated in gasification melting furnace by emission factors. Emissions from MSW with energy recovery are subtracted from the total emissions from this source and allocated to the waste sector.

$$E = \sum_i (EF_i \times A_i) \times (1 - R)$$

$E$ : $CH_4$ emission from the incineration of MSW [kg-$CH_4$]

$EF_i$ : Emission factor for incineration method $i$ (or furnace type $i$) (wet basis) [kg-$CH_4$/t]

$A_i$ : Amount of incinerated MSW by incineration method $i$ (or furnace type $i$) (wet basis) [t]

$R$ : Percentage of MSW incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Incinerator***

In order to implement countermeasures against dioxins, the renovations, repairs, or rebuilding of incineration facilities took place in the latter half of 1990 through the first half of 2000 in Japan. There have been some improvements made in $CH_4$ emission factors from the facilities renovated or rebuilt in FY2000 and later, compared to the values obtained before then (MOE, 2010). Therefore, based on the survey (MOE, 2010) and expert judgment, for the $CH_4$ emission factors for incinerator by incinerator type (stoker furnace and fluidized bed incinerator) and incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) for the period FY2001 and before (MOE, 2006b), and from FY2002 onward (MOE, 2010), respectively, different values are used. All the emission factors are established based on actual measurement survey.

In order to apply activity data based on the amount of incineration by incineration method, emission factors are established by incineration method (continuous incinerator, semi-continuous incinerator, and

batch type incinerator) using the weighted average of fraction of the amount of incineration by incinerator type for each fiscal year. The Correction taking into account $CH_4$ concentrations in the atmosphere is not made to these emission factors.

➢ ***Gasification Melting Furnace***

Different emission factor is used for each furnace type (shaft furnace, fluidized bed, and rotary kiln) (MOE, 2010). Also, in order to apply activity data based on the total amount of incineration, emission factors are determined by taking the weighted average of the amount of incineration by gasification melting furnace type for each year.

Table 7-38 $CH_4$ emission factors by type of incineration method (MSW)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Continuous incinerator | g-$CH_4$/t | 8.2 | 8.2 | 8.3 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| Semi-continuous incinerator | g-$CH_4$/t | 69.6 | 69.6 | 75.1 | 19.9 | 20.6 | 20.9 | 20.8 | 21.1 | 20.9 | 21.1 | 20.7 | 20.4 | 20.5 | 20.5 |
| Batch type incinerator | g-$CH_4$/t | 80.5 | 80.5 | 84.1 | 13.2 | 13.4 | 11.6 | 11.6 | 11.6 | 11.7 | 11.7 | 11.8 | 11.8 | 10.9 | 10.9 |
| Gasification melting furnace | g-$CH_4$/t | NA | NA | 5.6 | 6.9 | 7.0 | 7.0 | 7.0 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 |

Source: MOE (2000), MOE (2010), the *Waste Treatment in Japan* (MOE), Ishikawa Prefecture et al. (1991-1997), Japan Society for Atmospheric Environment: JSAE (1996), Ueno et al. (1992)

● ***Activity Data***

The activity data for $CH_4$ emissions for incinerator and gasification melting furnace are estimated by multiplying the amount of MSW incinerated (wet basis) provided in the *Cyclical Use of Waste Report* (publicized reports and the most current data from the reports prior to publication) by the fraction of incineration by incineration method of incinerator or gasification meting furnace provided by the *Waste Treatment in Japan*.

Table 7-39 Amount of incineration of MSW by incineration method

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Continuous incinerator | kt /year (wet) | 26,215 | 29,716 | 32,749 | 32,246 | 28,444 | 27,603 | 27,892 | 28,702 | 28,246 | 27,360 | 27,364 | 26,961 | 26,883 | 26,796 |
| Semi-continuous incinerator | kt /year (wet) | 4,810 | 5,455 | 5,882 | 4,047 | 3,155 | 2,968 | 2,932 | 2,849 | 2,827 | 2,524 | 2,349 | 2,164 | 2,072 | 2,065 |
| Batch type incinerator | kt /year (wet) | 5,643 | 4,328 | 3,131 | 1,562 | 1,144 | 1,078 | 1,057 | 1,061 | 970 | 867 | 842 | 744 | 693 | 691 |
| Gasification melting furnace | kt /year (wet) | NO | NO | 370 | 2,397 | 3,245 | 3,605 | 3,857 | 4,122 | 4,098 | 4,161 | 4,328 | 4,423 | 4,599 | 4,584 |

### *3) $N_2O$*

● ***Estimation Method***

$N_2O$ emissions from incinerator are estimated by multiplying the amount of MSW (wet basis) by incinerator method by each emission factor. $N_2O$ emissions from gasification melting furnace are estimated by multiplying the amount of MSW (wet basis) incinerated in gasification melting furnace by emission factors. Emissions from MSW with energy recovery are subtracted from the total emissions from this source and allocated to the waste sector.

$$E = \sum_i (EF_i \times A_i) \times (1 - R)$$

$E$ : $N_2O$ emission from the incineration of MSW [kg-$N_2O$]

$EF_i$ : Emission factor for incineration method $i$ (or furnace type $i$) (wet basis) [kg-$N_2O$ /t]

$A_i$ : Amount of incinerated MSW by incineration method $i$ (or furnace type $i$) (wet basis) [t]

$R$ : Percentage of MSW incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Incinerator***

Same as for $CH_4$ emissions estimation, for the $N_2O$ emission factors for incinerator by type and by incineration method, different values are used for the period FY2001 and before (MOE, 2006b), and from FY2002 onward (MOE, 2010), respectively. In order to apply activity data based on the amount of incineration by incineration method, emission factors are established by incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) using the weighted average of fraction of the amount of incineration by incinerator type for each fiscal year calculated based on the *Waste Treatment in Japan*.

➢ ***Gasification Melting Furnace***

Different emission factor is used for each furnace type (shaft furnace, fluidized bed, and rotary kiln) (MOE, 2010). In order to apply the activity data based on the total amount of incineration, emission factors are established by taking the weighted average of the amount of incineration by gasification melting furnace type for each year calculated based on the *Waste Treatment in Japan.*

Table 7-40 $N_2O$ emission factors by incineration types (MSW)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Continuous incinerator | g-$N_2O$/t | 58.8 | 58.8 | 59.1 | 37.9 | 37.9 | 38.0 | 38.0 | 38.0 | 38.0 | 38.1 | 38.1 | 38.1 | 37.9 | 37.9 |
| Semi-continuous incinerator | g-$N_2O$/t | 56.8 | 56.8 | 57.3 | 71.5 | 72.7 | 73.2 | 73.1 | 73.4 | 73.1 | 73.5 | 72.8 | 72.3 | 72.5 | 72.5 |
| Batch type incinerator | g-$N_2O$/t | 71.4 | 71.4 | 74.8 | 76.0 | 76.0 | 76.2 | 76.2 | 76.2 | 76.2 | 76.2 | 76.2 | 76.2 | 76.3 | 76.3 |
| Gasification melting furnace | g-$N_2O$/t | NA | NA | 16.9 | 12.0 | 11.2 | 11.5 | 11.9 | 11.7 | 11.7 | 12.0 | 12.2 | 12.5 | 12.1 | 12.1 |

Source: MOE (2006b), MOE (2010), *Waste Treatment in Japan* (MOE), Ishikawa Prefecture et al. (1991-1997), JSAE (1996), Ueno et al. (1992)

- ***Activity Data***

The activity data for $CH_4$ emissions from incinerators and gasification melting furnaces are also applied for the activity data for $N_2O$ emission from them.

***c) Uncertainties and Time-series Consistency***

- ***Uncertainties***

The uncertainties in $CO_2$ emission factors are evaluated by using the 95% confidence interval of carbon content data in plastics. The uncertainties in $CH_4$ and $N_2O$ emission factors are evaluated by using the 95% confidence interval in the actual measurement on the surveys for emissions factors. As for the uncertainties in activity data, the uncertainties in municipal solid waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-41 and Table 7-42.

Table 7-41 Uncertainty assessment for municipal solid waste on the category "waste incineration (5.C.1.-)" ($CO_2$)

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Plastics | $CO_2$ | -2% | +2% | -10% | +10% | -10% | +10% | Quoted from MOE (2010), a source of emission factors. | The uncertainty in municipal waste statistics based on expert judgment is applied. | Combined by using the formula for propagation of errors |
| Synthetic textile | $CO_2$ | -2% | +2% | -10% | +10% | -10% | +10% | It is evaluated at the 95% confidence interval in actual measurement data of carbon content in synthetic textile. | | |
| Paper/ cardboard | $CO_2$ | -100% | +400% | -10% | +10% | -101% | +400% | It is evaluated by combining the 95% confidence interval in actual measurement data of carbon content with the uncertainty of fossil-derived carbon ratio in the *2006 IPCC Guidelines* as default value. | | |
| Nappy | $CO_2$ | -23% | +29% | -10% | +10% | -25% | +30% | The uncertainty is evaluated according to the default uncertainty assessment in the *2006 IPCC Guidelines* because the emission factor for this item is the default value in the *2006 IPCC Guidelines*. | | |

Table 7-42 Uncertainty assessment for municipal solid waste on the category "waste incineration (5.C.1.-)" ($CH_4$ and $N_2O$)

| Item | | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| No corresponding category ($CH_4$) | Continuous incineration /Stoker furnace | $CH_4$ | -39% | +39% | -10% | +10% | -40% | +40% | The uncertainty is quoted from MOE (2010), a source of emission factors. | The uncertainty based on expert judgment in municipal waste statistics is applied. | Combined by using the formula for propagation of errors |
| | Continuous incineration /Fluidized bed furnace | $CH_4$ | -100% | +719% | -10% | +10% | -100% | +719% | | | |
| | Semi-continuous incineration/ Stoker furnace | $CH_4$ | -82% | +82% | -10% | +10% | -83% | +83% | | | |
| | Semi-continuous incineration / Fluidized bed furnace | $CH_4$ | -100% | +162% | -10% | +10% | -100% | +162% | | | |
| | Batch-type incineration/ Stoker furnace | $CH_4$ | -75% | +75% | -10% | +10% | -76% | +76% | | | |
| | Batch-type incineration /Fluidized bed furnace | $CH_4$ | -100% | +394% | -10% | +10% | -100% | +394% | | | |
| | Gasification melting furnace/ Shaft furnace | $CH_4$ | -100% | +203% | -10% | +10% | -100% | +203% | | | |
| | Gasification melting furnace/ Fluidized bed furnace | $CH_4$ | -100% | +133% | -10% | +10% | -100% | +134% | | | |
| | Gasification melting furnace/ Rotatory kiln | $CH_4$ | -54% | +54% | -10% | +10% | -55% | +55% | | | |
| No corresponding category ($N_2O$) | Continuous incineration /Stoker furnace | $N_2O$ | -34% | +34% | -10% | +10% | -35% | +35% | The uncertainty is quoted from MOE (2010), a source of emission factors. | The uncertainty based on expert judgment in municipal waste statistics is applied. | Combined by using the formula for propagation of errors |
| | Continuous incineration /Fluidized bed furnace | $N_2O$ | -98% | +98% | -10% | +10% | -99% | +99% | | | |
| | Semi-continuous incineration/ Stoker furnace | $N_2O$ | -82% | +82% | -10% | +10% | -82% | +82% | | | |
| | Semi-continuous incineration / Fluidized bed furnace | $N_2O$ | -64% | +64% | -10% | +10% | -64% | +64% | | | |
| | Batch-type incineration/ Stoker furnace | $N_2O$ | -100% | +111% | -10% | +10% | -100% | +111% | | | |
| | Batch-type incineration /Fluidized bed furnace | $N_2O$ | -100% | +133% | -10% | +10% | -100% | +134% | | | |
| | Gasification melting furnace/ Shaft furnace | $N_2O$ | -45% | +45% | -10% | +10% | -46% | +46% | | | |
| | Gasification melting furnace/ Fluidized bed furnace | $N_2O$ | -100% | +252% | -10% | +10% | -100% | +252% | | | |
| | Gasification melting furnace/ Rotatory kiln | $N_2O$ | -87% | +87% | -10% | +10% | -88% | +88% | | | |

- ***Time-series Consistency***

Because data on the amount of waste incinerated by type of waste are not available for years prior to FY1997, the data are estimated by using the total incinerated amount of MSW for each year and the ratio of amount of waste incinerated by waste type for FY1998. The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

By revisioning biomass-based plastic products data, $CO_2$ emissions were recalculated.

By updating the statistical data, emissions were recalculated. For detail, see the section "7.1.5. General Recalculations for Emissions from Waste Sector".

See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 7.4.1.2. Industrial Waste (5.C.1.-)

***a) Category Description***

This category covers $CO_2$, $CH_4$ and $N_2O$ emissions from incineration of industrial waste without energy recovery by each waste type and the emissions are reported in the corresponding category either "biogenic, industrial solid waste (ISW)", "biogenic, non-fossil liquid waste", "biogenic, sludge" "non-biogenic, industrial solid waste" or "non-biogenic, fossil liquid waste" (see Table 7-24).

***b) Methodological Issues***

***1) $CO_2$***

- ***Estimation Method***

Emissions of fossil-fuel derived $CO_2$ from this source are calculated by using the volume of waste oil, plastic, and paper/cardboard incinerated, Japan's country-specific emission factors, and the percentage of incinerated industrial waste with energy recovery at industrial waste incineration facilities in accordance. Note that since it is difficult to estimate percentages of water content in waste oil and plastic in industrial waste, the emission factors for these sources are identified as wet basis. Also, since industrial textiles does not include synthetic textile under the regulation of the Waste Management and Public Cleansing Act, the industrial textiles is regarded as waste natural fiber: thus the $CO_2$ emissions from incineration of industrial textiles are not included in national total because these emissions are biogenic-origin.

$$E_i = EF_i \times A_i \times (1 - R_i)$$

$E_i$ : $CO_2$ Emissions from incineration of waste type *i* [kg-$CO_2$]
$EF_i$ : Emission factor for incineration of waste type *i* [kg-$CO_2$/t]
(wet basis for waste oil and plastic; dry basis for paper/cardboard)
$A_i$ : Amount of incinerated waste type *i* [t]
(wet basis for waste oil and plastic; dry basis for paper/cardboard)
$R_i$ : Percentage of industrial waste incinerated at facilities with energy recovery (for waste type *i*)

- ***Emission Factor***

➢ ***Equation***

In accordance with the approach taken by the *2006 IPCC Guidelines*, emission factor is calculated by multiplying the carbon content of each type of waste by the oxidation factor for incineration facilities.

- ***Fossil-fuel derived waste oil, plastic***

$$EF_i = CF_i \times OF \times 44/12$$

$EF_i$ : Emission factor for the incineration of waste type *i* (wet basis) [kg-$CO_2$/t]
$CF_i$ : Carbon content in waste type *i* (wet basis) [%]
$OF$ : Oxidation factor [%]

- ***Paper/cardboard***

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

$EF_i$ : Emission factor for the incineration of fossil-fuel derived components in paper/cardboard (dry basis) [kg-$CO_2$/t]
$CF_i$ : Carbon content in paper/cardboard (dry basis) [%]
$FCF_i$ : Fossil-fuel derived fraction in carbon in paper/cardboard [%]
$OF$ : Oxidation factor [%]

➢ ***Carbon Content***

Carbon content in waste oil is deemed to be 80% based on the factor of 0.8 [t-C/t] given in Environmental Agency (1992).
Carbon content in plastic is deemed to be 70% based on the factor of 0.7 [t-C/t] given in the said report.

For the carbon content of paper/cardboard, the carbon content of default value in the *2006 IPCC Guidelines*, as same as the value in municipal solid waste.

Table 7-43 Carbon contents of waste oil, plastic and Paper/cardboard in industrial waste

| Item | Carbon contents | Remarks | References |
|---|---|---|---|
| Waste oil | 80% | wet basis | Environmental Agency (1992) |
| Plastics | 70% | wet basis | Environmental Agency (1992) |
| Paper/ cardboard | 46 % | dry basis | *2006 IPCC Guidelines* |

➢ ***Fossil-fuel derived fraction in carbon in paper/cardboard in industrial waste***

For the fossil-fuel derived fraction in carbon in paper/cardboard in industrial waste, the default value of 1% in the *2006 IPCC Guidelines* are applied as same as for paper/cardboard in municipal solid waste.

➢ ***Oxidation factor***

The default value of 100% given in the *2006 IPCC Guidelines* is used.

➢ ***Emission factor***

Emission factors calculated by methodologies above are shown in Table 7-44.

Table 7-44 Emission factors for fossil-fuel derived fraction of waste oil, plastics and paper/cardboard in industrial waste

| Item | Unit | Emission factor |
|---|---|---|
| Waste oil | kg-$CO_2$/t (wet) | 2,933 |
| Plastics | kg-$CO_2$/t (wet) | 2,567 |
| Paper/cardboard | kg-$CO_2$/t (dry) | 17 |

● ***Activity Data***

For the activity data for $CO_2$ emissions from the incineration of waste oil, plastics and paper/cardboard in industrial waste, the amount of incineration provided by the *Cyclical Use of Waste Report* is used.

However, the amount of incineration provided in this report includes the amount of incineration of specially controlled industrial waste which is separately reported under "Incineration of Specially Controlled Industrial Waste" (see the next section), thus it is subtracted from the activity data from this source. Details of methodologies to estimate activity data are shown below.

$$A_{oil} = IW_{oil} \times (1 - F_{bio}) - SIW_{oil}$$

$A_{oil}$ : Activity data for the incineration of waste fossil-fuel derived oil (wet basis) [ t (wet)]

$IW_{oil}$ : Amount of waste oil incinerated in industrial waste (wet basis) [ t (wet)]

$SIW_{oil}$ : Amount of waste oil incinerated in specially-controlled industrial waste[1)] (wet basis) [ t (wet)]

$F_{bio}$ : Fraction of waste oil from animal and vegetable origin[2)] [%]

Note:

1) All the waste oil in specially controlled industrial waste to be estimated for emissions are waste fossil-fuel derived oil.
2) From the survey conducted by the MOE

Table 7-45 Fraction of waste oil from animal and vegetable origin

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fraction of waste animal and vegetable oil | % | 2.6 | 3.5 | 4.5 | 5.4 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |

$$A_{plastics} = \left(IW_{plastics} - SIW_{inf.\,plastics}\right) \times FPF_{iw}$$

$A_{plastics}$ : Activity data for the incineration of plastics (wet basis) [t (wet)]

$IW_{plastics}$ : Amount of plastics incinerated in industrial waste (wet basis) [t (wet)]

$SIW_{inf.\,plastics}$ : Amount of plastics incinerated in specially-controlled industrial waste (wet basis) [t (wet)]

$FPF_{iw}$ : Fossil-fuel derived fraction of industrial waste plastics [%]

Note: Fossil-fuel derived fraction of plastics in industrial waste plastics incinerated is estimated in the same way as indicated in "7.4.1.1. Municipal Solid Waste (5.C.1.-) b) 1) $CO_2$". See also Table 7-34. Note it is assumed that activity data for plastics (IW) incinerated does not include plastic bottles unlike MSW plastics.

$$A_{paper} = \{IW_{paper} - (SIW_{inf.} - SIW_{inf.plastics})\} \times (1 - u_{paper})$$

$A_{paper}$ : Activity data for the incineration of paper/cardboard (dry basis) [t (dry)]

$IW_{paper}$ : Amount of paper/cardboard incinerated in industrial waste (wet basis) [t (wet)]

$SIW_{inf.}$ : Amount of infectious waste incinerated in specially controlled industrial waste (wet basis) [t (wet)]

$SIW_{inf.\,plastics}$ : Amount of plastic incinerated in specially-controlled industrial waste (wet basis) [t (wet)]

$u_{paper}$ : Percentage of waste content in paper or cardboard in industrial waste [%]

Note: Percentage of water content in paper/cardboard in industrial waste is given the value 15% (see Table 7-10).

For more detail of activity data estimated, see Table 7-48.

- ***Percentage of Industrial Waste Incinerated at Industrial Incineration Facilities for Energy Recovery (by type)***

Percentage of industrial waste that is incinerated at industrial incineration facilities with energy recovery stands for the one being incinerated at the facilities actually supply electricity or heat outside of them. The values are obtained from the *Survey of Industrial Waste Treatment Facilities* (MOE).

In Japan, industrial incineration facilities are installed mainly by private sector waste disposal enterprises. In comparison with the municipal waste incinerators installed primarily by municipal governments, energy recovery (for use in power generation and as a heat source) has not yet been so popular. The percentage for the industrial waste category is therefore smaller.

Table 7-46 Percentage of IW incinerated at incineration facilities with energy recovery

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Waste oil [1)] | % | 0.6 | 0.7 | 0.6 | 2.5 | 2.1 | 4.1 | 4.1 | 2.3 | 4.0 | 4.2 | 4.8 | 4.4 | 3.1 | 3.1 |
| Plastics | % | 1.4 | 1.4 | 4.1 | 6.6 | 9.2 | 13.3 | 17.8 | 17.5 | 13.3 | 16.7 | 19.2 | 18.4 | 17.6 | 17.6 |
| Wood [2)] | % | 0.2 | 0.8 | 1.1 | 1.5 | 4.8 | 5.9 | 15.7 | 13.1 | 8.5 | 10.5 | 10.2 | 9.7 | 8.5 | 8.5 |
| Sludge [3)] | % | 0.9 | 0.8 | 1.0 | 1.1 | 2.1 | 2.2 | 3.0 | 3.4 | 8.3 | 12.5 | 12.2 | 12.0 | 10.6 | 10.6 |
| Other [4)] | % | 0.2 | 0.8 | 1.1 | 1.5 | 2.5 | 1.5 | 2.2 | 1.8 | 1.9 | 2.6 | 4.2 | 5.0 | 3.3 | 3.3 |

Note:
1） “Waste oil” includes fossil-fuel derived/animal and vegetable oil.
2） “Wood” includes paper/cardboard and wood.
3） Not applicable for “sewage sludge”.
4） “Other” includes textiles (natural fiber), and animal and vegetable residues/animal carcasses.

### *2) $CH_4$*

- ***Estimation Method***

Emissions of methane from this source have been calculated by multiplying the volume of industrial waste incinerated by Japan’s country specific emission factor and by percentage of industrial waste incinerated at incineration facilities with energy recovery.

$$E = \sum_j \{EF_j \times A_j \times (1 - R_j)\}$$

$E$ : Emission of methane from the incineration of industrial waste [kg-$CH_4$]
$EF_j$ : Emission factor for waste type $j$ (wet basis) [kg-$CH_4$/t]
$A_j$ : Incinerated amount of waste type $j$ (wet basis) [t]
$Rj$ : Percentage of industrial waste $j$ incinerated at facilities with energy recovery

- ***Emission Factor***

Based on expert judgment which takes into account the countermeasures against dioxin emissions from incinerators, for the emission factors by waste type for the period FY1990 - FY2001 (MOE, 2006b) and from FY2002 onward (MOE, 2010), respectively, different values are used. These emission factors are established based on actual measurement survey. The correction taking into account $CH_4$ concentrations in the atmosphere is not made to these emission factors. The emission factor for paper/cardboard or wood in MOE (2006b) and MOE (2010) is substituted for the emission factor for textiles (natural fiber), and animal and vegetable residues/animal carcasses.

Table 7-47 $CH_4$ emission factors for industrial waste by type

| Item | Unit | FY1990-2001 | FY2002 - |
|---|---|---|---|
| Waste oil (fossil-fuel derived/animal and vegetable) | g-$CH_4$ /t | 4.8 | 4.0 |
| Plastics | g-$CH_4$ /t | 30 | 8.0 |
| Paper/cardboard | g-$CH_4$ /t | 22 | 225 |
| Wood | g-$CH_4$ /t | 22 | 225 |
| Textiles (natural fiber) | g-$CH_4$ /t | 22 | 225 |
| Animal and vegetable residues/animal carcasses | g-$CH_4$ /t | 22 | 225 |
| Sludge | g-$CH_4$ /t | 14 | 1.5 |
| Other than sewage sludge | g-$CH_4$ /t | 14 | 1.5 |

Reference: Environmental Agency (2000), MOE (2006b), MOE (2010), Ishikawa Pref. et al. (1991-1999), JSAE (1996)

- ***Activity Data***

The volume of waste incinerated (wet basis) by waste type is used as the activity data for $CH_4$ emissions from the incineration of industrial waste.

➢ ***Paper, Wood, Textiles (natural fiber) and Animal and Plant Residues/Animal Carcasses:***

The volume of waste incinerated for each type is obtained from the *Cyclical Use of Waste Report*. Animal and vegetable residues/animal carcasses waste is defined as the sum of items "animal and vegetable residues" and "animal carcasses" in the said reference.

➢ ***Sludge***

Activity data is taken as the aggregate of the values obtained from the "Volume of Other Incinerated Organic Sludge" section in the *Cyclical Use of Waste Report*, and the "Volume of Incinerated Sewage Sludge" reported in a survey by the Ministry of Lands, Infrastructure, Transport and Tourism (MLIT).

➢ ***Waste Oil (Fossil-fuel derived/Animal and Vegetable) and Plastic***

The activity data for waste oil and plastic are provided by the *Cyclical Use of Waste Report.* Because the values provided by this report include the amount of specially-controlled industrial waste which is allocated to the category of specially-controlled industrial waste (5.C.1.-), it is subtracted from the total amount to avoid double counting. Unlike the activity data for $CO_2$ emissions, waste fossil-fuel derived oil and also waste animal and vegetable oil are included for the estimation of activity data from this source. Note activity data for plastic includes biomass-based plastic.

Table 7-48 Incinerated industrial waste by waste types

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Waste fossil-fuel derived oil | kt / year (wet) | 1,258 | 1,498 | 1,646 | 1,493 | 1,104 | 1,467 | 1,410 | 1,546 | 1,297 | 1,420 | 1,191 | 1,375 | 1,301 | 1,219 |
| Waste animal and vegetable oil | kt / year (wet) | 40 | 69 | 103 | 115 | 113 | 121 | 110 | 117 | 103 | 115 | 100 | 113 | 103 | 96 |
| Plastics (fossil-fuel derived) | kt / year (wet) | 842 | 1,794 | 1,780 | 1,808 | 1,490 | 1,701 | 1,509 | 1,629 | 1,775 | 1,588 | 1,822 | 1,774 | 1,836 | 1,783 |
| Biomass-based plastics | kt / year (wet) | NO | NO | NO | 0.1 | 0.1 | 2.1 | 2.3 | 2.9 | 3.4 | 3.1 | 3.8 | 3.1 | 3.5 | 3.2 |
| Paper/cardboad | kt / year (wet) | 335 | 712 | 718 | 323 | 299 | 292 | 225 | 349 | 152 | 130 | 114 | 109 | 116 | 114 |
| Wood | kt / year (wet) | 2,679 | 4,744 | 3,114 | 1,865 | 1,283 | 1,101 | 1,135 | 1,181 | 1,388 | 1,137 | 1,120 | 1,062 | 1,263 | 1,284 |
| Textiles (natural fiber) | kt / year (wet) | 31 | 49 | 50 | 43 | 26 | 24 | 26 | 24 | 35 | 39 | 27 | 36 | 29 | 29 |
| Animal and vegetable residues/animal carcasses | kt / year (wet) | 77 | 125 | 272 | 167 | 181 | 190 | 184 | 153 | 151 | 153 | 168 | 154 | 133 | 130 |
| Sewage sludge | kt / year (wet) | 3,060 | 3,827 | 4,300 | 4,988 | 4,731 | 4,694 | 4,734 | 4,817 | 4,934 | 4,753 | 4,550 | 4,452 | 4,684 | 4,709 |
| Sludge other than sewage sludge | kt / year (wet) | 1,972 | 2,023 | 2,071 | 2,288 | 2,106 | 2,010 | 2,020 | 1,713 | 1,954 | 2,021 | 1,880 | 1,884 | 2,003 | 1,931 |

### *3) $N_2O$*

● ***Estimation Method***

Emissions of $N_2O$ from this source are calculated separately for the major emission source, sewage sludge, and the waste other than sewage sludge. With respect to sewage sludge, emission factors are set by type of flocculants and furnaces; and the ones for "high-molecular-weight, flocculant fluidized bed incinerator" are further determined by the incineration temperatures. Emissions from the industrial waste other than sewage sludge are estimated by multiplying the volume of waste incinerated by Japan's country-specific emission factor. Among those emissions, the ones to be reported in the waste sector are calculated by multiplying the percentage of industrial waste incinerated at the industrial waste incineration facilities with energy recovery.

$$E = \sum \{EF_j \times A_j \times (1 - R_j)\}$$

$E$ : Emission of nitrous oxide from the incineration of industrial waste [kg-$N_2O$]

$EF_j$ : Emission factor for waste type $j$ (wet basis) [kg-$N_2O$ /t]

$A_j$ : Incinerated amount of waste type $j$ (wet basis) [t]

$R_j$ : Percentage of industrial waste $j$ incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Sewage Sludge***

Emission factor for $N_2O$ emissions from sewage sludge incineration are determined by taking a weighted average of actually measured emission factors for $N_2O$ at each incineration facility based on the survey on the volume of sewage sludge incinerated at the facilities conducted by MLIT. Since emission factors are different depending on the types of flocculants, incinerators, and furnace temperatures, they are established for each category as given in Table 7-49 (MOE, 2006b).

Table 7-49 $N_2O$ emission factors for sewage sludge incineration (wet basis)

| Type of flocculant | Type of incinerator | Combustion Temperature | Emission factor[1)] [g-$N_2O$/t] |
|---|---|---|---|
| High-molecular weight flocculant | Fluidized bed incinerator | Normal temperature combustion (around 800˚C) | 1,508 |
| | Fluidized bed incinerator[2)] | High temperature combustion (around 850˚C) | 645 |
| | Multiple hearth | − | 882 |
| Other | − | − | |
| Lime Sludge | − | − | 294 |
| − | - Multiple hearth air injection incineration method fluidized bed incinerator<br>- Two-stage incineration method circulating fluidized bed incinerator<br>- Stoker furnace | High temperature combustion (around 850˚C) | 263 |
| − | Carbonization furnace for solid fuel production | − | 31.2 |

Reference:
MOE (2013b), Hyogo Pref. (1994), Kanagawa Pref. (1994), National Institute for Land and Infrastructure Management: NILIM (2001), NILIM (2002), Nakamura et al. (1998), Matsubara et al. (1994), Takeishi et al. (1996)
Note:
1) The same emission factors are used for all the reporting years.
2) Excludes multiple hearth air injection incineration method fluidized bed incinerator and two-stage incineration method circulating fluidized bed incinerator.

➢ ***Waste other than Sewage Sludge***

Based on expert judgment which takes into account the countermeasures against dioxin emissions from incinerators, for the emission factors by waste type for the period FY1990-FY2001 (MOE, 2006b) and from FY2002 onward (MOE, 2010), respectively, different values are used. These emission factors are established based on actual measurement survey. The correction taking into account $CH_4$ concentrations in the atmosphere is not made to these emission factors. The emission factor applied for paper/cardboard or wood is also used for textiles (natural fiber) and animal and vegetable residues/animal carcasses in the MOE (2006b) and MOE (2010).

Table 7-50 $N_2O$ Emission factors for industrial waste by type (wet basis)

| Item | Unit | FY1990-2001 | From FY2002 onward |
|---|---|---|---|
| Waste oil (fossil-fuel derived/animal and vegetable) | g-$N_2O$ /t | 12 | 62 |
| Plastics | g-$N_2O$ /t | 180 | 15 |
| Paper/cardboard | g-$N_2O$ /t | 21 | 77 |
| Wood | g-$N_2O$ /t | 21 | 77 |
| Textiles (natural fiber) | g-$N_2O$ /t | 21 | 77 |
| Animal and vegetable residues/animal carcasses | g-$N_2O$ /t | 21 | 77 |
| Sludge (excluding sewage sludge) | g-$N_2O$ /t | 457 | 99 |

Reference: MOE (2000), MOE (2010), Ishikawa Pref. et al. (1991-1997), JSAE (1996), Nakamura et al. (1998), Matsubara et al. (1994), Suzuki et al. (2001), Takeishi et al. (1994), Takeishi et al. (1996), Ueno et al. (1995), Yasuda et al. (1994)

- ***Activity Data***

➢ ***Sewage Sludge***

Data in the "volume of incinerated sewage sludge, by flocculants and by incinerator types" reported in a survey by MLIT are used as activity data (wet basis).

Table 7-51 Amount of sewage sludge incinerated

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High-molecular-weight flocculant/ fluidized bed incinerator (nomal temp.) | kt / year (wet) | 1,112 | 1,869 | 2,397 | 2,839 | 1,664 | 1,535 | 1,532 | 1,552 | 1,549 | 1,318 | 1,695 | 1,218 | 1,531 | 1,551 |
| High-molecular-weight flocculant/ fluidized bed incinerator (high temp.) | kt / year (wet) | 128 | 219 | 723 | 1,469 | 2,508 | 2,581 | 2,587 | 2,641 | 2,644 | 2,644 | 2,283 | 2,665 | 2,503 | 2,522 |
| High-molecular-weight flocculant/multiple hearth | kt / year (wet) | 560 | 656 | 572 | 102 | 64 | 61 | 52 | 43 | 40 | NO | NO | NO | NO | NO |
| Lime sludge | kt / year (wet) | 1,010 | 663 | 272 | 289 | 142 | 109 | 83 | 74 | 22 | 1 | 1 | 1 | 1 | 1 |
| Other | kt / year (wet) | 55 | 161 | 175 | 8 | 1 | 1 | 3 | 0.5 | 12 | 70 | 27 | 27 | 27 | 27 |
| - Multiple hearth air injection/blowing incineration method fluidized bed incinerator,<br>- Two-stage incineration method circulating fluidized bed incinerator,<br>- Stoker furnace | kt / year (wet) | 195 | 259 | 161 | 280 | 282 | 338 | 439 | 444 | 565 | 604 | 411 | 412 | 465 | 431 |
| Carbonization furnace for solid fuel production | kt / year (wet) | NO | NO | NO | NO | 71 | 70 | 39 | 63 | 103 | 116 | 133 | 128 | 156 | 177 |

➢ ***Industrial Waste other than Sewage Sludge***

Activity data (wet basis) is determined in the same manner as for the $CH_4$ emissions from industrial waste, with the exception that the "volume of other incinerated organic sludge" is used as activity data for the sludge (excluding sewage sludge).

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainties in $CO_2$ emission factors are evaluated by using the 95% confidence interval of carbon content data in fossil fuel-based waste. The uncertainties in $CH_4$ and $N_2O$ emission factors are evaluated by using the 95% confidence interval in the actual measurement on the surveys for emissions factors. As for the uncertainties in activity data, the uncertainties in industrial waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-52.

Table 7-52 Uncertainty assessment for industrial waste on the category "waste incineration (5.C.1.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Waste oil | $CO_2$ | -2% | +2% | -30% | +30% | -30% | +30% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment. | The uncertainty based on expert judgment in industrial waste statistics is applied. | Combined by using the formula for propagation of errors |
| | $CH_4$ | -100% | +181% | -30% | +30% | -104% | +184% | The uncertainty is quoted from MOE (2010), a source of emission factors. | | |
| | $N_2O$ | -76% | +76% | -30% | +30% | -81% | +81% | | | |
| Plastics | $CO_2$ | -2% | +2% | -30% | +30% | -30% | +30% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment. | | Combined by using the formula for propagation of errors |
| | $CH_4$ | -100% | +216% | -30% | +30% | -104% | +218% | The uncertainties are quoted from MOE (2010), a source of emission factors. | | |
| | $N_2O$ | -44% | +44% | -30% | +30% | -53% | +53% | | | |
| Paper/card board | $CO_2$ | -100% | +400% | -30% | +30% | -104% | +401% | It is evaluated by combining the 95% confidence interval in actual measurement data of carbon content with the uncertainty of default fossil-fuel derived fraction in carbon in the *2006 IPCC Guidelines* evaluated by its range. | | Combined by using the formula for propagation of errors |
| Paper/card board or wood | $CH_4$ | -100% | +412% | -30% | +30% | -104% | +413% | The uncertainty is quoted from MOE (2010), a source of emission factors. | | Combined by using the formula for propagation of errors |
| | $N_2O$ | -64% | +64% | -30% | +30% | -71% | +71% | | | |
| Sludge | $CH_4$ | -100% | +201% | -30% | +30% | -104% | +203% | | | Combined by using the formula for propagation of errors |
| | $N_2O$ | -84% | +84% | -30% | +30% | -89% | +89% | | | |
| Textiles (Natural fiber) | $CH_4$ | -100% | +412% | -30% | +30% | -104% | +413% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in paper/card board or wood is substituted based on expert judgment. | | Combined by using the formula for propagation of errors |
| | $N_2O$ | -64% | +64% | -30% | +30% | -71% | +71% | | | |
| Animal and vegetable residues/ animal carcasses | $CH_4$ | -100% | +412% | -30% | +30% | -104% | +413% | | | Combined by using the formula for propagation of errors |
| | $N_2O$ | -64% | +64% | -30% | +30% | -71% | +71% | | | |

- ***Time-series Consistency***

  Emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By revisioning biomass-based plastic products data, $CO_2$ emissions were recalculated.

By updating the statistical data, emissions were recalculated. For detail, see the section "7.1.5. General Recalculations for Emissions from Waste Sector".

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 7.4.1.3. Specially-Controlled Industrial Waste (5.C.1.-)

### *a) Category Description*

The specially-controlled industrial waste includes wastes with properties, such as explosiveness, toxicity and infectivity, that may be harmful to human health or to living environment. Waste types in this category are indicated in the Table 7-53.

Table 7-53 Substance in incineration of specially-controlled industrial waste

| Waste type | Substance |
|---|---|
| Flammable waste oil | Gasoline, Kerosene, Gas oil or diesel oil |
| Specified hazardous industrial waste oil | Trichlorethylene, tetrachlorethylene, dichloromethane, carbon tetrachloride, 1,2-dichloroethane, 1,1-dichloroethane, cis-1,2-dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,3 dichloropropene, thiuram, simazine, thiobencarb, benzene, selenium, 1,4-dioxane |
| Infectious waste plastic | Plastic |
| Infectious waste (except plastic) | Glasses, Textile, Paper |

In this category, $CO_2$, $CH_4$, and $N_2O$ emissions from incineration of specially-controlled industrial waste are estimated by each waste type and reported in the corresponding category either “Non-biogenic, Hazardous waste”, Non-biogenic, Clinical waste” or “Biogenic, Clinical waste” (see Table 7-24).

Because the actual state of energy recovery from the incineration of specially-controlled industrial waste is not sufficiently understood, the emissions from specially-controlled industrial waste are reported entirely in “Waste Incineration (Category 5.C.)”.

### *b) Methodological Issues*

#### *1) $CO_2$*

- ***Estimation Method***

Emissions of $CO_2$ from the incineration of flammable waste oil, specified hazardous industrial waste oil and infectious waste plastic contained in specially-controlled industrial waste are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* (Page 5.9, Fig. 5.1) by using Japan’s country-specific emission factors and the volume of waste incinerated.

- ***Emission Factor***

- ***Flammable waste oil***

Emission factors for waste oil in industrial waste is used for flammable waste oil in specially-controlled industrial waste, since the difference of carbon contents and oxidation factor in the two source categories is considered to be small.

- ***Specified hazardous industrial waste oil***

In accordance with the approach taken by the *2006 IPCC Guidelines*, emission factor for specified hazardous industrial waste oil is estimated by multiplying the carbon content of the item by the oxidation factor for incineration facilities.

$$EF = CF \times OF \times (1 - u) \times 44/12$$

*EF* : Emission factor for the incineration of specified hazardous industrial waste oil [kg-$CO_2$/t]
*CF* : Carbon content in specified hazardous industrial waste oil (dry basis) [%]
*OF* : Oxidation factor [%]
*u* : Percentage of water content in specified hazardous industrial waste oil [%]

Average carbon content in specified hazardous industrial waste oil (dry basis) is estimated using weighted average of carbon content in chemical formula of substances shown in Table X for incinerated substances based on MOE (2010-2011). For the oxidation factor, the default value of 100% indicated in the *2006 IPCC Guidelines* is used. The percentage of water content in specified hazardous industrial waste oil is determined to be 5% by expert judgment.

- ***Infectious plastic***

For infectious plastic, the emission factors for incineration of plastics in industrial waste are substituted since the difference in terms of carbon contents and oxidation factor in the two source categories is considered to be small.

Table 7-54 $CO_2$ Emission factors for incineration of specially-controlled waste

| Item | Unit | Emission factor |
|---|---|---|
| Flammable waste oil | kg-$CO_2$/t (wet) | 2,933 |
| Specified hazardous industrial waste oil | kg-$CO_2$/t (wet) | 1,024 |
| Infectious plastics | kg-$CO_2$/t (wet) | 2,567 |

- ***Activity Data***

Generally, the amount of specially-controlled industrial waste incinerated obtained from the *Cyclical Use of Waste Report* is used as the activity data in and after FY2008. As for the past activity data which the survey data is not available, output volume of waste oil indicated in the *Report on Survey of Organizations in Industrial Waste Administration* (Water Supply Division, Health Service Bureau, the Ministry of Health and Welfare) is used on the assumption that the entire volume of waste oil and infectious plastic waste contained in specially-controlled industrial waste is incinerated. Details are shown below.

- ***Flammable waste oil***

The amount of specially-controlled industrial waste oil incinerated from the *Cyclical Use of Waste Report* is used as the activity data. Since the data includes both of incinerated amounts of flammable waste oil and specified hazardous industrial waste oil, the amounts of flammable waste oil are estimated by following equation. All the waste oil in specially-controlled industrial waste to be estimated for emissions is waste fossil-fuel derived oil.

$$A_{flam.oil} = SIW_{oil} - A_{s-hazard.oil}$$

$A_{flam.\ oil}$ : Amount of flammable waste oil incinerated (wet basis) [t]
$SIW_{oil}$ : Total amount of specially-controlled industrial waste oil incinerated (wet basis) [t]
$A_{s\text{-}hazard.\ oil}$ : Amount of specified hazardous industrial waste oil incinerated (wet basis) [t]

- ***Specified hazardous industrial waste oil***

The activity data is obtained from following equation using the amount of specified hazardous industrial waste oil reduced in incineration from the *Report on the survey for the estimation of GHG emissions from specially-controlled industrial was*te (MOE) and Residual fraction of incinerated waste oil from the *Cyclical Use of Waste Report*.

$$A_{s-hazard.oil} = R_{s-hazard.oil} \times (1 + r)$$

$A_{s\text{-}hazard.\ oil}$ : Amount of specified hazardous industrial waste oil incinerated (wet basis) [t]
$R_{s\text{-}hazard.\ oil}$ : Amount of specified hazardous industrial waste oil reduced in incineration (wet basis) [t]
$r$ : Residual fraction of incinerated waste oil [%]

- ***Infectious plastic***

The activity data is obtained from following equation using the amount of infectious waste incinerated from the *Cyclical Use of Waste Report* and Percentage of plastic content in infectious waste from Japan Society of Waste Management Experts: JSWME (1997). All of Infectious plastics are considered to be fossil-fuel derived.

$$A_{inf.plastics} = ISW_{inf.} \times C_{inf.plastics}$$

$A_{inf.\ plastics}$ : Amount of Infectious plastics incinerated (wet basis) [ t ]
$ISW_{inf.}$ : Total amount of infectious waste incinerated (wet basis) [ t ]
$C_{inf.\ plastics}$ : Percentage of plastic content in infectious waste [%]

### *2) $CH_4$*

- ***Estimation Method***

Emissions of $CH_4$ from the incineration of waste oil and infectious waste included in the specially controlled industrial waste are calculated by multiplying the volume of incinerated waste by type (wet basis) by Japan's country-specific emission factor.

- ***Emission Factor***

Because actual measurement data are not available, the emission factors for the incineration of industrial waste are used as substitutes for the emission factor for the specially-controlled industrial waste by type. Specifically, the substitute emission factors used are: the waste fossil-fuel derived oil in industrial waste for the flammable waste oil and specified hazardous waste oil; the plastic in industrial waste for the infectious plastic; and the paper/cardboard and wood in industrial waste for the other infectious waste (biogenic).

- ***Activity Data***

- ***Flammable waste oil***

Activity data is the same as those used for $CO_2$ emission.

- ***Specified hazardous industrial waste oil***

Activity data is the same as those used for $CO_2$ emission.

- ***Infectious plastics***

Activity data is the same as those used for $CO_2$ emission.

- ***Infectious waste except plastics***

The activity data is obtained from similar equation to Infectious plastics, as follows.

$$A_{inf.exc.\ plastics} = ISW_{inf.} \times \left(1 - C_{inf.plastics}\right)$$

$A_{inf.\ exc.\ plastics}$ : Amount of Infectious waste except plastics incinerated (wet basis) [ t ]

$ISW_{inf.}$ :Total amount of infectious waste incinerated (wet basis) [ t ]

$C_{inf.\ plastics}$ : Percentage of plastic content in infectious waste [%]

### *3) $N_2O$*

- ***Estimation Method***

Emissions of $N_2O$ from the incineration of waste oil and infectious waste in specially controlled industrial waste are calculated by multiplying the incinerated volume of each type of waste (wet basis) by Japan's country-specific emission factor.

- ***Emission Factor***

Because actual measurement data are not available, the $N_2O$ emission factors for the incineration of industrial waste are used as substitutes for determining the emission factor for each type of specially controlled industrial waste. Specifically, the substitute emission factors used are: the waste oil in industrial waste for the flammable waste oil and specified hazardous waste oil; the plastics in industrial waste for the infectious plastics; and the paper/cardboard and wood in industrial waste for the waste other than infectious plastics.

- ***Activity Data***

The same activity data used for $CH_4$ emissions is used.

Table 7-55 Amount of incineration of specially controlled industrial waste

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flammable waste oil | kt / year (wet) | 238 | 353 | 520 | 478 | 629 | 390 | 278 | 267 | 271 | 266 | 236 | 278 | 191 | 164 |
| Specified hazardous industrial waste oil | kt / year (wet) | 18 | 27 | 40 | 37 | 38 | 41 | 43 | 25 | 54 | 122 | 145 | 128 | 124 | 124 |
| Infectious waste (plastic) | kt / year (wet) | 78 | 128 | 167 | 169 | 143 | 154 | 176 | 131 | 133 | 176 | 166 | 160 | 154 | 153 |
| Infectious waste (except plastics) | kt / year (wet) | 105 | 172 | 225 | 228 | 99 | 106 | 121 | 90 | 92 | 121 | 114 | 110 | 106 | 106 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainty assessment is conducted as well as the assessment for the industrial waste incineration. As for the uncertainties in activity data, the uncertainties in specially-controlled industrial waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in Table 7-56.

Table 7-56 Uncertainty assessment for specially-controlled industrial waste on the category "waste incineration (5.C.1.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission/removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Specially-controlled industrial waste | $CO_2$ | -2% | +2% | -60% | +60% | -60% | +60% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment. | The uncertainty in specially-controlled industrial waste based on expert judgment is used. | Combined by using the formula for propagation of errors |
| | $CH_4$ | -100% | +216% | -60% | +60% | -117% | +224% | | | |
| | $N_2O$ | -44% | +44% | -60% | +60% | -74% | +74% | | | |

- ***Time-series Consistency***

Since some basic data used for calculating activity data are available only for part of time series, consistent data over the time series are developed based on the estimation. The emissions are calculated in a consistent manner.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

By updating the statistical data on the amount of specially-controlled waste, emissions were recalculated. For detail, see the section "7.1.5. General Recalculations for Emissions from Waste Sector".

See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

No improvements are planned.

## 7.4.2. Open Burning of Waste (5.C.2.)

### 7.4.2.1. Municipal Solid Waste (5.C.2.-)

***a) Category Description***

In Japan, since the Waste Management and Public Cleansing Act prohibits open burning of waste, the emissions from open burning of municipal solid waste are reported as "NO".

### 7.4.2.2. Industrial Waste (5.C.2.-)

***a) Category Description***

This category covers $CO_2$, $CH_4$ and $N_2O$ emissions from illegal open burning of industrial waste (wood, construction and demolition, plastics, and other/unknown), and the emissions are reported in the category "non-biogenic, industrial solid waste (ISW)".

### *b) Methodological Issues*

#### *1) $CO_2$*

- ***Estimation Method***

$CO_2$ emissions from the open burning of industrial waste plastics are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* by using Japan's country-specific emission factors and the volume of waste burned in the open air.

- ***Emission Factor***

In accordance with the approach taken by the *2006 IPCC Guidelines*, emission factor is calculated by multiplying the carbon content of industrial waste plastics by the oxidation factor for open burning.

$$EF = CF \times OF \times 44/12$$

*EF* : Emission factor for the open burning of industrial waste plastics (wet basis) [kg-$CO_2$/t]

*CF* : Carbon content in industrial waste plastics (wet basis) [%]

*OF* : Oxidation factor [%]

Table 7-57 $CO_2$ emission factors and relevant parameters of open burning of industrial waste plastics

| Item | Value | Reference | Note |
|---|---|---|---|
| *EF* | 1,489 [kg-$CO_2$/t (wet)] | - | Country-specific |
| *CF* | 70 % | Environmental Agency (1992) | See also "7.4.1.2. Industrial Waste (5.C.1.-)". |
| *OF* | 58 % | *2006 IPCC Guidelines* | Default value |

- ***Activity Data***

The amount of plastics as industrial waste burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) is used as the activity data in and after FY1996. As for the past activity data from FY1990 to FY1995, for which the survey data is not available, the data of FY1996 is uniformly used as a substitute since there are no other appropriate way to estimate before FY1995. Since it is unclear that plastics burned in the open air include biogenic fraction, whole of those plastics are assumed to be derived from fossil-fuel.

Table 7-58 The amount of fossil-fuel derived industrial waste burned in the open air (wet basis)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plastics | kt /year (wet) | 3.4 | 3.4 | 0.9 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.02 | 0.05 | 0.05 | 0.05 |

#### *2) $CH_4$ , $N_2O$*

- ***Estimation Method***

Emissions of $CH_4$ and $N_2O$ from the open burning of industrial waste are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* by using the IPCC default emission factors and the Japan's country-specific volume of waste burned in the open air.

- ***Emission Factor***

As no knowledge is obtained for making it possible to set emission factors specific to Japan, the default values given in the *2006 IPCC Guidelines* are applied.

Table 7-59 $CH_4$ and $N_2O$ emission factors for open burning of industrial waste

| Gas | EFs | Unit | Reference |
|---|---|---|---|
| $CH_4$ | 6.5 | kg-$CH_4$/t (wet) | *2006 IPCC Guidelines* |
| $N_2O$ | 0.15 | kg-$N_2O$/t (dry) | *2006 IPCC Guidelines* |

- ***Activity Data***

The total amount (wet basis) summed up all industrial waste burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) is used as the activity data for $CH_4$ emission estimates. As for the activity data for $N_2O$ emission estimates, the amounts (wet basis) mentioned above are converted to dry basis by using water contents for each waste type. To be consistent with the IPCC default emission factor applied in estimations, default water contents of the *2006 IPCC Guidelines* (wood: 15%, plastics: 0%, construction and demolition: 0%, and other/unknown:10%) are applied in this conversion. As for the past activity data from FY1990 to 1995, for which the survey data is not available, the data of FY1996 is uniformly used as a substitute since there are no other appropriate way to estimate.

Table 7-60 The amount of industrial waste burned in the open air

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total wet weight amount | kt /year (wet) | 72.2 | 72.2 | 28.9 | 3.5 | 1.7 | 1.3 | 1.2 | 0.9 | 1.3 | 0.6 | 1.0 | 0.5 | 0.5 | 0.5 |
| Total dry weight amount | kt /year (dry) | 62.4 | 62.4 | 25.5 | 3.1 | 1.5 | 1.1 | 1.0 | 0.8 | 1.2 | 0.5 | 0.8 | 0.5 | 0.5 | 0.5 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

Details of the uncertainty assessment on this category are indicated in Table 7-61.

Table 7-61 Uncertainty assessment on the category "open burning of waste (5.C.2.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission/removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Plastics | $CO_2$ | -2% | +2% | -30% | +30% | -30% | +30% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment. | The uncertainty in specially-controlled industrial waste based on expert judgment is used. | Combined by using the formula for propagation of errors |
| Industrial waste | $CH_4$ | -100% | +100% | -30% | +30% | -104% | +104% | The uncertainties are assessed as those of the *2006 IPCC Guidelines*' default emission factors. | | |
| | $N_2O$ | -100% | +100% | -30% | +30% | -104% | +104% | | | |

- ***Time-series Consistency***

Since activity data based on the survey are available only for and after FY1996, consistent data over the time series are developed based on the estimation. The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By updating the statistical data, emissions were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 7.4.3. Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)

### 7.4.3.1. Waste Incineration with Energy Recovery (1.A.)

#### *a) Category Description*

In this category, $CO_2$, $CH_4$, and $N_2O$ emissions from the incineration of municipal and industrial waste with energy recovery are estimated and reported. The reporting category for the emissions is "Other sectors (Category 1.A.4.)" and the fuel types are classified as "Other fossil fuels" and/or "Biomass" as shown on the Table 7-25.

#### *b) Methodological Issues*

Methodologies similar to the ones used in "7.4.1.1. Municipal Solid Waste (5.C.1.-)" and "7.4.1.2. Industrial Waste (5.C.1.-)" are used. Emissions are calculated using the following equations:

#### *1) $CO_2$*

- ***Estimation Method***

➢ ***Municipal Solid Waste***

$$E = EF \times A \times R$$

| | |
|---|---|
| *E* | : Emission of $CO_2$ from waste incineration [kg-$CO_2$] |
| *EF* | : Emission factor for incineration (dry basis) [kg-$CO_2$/t] |
| *A* | : Amount of waste incinerated (dry basis) [t] |
| *R* | : Percentage of municipal solid waste incinerated at incineration facilities with energy recovery |

➢ ***Industrial Waste***

$$E = EF \times A \times R$$

| | |
|---|---|
| *E* | : Emission of $CO_2$ from waste incineration [kg-$CO_2$] |
| *EF* | : Emission factor for waste incineration (wet basis) [kg-$CO_2$/t] |
| *A* | : Amount of waste incinerated (wet basis) [t] |
| *R* | : Fraction of industrial waste incinerated at industrial waste incineration facilities with energy recovery (by waste type) |

#### *2) $CH_4$ , $N_2O$*

- ***Estimation Method***

➢ ***Municipal Solid Waste***

$$E = \sum_i (EF_i \times A_i) \times R$$

| | |
|---|---|
| $E$ | : Emissions of $CH_4$ or $N_2O$ from incineration of municipal solid waste [kg-$CH_4$], [kg-$N_2O$] |
| $EF_i$ | : Emission factor for municipal solid waste incinerator type *i* (wet basis) [kg-$CH_4$/t] [kg-$N_2O$/t] |
| $A_i$ | : Amount of municipal solid waste incinerated for incinerator type *i* (wet basis) [t] |
| $R$ | : Percentage of municipal solid waste incinerated at facilities with energy recovery |

➢ ***Industrial Waste***

$$E = \sum_j \left(EF_j \times A_j \times R_j\right)$$

| | |
|---|---|
| $E$ | : Emissions of $CH_4$ or $N_2O$ from incineration of industrial waste [kg-$CH_4$], [kg-$N_2O$] |
| $EF_j$ | : Emission factor for industrial waste type *j* (wet basis) [kg-$CH_4$/t], [kg-$N_2O$/t] |
| $A_j$ | : Amount of industrial waste type *j* incinerated (wet basis) [t] |
| $R_j$ | : Fraction of industrial waste type *j* incinerated at industrial waste incineration facilities with energy recovery |

● ***Activity Data Converted into Energy Units (Reference Value)***

Activity data converted into energy units to be reported in CRF is estimated as indicated below.

➢ ***Municipal Solid Waste***

$$A_E = A \times GCV \times R/10^6$$

| | |
|---|---|
| $A_E$ | : Calorific value of activity data of MSW [TJ] |
| $A$ | : Total amount of MSW incinerated [kg (wet basis)] |
| $GCV$ | : Gross calorific value of MSW [MJ/kg] |
| $R$ | : Fraction of MSW incinerated at MSW incineration facility with energy recovery |

Based on the actual measurement results obtained at municipality, the calorific value of MSW is 9.9 (MJ/kg).

➢ ***Industrial Waste***

$$A_E = \sum_j A_j \times GCV_j \times R/10^6$$

| | |
|---|---|
| $A_E$ | : Calorific value of activity data of industrial waste [TJ] |
| $Aj$ | : Amount of industrial waste type *j* incinerated [kg (wet basis)] |
| $GCVj$ | : Gross calorific value of industrial waste type *j* [MJ/kg] |
| $R$ | : Fraction of industrial waste type *j* incinerated at industrial waste incineration facility with energy recovery |

Calorific value of industrial waste is indicated in Table 7-66 (as referred to hereinafter).

***c) Uncertainties and Time-series Consistency***

Methodologies similar to the ones used in “7.4.1.1. Municipal Solid Waste (5.C.1.-)” and “7.4.1.2. Industrial Waste (5.C.1.-)” are used.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

Same recalculations as the category waste incineration (without energy recovery) were conducted. For details, see the paragraphs for category-specific recalculations on "7.4.1.1. Municipal Solid Waste (5.C.1.-)" and "7.4.1.2. Industrial Waste (5.C.1.-)".

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)

### *a) Category Description*

In this category, $CO_2$, $CH_4$, and $N_2O$ emissions from waste directly used as alternative fuel are estimated and reported. The reporting category for the emissions for each type of waste is, according to its use as raw material or fuel, either "Energy industries (Category 1.A.1.)", "Manufacturing industries and Construction (1.A.2.)" or "Other sectors (Category 1.A.4.)". The fuel types are classified as "Other fossil fuels" and/or "Biomass" as indicated in Table 7-25.

Greenhouse gas emissions during the direct use of waste as a raw material, such as plastics used as reducing agents in blast furnaces or as a chemical material in coking furnaces, or use of intermediate products manufactured using the waste as a raw material, are estimated in this category. The waste used as raw material and the ones used as alternative fuel are combined and expressed as "Raw Material/Fuel Use" in this section.

### *b) Methodological Issues*

### *1) $CO_2$*

- ***Estimation Method***

Emissions are estimated by multiplying the incinerated volume of each type of waste used as raw material or fuel by Japan's country-specific emission factor. The wastes included in the estimation are the portions used as raw material or fuel of: plastics in MSW, plastics and waste fossil-fuel derived oil in industrial waste, and waste tires.

- ***Emission Factor***

Emission factors are established for the plastics from MSW that are used as chemical raw material in coke ovens and waste tires. The remaining emission sources used the emission factors for "7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)".

Table 7-62 $CO_2$ Emission factors specially defined for this category

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSW-coke oven | kg-$CO_2$/t(dry) | 1,434 | 1,434 | 1,434 | 1,434 | 1,434 | 1,434 | 1,434 | 1,434 | 1,434 | 1,434 | 1,434 | 1,434 | 1,434 | 1,434 |
| Waste tire | kg-$CO_2$/t(dry) | 1,867 | 1,794 | 1,799 | 1,746 | 1,738 | 1,759 | 1,744 | 1,743 | 1,744 | 1,736 | 1,698 | 1,677 | 1,673 | 1,661 |

- ***Activity Data***

For details of the amount of waste used as raw materials or fuels, see the7.4.3.2.a - 7.4.3.2.c.

Table 7-63 Amount of direct use of waste as alternative fuel (wet basis)

| Waste type | | Application brakedown | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSW | Plastics | Liquefaction | kt (wet) | NO | NO | 3 | 7 | 7 | 1 | NO | NO | NO | NO | NO | NO | NO | NO |
| | | Blast furnace reducing agent | kt (wet) | NO | NO | 25 | 37 | 28 | 27 | 26 | 26 | 30 | 27 | 31 | 29 | 28 | 29 |
| | | Coke oven chemical feedstock | kt (wet) | NO | NO | 11 | 175 | 150 | 177 | 169 | 171 | NO | 17 | 29 | 25 | 32 | 18 |
| | | Gasification | kt (wet) | NO | NO | 1 | 59 | 45 | 53 | 51 | 62 | 58 | 51 | 55 | 55 | 57 | 46 |
| Industrial waste | Waste oil | (Unclassified) | kt (wet) | 1,243 | 1,461 | 1,452 | 1,848 | 1,620 | 1,701 | 1,686 | 1,764 | 1,707 | 1,633 | 1,786 | 1,664 | 1,664 | 1,596 |
| | Plastics | Blast furnace reducing agent | kt (wet) | NO | NO | 57 | 160 | 97 | 134 | 114 | 134 | 107 | 149 | 144 | 156 | 168 | 131 |
| | | Chemical industry | kt (wet) | 5 | 4 | 5 | 2 | 1 | 1 | 1 | 1 | 1 | 0.4 | 0.4 | 0.2 | 3.0 | 3.5 |
| | | Paper industry | kt (wet) | NO | NO | 3 | 3 | 17 | 18 | 16 | 15 | 14 | 18 | 16 | 17 | 18 | 18 |
| | | Cement burning | kt (wet) | NO | 9 | 102 | 302 | 457 | 445 | 469 | 479 | 518 | 595 | 576 | 623 | 643 | 718 |
| | | Automobile manufacturere | kt (wet) | 16 | 10 | 8 | 4 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | | Liquefaction | kt (wet) | NO | NO | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.1 | NO | 1 |
| | | Gasification | kt (wet) | NO | NO | NO | 11 | 92 | 117 | 78 | 79 | 97 | 90 | 81 | 79 | 91 | 97 |
| | Wood | (Unclassified) | kt (wet) | 1,635 | 1,635 | 2,061 | 2,683 | 3,918 | 3,900 | 4,065 | 4,151 | 4,425 | 4,878 | 4,628 | 4,555 | 4,832 | 4,906 |
| Waste tire | | Cement burning | kt (wet) | 111 | 275 | 361 | 181 | 112 | 95 | 77 | 66 | 62 | 53 | 59 | 63 | 70 | 64 |
| | | Boiler | kt (wet) | 119 | 126 | 75 | 12 | 9 | 8 | 6 | 6 | 6 | 2 | 2 | 5 | 3 | 3 |
| | | Iron manufacture | kt (wet) | NO | NO | 57 | 51 | 28 | 30 | 31 | 30 | 27 | 27 | 20 | 19 | 17 | 14 |
| | | Gasification | kt (wet) | NO | NO | NO | 27 | 48 | 49 | 45 | 45 | 44 | 50 | 49 | 51 | 58 | 61 |
| | | Metal refining | kt (wet) | 67 | 37 | 30 | 10 | 1 | 1 | 1 | NO | NO | NO | NO | NO | NO | NO |
| | | Tire manufacture | kt (wet) | NO | 32 | 39 | 24 | 18 | 23 | 20 | 27 | 27 | 22 | 23 | 23 | 21 | 20 |
| | | Paper manufacture | kt (wet) | NO | 26 | 42 | 210 | 349 | 388 | 377 | 363 | 372 | 415 | 439 | 407 | 436 | 446 |
| | | Power generation | kt (wet) | NO | NO | 7 | 9 | 11 | 9 | 32 | 37 | 40 | 46 | 51 | 58 | 47 | 66 |
| Refuse-derived fuel (RDF) | | (Unclassified) | kt (wet) | 34 | 39 | 148 | 415 | 376 | 380 | 389 | 384 | 386 | 388 | 361 | 360 | 359 | 362 |
| Refuse paper and plastic fuel (RPF) | | Petroleum product manufacturer | kt (wet) | NO | NO | 0.4 | 5 | 3 | 4 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 0.2 |
| | | Chemical industry | kt (wet) | NO | NO | 7 | 15 | 25 | 22 | 26 | 27 | 26 | 20 | 22 | 19 | 18 | 17 |
| | | Paper industry | kt (wet) | NO | 8 | 25 | 465 | 753 | 747 | 783 | 820 | 869 | 852 | 872 | 948 | 960 | 970 |
| | | Cement manufacturer | kt (wet) | NO | NO | 0.2 | 8 | 21 | 15 | 16 | 14 | 16 | 17 | 14 | 11 | 13 | 15 |

Note:

- The amount of biogenic fraction such as biomass-based plastics, waste animal and vegetable oil, and wood are not included in the activity data for the estimation of $CO_2$ emissions.
- For the activity data to estimate $CO_2$ emissions except for waste oils and plastics in industrial waste, the figures in the above table are converted into dry basis amount by subtracting water contents.
- Waste oil includes “used lubricant” and “used solvent”.

### *2) $CH_4$, $N_2O$*

- ***Estimation Method***

Emissions are estimated by multiplying the amount of each type of waste used as raw material or fuel by the country-specific emission factor.

- ***Emission Factor***

Emission factors for waste used as raw material and fuel are determined by multiplying the emission factor for applicable types of furnaces by the calorific value of each waste type, and converting the result to the weight-based values.

Table 7-64 shows the data used in the estimation.

$$EF_i = EF_{E,i} \times GCV_i / 1000$$

$EF_i$ : Emission factor for waste type *i* [ kg-$CH_4$ / t(wet)], [kg-$N_2O$/ t(wet)]
$EF_{E,i}$ : Emission factor for waste type *i* on calorie basis [kg-CH4/TJ], [kg-$N_2O$/TJ]
$GCV_i$ : Gross calorific value of waste type *i* [MJ/kg]

Table 7-64 Data used for the calculation of $CH_4$ and $N_2O$ emission factors for direct use of wastes as alternative fuel

| Waste type | | Application breakdown | Emission factor for furnaces and ovens (Energy sector) | | Calorific value |
|---|---|---|---|---|---|
| | | | $CH_4$ | $N_2O$ | |
| MSW | Plastics | Liquefaction | Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels) | | Calorific value of plastic |
| | | Blast furnace reducing agent | NA | | NA |
| | | Coke oven chemical feedstock | NA | | NA |
| | | Gasification | NA | | NA |
| Industrial waste | Waste oil | (Unclassified) | Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels) | | Specific gravity of reclaimed oil/waste oil [1)] |
| | Plastics | Blast furnace reducing agent | NA | | NA |
| | | Chemical industry | Boilers (wood, charcoal, and other solid fuel) | Fluidized-bed boilers (solid fuel) | Calorific value of plastic |
| | | Paper industry | | | |
| | | Automobile manufacturer | | | |
| | | Cement burning | Other industrial furnaces (solid fuel) | | |
| | | Liquefaction | Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels) | | |
| | | Gasification | NA | | NA |
| | Wood | (Unclassified) | Boilers (wood, charcoal) | Boilers (other than fluidized-bed) (solid fuel) | Calorific value of wood [2)] |
| Waste tire | | Iron manufacture | NA | | NA |
| | | Cement burning | Other industrial furnaces (solid fuel) | | Calorific value of waste tires |
| | | Gasification | Other industrial furnaces (gas fuels) and other industrial furnaces (liquid fuels) [3)] | | |
| | | Metal refining (pyrolysis) | Boilers (gas fuels) | | |
| | | Boiler | Boilers (wood, charcoal, and other solid fuel) | Boilers (other than fluidized-bed) (solid fuel) | |
| | | Tire manufacture | | | |
| | | Paper manufacture | | | |
| | | Power generation | | | |
| Refuse-derived fuel (RDF) | | (Unclassified) | Boilers (wood, charcoal, and other solid fuel) | Boilers (other than fluidized-bed) (solid fuel) | Calorific value of RDF |
| Refuse-derived fuel (RPF) | | Petroleum product manufacturer | Boilers (wood, charcoal, and other solid fuel) | Boilers (other than fluidized-bed) (solid fuel) | Calorific value of RPF [4)] |
| | | Chemical industry | | | |
| | | Paper industry | | | |
| | | Cement manufacturer | Other industrial furnaces (solid fuel) | | |

Note:

1) Calorific value per unit volume is determined by dividing by the specific gravity of waste oil (0.9 kg/l) obtained from JSWME (1997).
2) Data from Environmental Agency (1995)
3) The percentage of substances recovered during the gasification of waste tires. A weighted average is calculated by using the proportions of gas and oil (22% and 43%) reported in the Hyogo Pref. (2003).
4) Weighted average of calorific values calculated based on the manufacturing ratio of Coal substitution RPF and Coke substitution RPF given by the Japan RPF Industry Association (2004)

Table 7-65 $CH_4$ and $N_2O$ emission factors for the use of waste as raw material or fuel used in the Energy sector

| Furnace type/Fuel type | $CH_4$ Emission factor [kg-$CH_4$/TJ] | $N_2O$ Emission factor [kg-$N_2O$/TJ] |
|---|---|---|
| Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels) | 0.26 | 0.19 |
| Boilers (gas fuels) | 0.23 | 0.17 |
| Boilers (steam coal, coke, other solid fuels) | 0.13 | - |
| Boilers (wood, charcoal) | 74.9 | - |
| Boilers (other than fluidized-bed) (solid fuels) | - | 0.85 |
| Normal pressure fluidized-bed boilers (solid fuels) | - | 54.39 |
| Other industrial furnaces (liquid fuel) | 0.83 | 1.8 |
| Other industrial furnaces (solid fuel) | 13.1 | 1.1 |
| Other industrial furnaces (gaseous fuel) | 2.3 | 1.2 |

Reference: MOE (2006a)

Table 7-66 Calorific Value of waste incinerated and used as raw material or fuel

| Item | | Unit | GCV | Reference |
|---|---|---|---|---|
| Waste oil (including reclaimed oil) | | TJ/l | 40.2 | *General Energy Statistics* (ANRE); estimated with 0.9[kg/L] (JSWME, 1997) |
| Plastics | | MJ/kg | 29.3 | *General Energy Statistics* (ANRE) |
| Paper/cardboard | | MJ/kg | 15.1 | JSWME (1997), dry basis; value is obtained by subtracting water content |
| Wood | | MJ/kg | 14.4 | *General Energy Statistics* (ANRE) |
| Textiles | | MJ/kg | 17.9 | JSWME (1997), dry basis; value is obtained by subtracting water content |
| Food waste (Animal and vegetable residues/animal carcasses) | | MJ/kg | 4.4 | JSWME (1997), dry basis; value is obtained by subtracting water content |
| Sludge (including sewage sludge) | | MJ/kg | 4.7 | *General Energy Statistics* (ANRE), dry basis; value is obtained by subtracting water content |
| Waste tire | 2004 and before | MJ/kg | 20.9 | *General Energy Statistics* (ANRE) |
| | 2005 and later | MJ/kg | 33.2 | *General Energy Statistics* (ANRE) |
| RDF | | MJ/kg | 18.0 | *General Energy Statistics* (ANRE) |
| RPF | | MJ/kg | 29.3 | *General Energy Statistics* (ANRE) |

- ***Activity Data***

➢ ***Amount of Waste Used as Raw Material or Fuel***

Activity data are determined for each category using the wet-basis values (Table 7-63). For more details, see each section.

➢ ***Activity Data Converted into Energy Units (Reference Value)***

Activity data converted into energy units to be reported in CRF are calculated as indicated below.

$$A_{E,i} = N_i \times GCV_i / 10^6$$

$A_{E,i}$ : Activity data of waste type *i*, converted into energy units [TJ]
$N_i$ : Amount of waste type *i* used as raw material or fuel [kg (wet)]
$GCV_i$ : Gross calorific value of waste type *i* [MJ/kg]

### *c) Uncertainties and Time-series Consistency*

See the respective section.

### *d) Category-specific QA/QC and Verification*

See the respective section.

### *e) Category-specific Recalculations*

See the respective section.

### *f) Category-specific Planned Improvements*

See the respective section.

## 7.4.3.2.a. Municipal Waste (Plastic) Used as Alternative Fuel (1.A.1 and 1.A.2)

### *a) Category Description*

This category covers the emissions from municipal waste (plastic) used as alternative fuels. Plastics in MSW collected under the Containers and Packaging Recycling Law are processed into petrochemical, blast furnace reducing agent, chemical raw material in coke oven, and gasification to be used as alternative fuel or raw material.

### *b) Methodological Issues*

### *1) $CO_2$*

- ***Estimation Method***

Emissions are calculated by multiplying the amount of fossil-fuel derived plastic in MSW by each usage (petrochemical, blast furnace reducing agent, chemical raw material in coke oven, and gasification) by Japan's country-specific emission factor.

- ***Emission Factor***

For the emission factors for plastics in MSW in the usage of petrochemical, blast furnace reducing agent, and gasification, the same values applied in "7.4.1.1. Municipal Solid Waste (5.C.1.-) are applied. The emission factor for plastics used as chemical raw material in coke ovens is set as the volume of hydrocarbon that is used as chemical raw material and from which no $CO_2$ is emitted into the air by subtracting the percentage of carbon in the plastics that migrates to hydrocarbon oil in the coke oven (47.9%) from emission factor for plastics (MSW).

$$EF_{\text{coke}} = EF_{plastics} \times (1 - M)$$

$EF_{coke}$ : Emission factor for plastics used as raw material in coke ovens (dry basis)
$EF_{plastics}$ : Emission factor for the incineration of plastics in municipal solid waste (dry basis)
$M$ : Fraction of carbon in plastics used as chemical raw material for coke ovens that migrates to hydrocarbon

- ***Activity Data***

The amount of plastics in MSW used as raw material or fuel by usage (wet basis) is estimated by the total amount collected by designated legal bodies and municipalities to be processed as raw material or fuel by usage (wet basis). The methodology to estimate activity data for this category is the same as that in the section "7.4.1.1. Municipal Solid Waste (5.C.1.-) b) 1) $CO_2$".Note that only fossil-fuel derived fraction of "plastics other than plastic bottles in MSW" are applied for this category since this category does not include emissions from plastic bottles incineration.

$$A_i = WP_i \times (1 - u_{plastics}) \times FPF$$

$A_i$ : Amount of fossil-fuel derived plastics used as raw material or fuel for usage $i$ [t (dry)]
$WP_i$ : Amount of plastics used as raw material or fuel for usage $i$ [t (wet)]
$u_{plastics}$ : Percentage of water content in plastics [%]
$FPF$ : Fossil-fuel derived fraction of plastics other than plastic bottles in MSW [%]

➢ ***The Amount of Plastics in MSW Used as Raw Material or Fuel by Usage (Wet Basis)***

- ***Processing of plastics collected by designated legal bodies***

The amount of the plastics in MSW collected by designated legal bodies into raw material or fuel is determined from the amount reported (pyrolytic oil: petrochemical, blast furnace reducing agent, chemical raw material in coke-oven, syngas, and gasification) in the "Plastic Containers and Packaging (Other Plastics, Food Trays)" section of the *Statistics of Commercial Recycling of Plastics (Recycling)* compiled by the Japan Containers and Packaging Recycling Association. Usage in products that do not emit $CO_2$ is deducted.

- ***Processing of plastics collected by municipalities***

The amount of plastics in MSW collected by municipalities and processed into raw material or fuel is calculated as indicated below.

$$P_{LG} = \sum (PR - P_{JCPRA}) \times F_i \times R_i$$

$P_{LG}$ : Amount of plastics in MSW collected by municipalities and processed into raw material or fuel [t (wet)]
$PR$ : Amount of all plastics that are commercially recycled under the Plastic Containers and Packaging Recycling Law (wet basis)[1)] [t (wet)]
$P_{JCPRA}$ : Amount of plastics (wet basis) that is commercially recycled through designated legal bodies)[2)] [t (wet)]
$F_i$ : Percentage of commercially recycled plastics by recycling method $i$[3)] [%]
$R_i$ : Percentage of commercially recycled plastic products by recycling method $i$[4)] [%] (The percentage for designated legal bodies is substituted for the value for municipalities.)

Note:
1) Amount of plastics commercially recycled under the Plastic Containers and Packaging Recycling Law (wet basis)
The results of the selective collections by municipalities and commercial recycling under the Plastic Containers and Packaging Recycling Law are determined from Annual Recycling Statistics by the Environmental Regeneration and Material Cycles Bureau of MOE.
2) Amount of plastics commercially recycled through designated legal body channels (wet basis)
The amount is determined from the "Actual Collection of Plastic Containers and Packages" section of the Statistics of Commercial Recycling of Plastics (Recycling).
3) Percentage of commercially recycled plastics by recycling method
The rates are obtained from the percentages for various methods of commercial recycling of the plastics collected through municipal channels in the Results of the 2001 Questionnaire to Municipalities on Waste Plastic Processing compiled by the Plastic Waste Management Institute.
4) Percentage of commercially recycled plastic products by recycling method
The values for the commercial recycling of the plastics collected through the municipal channels are substituted for the percentage of commercially recycled plastic products collected through designated legal body channels. The percentages are calculated by dividing the amounts of commercially recycled plastic products by various recycling methods, which are established in the activity data for recycling through designated legal body channels, by the amount of commercially recycled plastics. The amount of commercially recycled plastics by each of the recycling methods is calculated by multiplying the amount of plastics commercially recycled through designated legal body channels, by the percentage of commercially recycled plastics by recycling method obtained from the Assessment and Deliberation of the Plastic Containers and Packaging Recycling Law, the Japan Containers and Packaging Recycling Association.

➢ ***Water Content Ratio***

Water content ratio of 4% is determined based on the data provided by the *Japan Containers and Packaging Recycling Association*.

➢ ***Fossil-fuel Derived Fraction of Plastics other than plastic bottles in MSW***

See Table 7-34 in the section "7.4.1.1. Municipal Solid Waste (5.C.1.-)."

***2) $CH_4$, $N_2O$***

For estimation method and emission factors, see the section "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)". The amount of plastics used as raw material or fuel by usage (wet basis) is determined by

the total amount collected by designated legal bodies and municipalities to be processed as raw material or fuel by usage (wet basis); this value includes the amount of biomass-based plastics consumed.

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainty assessment is conducted as well as assessment in the category of the municipal waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-67.

Table 7-67 Uncertainty assessment for municipal waste plastics used as alternative fuels (1.A.1 and 1.A.2)

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Plastics | $CO_2$ | -2% | +2% | -10% | +10% | -10% | +10% | The equivalent assessment of the uncertainty in municipal waste plastics in "5.C Incineration" is used. | The uncertainty in municipal waste statistics based on expert judgment is used. | Combined by using the formula for propagation of errors |
| | $CH_4$ | -39% | +39% | -10% | +10% | -40% | +40% | The equivalent assessment of the uncertainty in municipal waste in "5.C Incineration" is used. | | |
| | $N_2O$ | -34% | +34% | -10% | +10% | -35% | +35% | | | |

- ***Time-series Consistency***

Time series consistency in emission estimates has been ensured. However, the statistical data for activity data have been available since FY2000 because the use of waste as alternative fuel or raw material was not a common practice prior to FY2000 in Japan.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By revisioning biomass-based plastic products data, $CO_2$ emissions were recalculated. By updating the statistical data, emissions were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 7.4.3.2.b. Industrial Waste (Plastics, Waste Oil, and Wood) Used as Alternative Fuels (1.A.2.))

### *a) Category Description*

This category covers greenhouse gas emissions from industrial waste (plastics, waste oil, and wood) used as raw material or fuels.

***b) Methodological Issues***

***1) $CO_2$***

- ***Estimation Method and Emission Factor***

Emissions are estimated by multiplying the amount of fossil-fuel derived plastics incinerated used as raw material or fuel and waste fossil-fuel derived oil used as raw material or fuels by emission factor used for incineration of industrial waste.

- ***Activity Data***

➢ ***Plastics***

Estimated activity data are the amounts of plastics (wet basis) in industrial waste used as raw material or fuel in steel industry, chemical industry, paper industry, cement Manufacturer, automobile manufacturer, and "other industry". The amount of plastics in industrial waste used as raw material or fuel in each industry is provided by the following data sources: for steel industry, the *Current State of Plastics Waste Recycling and Future Tasks* published by the Japan Iron and Steel Federation; for cement manufacturing industry, from the *Cement Handbook* published by the Japan Cement Association; for chemical industry, paper industry, and automobile manufacturer, the amount of plastics used for fluid bed boiler provided by the Japan Chemical Industry Association, the Japan Paper Association, the Japan Automobile Manufacturers Association. For "other industry", the activity data is obtained from the *Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics* (Environmental Regeneration and Material Cycles Bureau of MOE) distinguished between plastics liquefaction and gasification. The fossil-fuel derived fraction in industrial waste plastics is estimated in the same way as indicated in "7.4.1.2. Industrial Waste (5.C.1.-) 7.4.1.2. b)1) $CO_2$".

➢ ***Waste Oil (Fossil-fuel derived)***

The activity data for waste oil is mainly obtained from the *Cyclical Use of Waste Report*. The valuables, which are not included in the *Cyclical Use of Waste Report*, is additionally obtained from the other sources as "Used lubricant" and "Used solvent".

- ***Waste Oil***

The amount of waste oil indicated as "Fuel Usage" of "Direct Recycle Usage" and "Recycle Usage after Treatment" of industrial waste is used as the activity data of the waste oil that includes biogenic fraction. Hence in the estimation method for $CO_2$ emissions, the amount of biogenic "waste animal and vegetable oil" is subtracted from this item in the same way as indicated in "7.4.1.2. Industrial Waste (5.C.1.-) 7.4.1.2. b)1) $CO_2$". The data for FY1997 and before are estimated by using the trend of the amount of incinerated industrial waste oil.

- ***Used lubricants***

The amount of recycled heavy oil products derived from used lubricant, indicated in the *Lubricant Recycle Handbook*, Japan Lubricating Oil Society is also used as activity data of fossil fuel-derived waste oil. All used lubricants are assumed to be fossil-fuel derived. The data for FY2001 and before are estimated by using the trend of the amount of incinerated industrial waste oil.

- ***Used solvents***

The data of the amount of used solvents to be used as alternative fuel (valuables-origin), surveyed by the Japan Solvent Recycling Industry Association is also used as activity data for fossil fuel-derived waste oil. All used solvents are assumed to be fossil fuel- derived.

### 2) $CH_4$, $N_2O$

- ***Estimation Method and Emission Factor***

See the section "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)"

- ***Activity Data***

➢ ***Plastics***

The activity data used for $CO_2$ emission estimates from this source is also used for $CH_4$ and $N_2O$ emission estimates. Note plastics as blast furnace reducing agent and plastics gasified are not included in the activity data (see also Table 7-26).

➢ ***Waste Oil (Fossil-fuel derived / Animal and Vegetable)***

The activity data used for $CO_2$ emission estimates from this source is also used for $CH_4$ and $N_2O$ emission estimates. Unlike the activity data for $CO_2$ emissions, waste animal and vegetable oil are also included for the estimation of activity data from this source.

➢ ***Wood***

The amount of usage of wood as raw material or fuel is obtained from the "fuel usage" in the "direct recycle usage" and the "fuel usage" in the "recycle usage after treatment" in the *Cyclical Use of Waste Report*. The values before FY1997 are estimated by using the average value in the period of FY1998-2002.

### c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainty assessment is conducted as well as assessment in the category of the industrial waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-68.

Table 7-68 Uncertainty assessment for industrial waste plastics used as alternative fuels (1.A.2)

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Plastics | $CO_2$ | -2% | +2% | -30% | +30% | -30% | +30% | The equivalent assessment of the uncertainty in industrial waste plastics in "5.C Incineration" is used. | The uncertainty based on expert judgment in industrial waste statistics is applied. | Combined by using the formula for propagation of errors |
| | $CH_4$ | -100% | +216% | -30% | +30% | -104% | +218% | | | |
| | $N_2O$ | -44% | +44% | -30% | +30% | -53% | +53% | | | |
| Waste oil | $CO_2$ | -2% | +2% | -30% | +30% | -30% | +30% | The equivalent assessment of the uncertainty in industrial waste oil in "5.C Incineration" is used. | | Combined by using the formula for propagation of errors |
| | $CH_4$ | -100% | +181% | -30% | +30% | -104% | +184% | | | |
| | $N_2O$ | -76% | +76% | -30% | +30% | -81% | +81% | | | |
| Wood | $CH_4$ | -100% | +412% | -30% | +30% | -104% | +413% | The equivalent assessment of the uncertainty in industrial waste paper/cardboard or wood in "5.C Incineration" is used. | | Combined by using the formula for propagation of errors |
| | $N_2O$ | -64% | +64% | -30% | +30% | -71% | +71% | | | |

- ***Time-series Consistency***

Data on the amount of waste oil and wood used as alternative fuels have been available since FY1998. For waste oil, consistent data over the time series are developed by using the total amount of waste oil incinerated without the use of waste oil as alternative fuel. For wood, the average of FY1998–2002 data is used to estimate the amount of wood for the past years. The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By revisioning biomass-based plastic products data, $CO_2$ emissions were recalculated.

By updating the statistical data, emissions were recalculated. For detail, see the section "7.1.5. General Recalculations for Emissions from Waste Sector"

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 7.4.3.2.c. Waste Tires Used as Alternative Fuels (1.A.1 and 1.A.2)

### *a) Category Description*

This category covers the emissions from the use of waste tires as raw materials or fuels.

### *b) Methodological Issues*

### *1) $CO_2$*

- ***Estimation Method***

The emissions are calculated by multiplying the incinerated amount of waste tires used as raw materials or fuels by Japan's country-specific emission factor.

- ***Emission Factor***

The emission factor for waste tires is calculated by multiplying the fossil fuel-derived carbon content of the waste tires by the oxidation factor of the waste tires at the facilities that use waste tires as fuel. The volume of the fossil fuel-derived carbon in the waste tires is calculated by the material contents of new tires. The oxidation factor for waste tires is set to the default value of 100% indicated in the *2006 IPCC Guidelines*.

$$EF = C \times OF \times 1000 \times 44/12$$

*EF* : Emission factor for the incineration of waste tires (dry basis) [kg-$CO_2$/t]
*C* : Fossil fuel-derived carbon content in waste tires [-]
*OF* : Oxidation factor of waste tires [-]

- ***Activity Data***

Activity data (dry basis) is calculated by subtracting the water content in the waste tires determined from analyses of three constituents of divided tires reported in *the Basic Waste Date Fact Book (2000)* published by Japan Environmental Sanitation Center from the amount of waste tires used as raw material or fuel (wet basis) in the *Tire Industry of Japan*, published by the Japan Automobile Tire Manufacturers Association, Inc.

### 2) $CH_4$, $N_2O$

- ***Estimation Method and Emission Factor***

See the section "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)"

- ***Activity Data***

The volume of waste tires used as raw material or fuel by usage that is determined during the calculation of the $CO_2$ emissions from this source is used. For the activity data, the volume of waste tires recorded in the following categories are used: "Cement kilns" for use in cement kilns; "Medium to small boilers", "Use by tire factories", "Use by paper manufacturers", and "Power generation" for use in boilers; "metal refining" for use in carbonization; and "Gasification" for use in gasification processes.

### c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainty assessment is conducted as well as assessment in the category of the industrial waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-69.

Table 7-69 Uncertainty assessment for waste tire used as alternative fuels (1.A.1 and 1.A.2)

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Waste tire | $CO_2$ | -2% | +2% | -30% | +30% | -30% | +30% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in industrial waste plastic is substituted based on expert judgment. | The uncertainty based on expert judgment in industrial waste statistics is applied. | Combined by using the formula for propagation of errors |
| | $CH_4$ | -100% | +216% | -30% | +30% | -104% | +218% | | | |
| | $N_2O$ | -44% | +44% | -30% | +30% | -53% | +53% | | | |

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

### d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) Category-specific Recalculations

No recalculations are conducted.

### f) Category-specific Planned Improvements

No improvements are planned.

### 7.4.3.3. Incineration of Waste Processed as Fuel (1.A.)

### 7.4.3.3.a. Incineration of Refuse-based Solid Fuels (RDF and RPF) (1.A.1 and 1.A.2)

#### *a) Category Description*

In this category, $CO_2$, $CH_4$, and $N_2O$ emissions from waste that is processed and used as fuel are estimated and reported. Refuse-derived solid fuels (RDF as Refuse Derived Fuel and RPF as Refuse Paper and Plastic Fuel) are used for the estimation of emissions from fuels produced from waste. The reporting categories for the above emissions are included in "Energy industries (1.A.1.)" and "Manufacturing industries and construction (1.A.2)" as indicated in Table 7-26 The fuel types are classified as "Other fossil fuels" and/or "Biomass" as indicated in Table 7-25.

#### *b) Methodological Issues*

#### *1) $CO_2$*

- ***Estimation Method***

Emissions are estimated by multiplying the amount of RDF and RPF incinerated by Japan's country-specific emission factor.

$$E_{RDF} = EF_{RDF} \times AD_{RDF}$$

$E_{RDF}$ : $CO_2$ Emissions from RDF use [kg-$CO_2$]
$EF_{RDF}$ : Emission factor for RDF use (dry basis) [kg-$CO_2$/t]
$AD_{RDF}$ : Activity data for RDF use (dry basis) [t]

$$E_{RPF} = EF_{RPF} \times AD_{RPF}$$

$E_{RPF}$ : $CO_2$ Emissions from RPF use [kg-$CO_2$]
$EF_{RPF}$ : Emission factor for RPF use (dry basis) [kg-$CO_2$/t]
$AD_{RPF}$ : Activity data for RPF use (dry basis) [t]

- ***Emission Factor***

Emission factor associated with the use of the refuse-derived solid fuels (RDF and RPF) is calculated for RDF and RPF respectively by the equation shown below.

➢ ***RDF***

Emission factor for RDF use is estimated by multiplying the fraction of plastic-derived content contained in RDF (dry basis) by the fraction of carbon content contained in plastic by, the combustion rate of RDF at RDF combustion facilities by fossil-fuel derived fraction of plastic in RDF.

$$\begin{aligned} EF_{RDF} &= 1000 \times P_{RDF} \times C \times OF_{RDF} \times 44 / 12 \times FPF_{RDF} \\ &= 1000 \times 0.296 \times 0.751 \times 1.0 \times 44 / 12 \times FPF_{RDF} \\ &= 816\ [\text{kg-}CO_2/\text{t}] \times FPF_{RDF} \end{aligned}$$

$P_{RDF}$ : Fraction of plastic-derived content contained in RDF (dry basis)
$C$ : Fraction of carbon content contained in plastic (dry basis)
$OF_{RDF}$ : Oxidation factor of RDF at RDF combustion facilities
$FPF_{RDF}$ : Fossil-fuel derived fraction of plastic in RDF

- ***Fraction of Plastic-derived Content Contained in RDF (Dry basis)( $P_{RDF}$)***

Fraction of plastic-derived content contained in RDF in dry basis is converted from that in wet basis. Fraction of plastic-derived content contained in RDF in wet basis (24.7%) is estimated based on the *Proper Management of Refuse-derived Fuels compiled by the Study Group for Proper Management of*

*RDF*. It is converted into the value in dry basis with the fraction of water content of MSW (20%) applied in "7.2.1. Managed Disposal Sites (5.A.1.)" as well as "7.4.1.2. Industrial Waste (5.C.1.-), $CO_2$".

- ***Fraction of Carbon Content Contained in Plastic (Dry basis)(C)***

Due to the fact that most of plastic contained in RDF is considered to be municipal solid waste-derived, the average fraction of carbon content used in "7.4.1.1. Municipal Solid Waste (5.C.1.-)" as shown in Table 7-29 is applied for the fraction of carbon content contained in plastic (dry basis).

- ***Oxidation factor for RDF at RDF Combustion Facilities ($OF_{RDF}$)***

As applied in "7.4.1.1. Municipal Solid Waste (5.C.1.-), $CO_2$", the default value provided in the *2006 IPCC Guidelines* (100%) is also applied for the oxidation factor for RDF at RDF combustion facilities.

- ***Fossil-fuel derived fraction of plastic in RDF ($FPF_{RDF}$)***

Due to the fact that most of plastic contained in RDF is considered to be municipal solid waste-derived, the same values in "7.4.1.1. Municipal Solid Waste (5.C.1.-)" are applied. Note it is assumed that plastic in RDF consist of similar composition (plastic bottles/plastics other than plastic bottles) in municipal solid waste plastics incinerated.

➢ ***RPF***

Because the quality of RPF is categorized into "coal-equivalent product" and "coke-equivalent product" (Japan RPF Association, 2004), emission factor for RPF is established for each quality of product. However, in the case that the amount of use of each quality of product for estimating activity data is unavailable, emission factor is established by the weighted average of each emission factor for coal-equivalent product and coke-equivalent product with the average fraction of amount of use of each product (see "*Emission Factor for the Use of RPF (Weighted Average) (Dry basis)*" as described herein below.)

*Coal-equivalent product*

$$EF_{RPF,coal} = 1000 \times P_{RPF,coal} \times C \times OF_{RPF} \times 44/12 \times FPF_{RPF}$$
$$= 1000 \times 0.528 \times 0.737 \times 1.0 \times 44/12 \times FPF_{RPF}$$
$$= 1426\ [\text{kg-}CO_2/\text{t}] \times FPF_{RPF}$$

*Coke-equivalent product*

$$EF_{RPF,coke} = 1000 \times P_{RPF,coke} \times C \times OF_{RPF} \times 44 / 12 \times FPF_{RPF}$$
$$= 1000 \times 0.910 \times 0.737 \times 1.0 \times 44 / 12 \times FPF_{RPF}$$
$$= 2457\ [\text{kg-}CO_2/\text{t}] \times FPF_{RPF}$$

| | |
|---|---|
| $EF_{RPF,coal}$ | : Emission factor for the use of coal-equivalent product RPF (dry basis) [kg-$CO_2$/t] |
| $EF_{RPF,coke}$ | : Emission factor for the use of coke-equivalent product RPF (dry basis) [kg-$CO_2$/t] |
| $P_{RPF,coal}$ | : Fraction of plastic-derived content contained in coal-equivalent product RPF (dry basis) |
| $P_{RPF,coke}$ | : Fraction of plastic-derived content contained in coke-equivalent product RPF (dry basis) |
| $C$ | : Fraction of carbon content contained in plastic (dry basis) |
| $OF_{RPF}$ | : Oxidation factor of RPF at RPF combustion facilities |
| $FPF_{RPF}$ | : Fossil-fuel derived fraction of plastic in RPF |

- ***Fraction of Waste Plastic-derived Content Contained in RPF (Dry basis) ($P_{RPF,coal/coke}$)***

The fraction of waste plastic-derived content contained in RPF in wet basis is established at 50% for coal-equivalent product and at 90% for coke-equivalent product based on the results of fact-finding survey conducted by the Japan RPF Industry Association.

The fraction of waste plastic-derived content contained in RPF in dry basis is calculated with the fraction of water content of RDF, to which the average water content of industrial waste plastics used for RPF production is applied; it is established at 5% based on expert judgment.

- ***Fraction of Carbon Content Contained in Plastic (Dry basis) (C)***

Due to the fact that most of plastic contained in RDF is industrial waste-derive (Seki, 2004), the fraction of carbon content contained in plastic in dry basis (73.7%) is calculated by using the fraction of carbon content contained in industrial waste plastic applied in "7.4.1.2. Industrial Waste (5.C.1.-), $CO_2$" (70%) and the fraction of water content of industrial waste plastic (5%).

- ***Oxidation factor for RPF at RPF Fuel Facilities ($OF_{RPF}$)***

As applied in "7.4.1.2. Industrial Waste (5.C.1.-)", the value provided in the *2006 IPCC Guidelines* (100%) is also applied for the oxidation factor for RPF at RPF combustion facilities.

- ***Fossil-fuel derived fraction of plastic in RPF***

The same values for industrial waste plastic are applied (See Table 7-34).

- ***Emission Factor for RPF Use (Weighted Average) ($EF_{RPF,av}$) (Dry basis)***

In the case that the amount of use of coal-equivalent product RPF and coke-equivalent product RPF for estimating activity data is unavailable, emission factor is determined by the weighted average of each emission factor for coal-equivalent product and coke-equivalent product with the average fraction of the amount of use of each product.

Production percentage of RPF of coal-equivalent product and coke-equivalent product (wet basis) is obtained from the survey results conducted by Japan RPF Industry Association and is converted into the value in dry basis. The fraction of water content of RPF is established at 3% for coal-equivalent product and at 1% for coke-equivalent product based on the RPF quality standards provided by the Japan RPF Industry Association. The estimated fractions of production percentage in dry basis are applied to all the reporting years because relevant statistics is unavailable.

$$
\begin{aligned}
EF_{RPF,av} &= EF_{RPF,coal} \times P_{coal} + EF_{RPF,coke} \times P_{coke} \\
&= (1426 \times FPF_{RPF}) \times 0.797 + (2457 \times FPF_{RPF}) \times 0.203 \\
&= 1636\ [\text{kg-}CO_2/\text{t}] \times FPF_{RPF}
\end{aligned}
$$

$EF_{RPF,av}$ : Emission factor for RPF use (Weighted Average) (dry basis) [kg-$CO_2$/t]
$P_{coal}$ : Fraction of the use of coal-equivalent product RPF (dry basis)
$P_{coke}$ : Fraction of the use of coke-equivalent product RPF (dry basis)
$FPF_{RPF}$ : Fossil-fuel derived fraction of plastic in RPF

Table 7-70 $CO_2$ emission factors for the emissions from the use of refused-derived fuel (RDF)or refuse paper & plastic fuel (RPF)

| Item | Emission Factor [kg-$CO_2$/t (dry)] |
|---|---|
| RDF | 816 |
| RPF (coal-equivalent products) | 1,426 |
| RPF (coke-equivalent products) | 2,457 |
| RPF (weighted average values) | 1,636 |

Note: Each emission factor indicated in the table are applied 100% of fossil-fuel derived fraction (*FPF*)

- ***Activity Data***

➢ ***RDF***

The amount of RDF production is used as the substitute for the amount of use of RDF. Activity data (dry basis) is calculated by subtracting the water content of RDF from the amount of RDF production at RDF production facilities (wet basis) provided by the *Report on Survey of State of Treatment of Municipal Solid Waste*. For the fiscal years that the data are unavailable, emission estimates are conducted substituting the values of the refuse processing capacity.

$$A_{RDF} = a_{RDF} \times (1 - u_{RDF})$$

$A_{RDF}$ : Activity data for RDF use (dry basis)
$a_{RDF}$ : Amount for RDF production at RDF production facilities (wet basis) [t]
$u_{RDF}$ : Fraction of water content in RDF

➢ ***RPF***

The amounts of RPF used in chemical industry, paper industry, cement manufacturer, and petroleum product manufacturer are estimated (See also Table 7-63). The amount of RPF (dry basis) for paper industry is obtained from the survey results conducted by the Japan Paper Association. The amounts of RPF (dry basis) for the chemical industry, cement manufacturers, and petroleum product manufacturers are obtained by using the averaged water content of RPF and the survey results (wet basis) conducted by the *Japan Chemical Industry Association*, the *Japan Cement Association* and the *Petroleum Association of Japan*.

***2) $CH_4$, $N_2O$***

- ***Estimation Method and Emission Factor***

For the estimation method and the emission factors used, see "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)".

- ***Activity Data***

➢ ***RDF***

The entire amount of RDF production (wet basis) used for $CO_2$ emission estimates is also used for the amount of use of RDF for boiler.

➢ ***RPF***

Out of the amount of RPF used for $CO_2$ emission estimates, the amounts of RPF used in chemical industry, paper industry, and petroleum products manufacturer are applied to the amount of PRF used for boiler (wet basis). The amount of PRF used in cement industry is applied to the amount of RPF used for cement kiln (wet basis). Because the amount of RPF used in paper industry is on a dry basis, the average water content of RPF is added to obtain the value on a wet basis.

➢ ***Activity Data Converted into Energy Units (Reference Value)***

Activity data converted into energy units to be reported in CRF is calculated as indicated below.

$$A_{E,i} = A_i \times GCV_i / 10^6$$

$A_{E,i}$ : Activity data of fuel type *i* converted into energy units [TJ]
$A_i$ : Amount of consumed fuel type *i* [kg (wet)]
$GCV_i$ : Gross calorific value of fuel type *i* [MJ/kg]

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainty assessment is conducted as well as the assessment for the municipal waste or industrial waste incineration. Details of the uncertainty assessment on this category are indicated in the Table 7-71.

Table 7-71 Uncertainty assessment for incineration of waste refuse-based solid fuels (1.A.1 and 1.A.2)

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| RDF | $CO_2$ | -2% | +2% | -10% | +10% | -10% | +10% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment. | The uncertainty in municipal waste statistics based on expert judgment is used. | Combined by using the formula for propagation of errors |
| | $CH_4$ | -39% | +39% | -10% | +10% | -40% | +40% | | | |
| | $N_2O$ | -34% | +34% | -10% | +10% | -35% | +35% | | | |
| RPF | $CO_2$ | -2% | +2% | -30% | +30% | -30% | +30% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment. | The uncertainty based on expert judgment in industrial waste statistics is applied. | Combined by using the formula for propagation of errors |
| | $CH_4$ | -100% | +216% | -30% | +30% | -104% | +218% | | | |
| | $N_2O$ | -44% | +44% | -30% | +30% | -53% | +53% | | | |

- ***Time-series Consistency***

Since data on the amount of RDF produced are not available for the years prior to FY1997, these data are estimated by using the trend on capacity of refuse-based fuel-producing facilities. The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By revisioning biomass-based plastic products data, $CO_2$ emissions were recalculated.

By updating the statistical data including emissions were recalculated.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 7.5. Wastewater Treatment and Discharge (5.D.)

The $CH_4$ and $N_2O$ emissions from wastewater handling are reported under the category “Wastewater Treatment and Discharge (5.D.)”. The target categories are shown in Table 7-72. Since an emission factor that takes into account emissions from wastewater and sludge treatment processes is used in Japan,

emissions from these processes are reported altogether. Note since this category includes various type of sources, it is difficult to analyze the trend in the IEFs.

Table 7-72 Categories overview for wastewater treatment and discharge (5.D.)

| Category | Wastewater type | | | | | Treatment type | | | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.D.1. (7.5.1) | Domestic wastewater | In treatment systems | Public sewer system | Sewage | | Sewage treatment plants (7.5.1.1) | Standard activated sludge process | | ○ | ○ |
| | | | | | | | Anaerobic-aerobic activated sludge process | | | ○ |
| | | | | | | | Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process | | | ○ |
| | | | | | | | Recycled nitrification-denitrification membrane bioreactor | | | ○ |
| | | | Other sewer system | Human waste | Miscellaneous wastewater | Domestic sewage treatment plants (mainly *Johkasou*) (7.5.1.2) | Community plant | | ○ | ○ |
| | | | | | | | Current type *Johkasou* | Advanced type: TN removal type | ○ | ○ |
| | | | | | | | | Advanced type: TN and TP removal type | | |
| | | | | | | | | Advanced type: BOD removal type | | |
| | | | | | | | | Advanced type: Other advanced type | ○ | ○ |
| | | | | | | | | Standard type | ○ | ○ |
| | | | | | | | Old type *Johkasou* | | ○ | ○ |
| | | | | | | | Vault toilet | | ○ | ○ |
| | | | | Collected human waste | Human waste and *Johkasou* sludge (from domestic sewage treatment plants) | Human-waste treatment plants (7.5.1.3) | High-load denitrification treatment | | ○ | ○ |
| | | | | | | | Membrane separation | | ○ | ○ |
| | | | | | | | Anaerobic treatment | | ○ | ○ |
| | | | | | | | Aerobic treatment | | ○ | |
| | | | | | | | Standard denitrification treatment | | ○ | |
| | | | | | | | Other | | ○ | |
| | | Into public waters | Wastewater | | Untreated wastewater | Natural decomposition of domestic wastewater (7.5.1.4) | Discharge of untreated wastewater | From old type *Johkasou* | ○ | ○ |
| | | | | | | | | From vault toilet | ○ | ○ |
| | | | | | | | | From on-site treatment | ○ | ○ |
| | | | | | Treated wastewater | | Discharge of treated wastewater | (From each treatment plant) | NA | ○ |
| | | | Sludge | | Human waste and *Johkasou* sludge | | Ocean dumping of sludge[1)] | (From domestic sewage treatment plants) | ○ | ○ |
| | | | | | Sewage sludge | | | (From sewage treatment plants) | ○ | ○ |
| 5.D.2. (7.5.2) | Industrial wastewater | In treatment systems | Manufacture of food | | | Industrial wastewater treatment (7.5.2.1) | (Industrial wastewater treatment plants) | | ○ | ○ |
| | | | Manufacture of pulp, paper and paper products | | | | | | ○ | ○ |
| | | | Manufacture of chemical and allied product | | | | | | ○ | ○ |
| | | | Manufacture of iron and steel | | | | | | ○ | ○ |
| | | | Manufacture of beverages, tobacco and feed | | | | | | ○ | ○ |
| | | | Manufacture of textile products | | | | | | | |
| | | | Manufacture of petroleum and coal products | | | | | | | |
| | | | Manufacture of plastic products | | | | | | | |
| | | | Manufacture of rubber products | | | | | | | |
| | | | Manufacture of leather tanning, leather products and fur skins | | | | | | | |
| | | Into public waters | Wastewater | | Untreated wastewater | Natural decomposition of Industrial wastewater (7.5.2.2) | Discharge of untreated wastewater | (from industrial plants/facilities) | ○ | ○ |
| | | | | | Treated wastewater | | Discharge of treated wastewater | (from industrial wastewater treatment plants) | NA | ○ |
| | Landfill leachate | | | | | Landfill leachate treatment (7.5.2.3) | | | ○ | ○ |

Note:
1) Due to legal regulations on sludge disposal at sea, there has been no activity since FY2009.

Estimated greenhouse gas emissions from wastewater handling are shown in Table 7-73. In FY2018, emissions from this source category are 3,600 kt-$CO_2$ eq. and accounted for 0.3% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 32.4% compared to those in FY1990. This emission decrease is the result of decrease in the amount of $CH_4$ emissions from "Natural decomposition of domestic wastewater" because the practice of wastewater

treatment at wastewater treatment plants increased in Japan. Due to the same reason, the $N_2O$ emissions from the subcategory of "Sewage Treatment Plants (5.D.1.-)" for FY1995 through FY1998 increased.

Table 7-73 GHG emissions from wastewater treatment and discharge (5.D.)

| Gas | Category | | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 5.D.1. Domestic wastewater | Sewage treatment plant | kt-$CH_4$ | 8.6 | 9.9 | 11.1 | 12.1 | 12.7 | 12.7 | 12.7 | 12.1 | 12.5 | 12.6 | 12.4 | 12.6 | 12.1 | 12.1 |
| | | Domestic sewage treatment plant | kt-$CH_4$ | 30.4 | 35.0 | 38.8 | 38.3 | 37.0 | 36.8 | 36.2 | 35.8 | 35.3 | 34.7 | 34.3 | 33.8 | 32.9 | 32.4 |
| | | Human-waste treatment plant | kt-$CH_4$ | 5.2 | 3.2 | 1.8 | 1.0 | 0.7 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 |
| | | Natural decomposition of domestic wastewater | kt-$CH_4$ | 61.7 | 50.8 | 39.5 | 28.7 | 22.4 | 21.1 | 20.0 | 19.3 | 18.1 | 17.2 | 16.4 | 15.8 | 15.0 | 14.3 |
| | 5.D.2. Industrial wastewater | Industrial wastewater treatment | kt-$CH_4$ | 2.2 | 2.2 | 2.1 | 1.9 | 1.9 | 1.8 | 1.7 | 1.7 | 1.6 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |
| | | Natural decomposition of industrial wastewater | kt-$CH_4$ | 8.2 | 7.8 | 7.9 | 8.3 | 4.9 | 4.9 | 4.8 | 4.5 | 4.1 | 4.3 | 4.6 | 4.1 | 3.7 | 3.7 |
| | | Landfill leachate treatment | kt-$CH_4$ | 1.2 | 1.2 | 1.1 | 0.8 | 0.4 | 0.4 | 0.3 | 0.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| | Total | | kt-$CH_4$ | 117.7 | 110.0 | 102.2 | 91.2 | 79.9 | 78.1 | 76.3 | 74.2 | 72.5 | 71.2 | 70.0 | 68.6 | 65.9 | 64.7 |
| | | | kt-$CO_2$ eq. | 2,942 | 2,750 | 2,556 | 2,280 | 1,997 | 1,954 | 1,908 | 1,855 | 1,811 | 1,779 | 1,749 | 1,714 | 1,648 | 1,617 |
| $N_2O$ | 5.D.1. Domestic wastewater | Sewage treatment plant | kt-$N_2O$ | 1.39 | 1.55 | 1.58 | 1.67 | 1.70 | 1.67 | 1.67 | 1.55 | 1.59 | 1.59 | 1.55 | 1.55 | 1.45 | 1.45 |
| | | Domestic sewage treatment plant | kt-$N_2O$ | 1.52 | 1.65 | 1.70 | 1.57 | 1.52 | 1.53 | 1.54 | 1.56 | 1.56 | 1.56 | 1.55 | 1.56 | 1.56 | 1.55 |
| | | Human-waste treatment plant | kt-$N_2O$ | 0.22 | 0.26 | 0.12 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | Natural decomposition of domestic wastewater | kt-$N_2O$ | 2.79 | 2.72 | 2.49 | 2.29 | 2.09 | 2.11 | 2.13 | 2.04 | 2.08 | 2.01 | 2.02 | 2.00 | 1.98 | 1.96 |
| | 5.D.2. Industrial wastewater | Industrial wastewater treatment | kt-$N_2O$ | 1.00 | 0.96 | 0.81 | 1.10 | 1.02 | 1.09 | 1.12 | 1.16 | 1.15 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 |
| | | Natural decomposition of industrial wastewater | kt-$N_2O$ | 1.06 | 1.02 | 1.02 | 0.97 | 0.67 | 0.66 | 0.65 | 0.62 | 0.59 | 0.56 | 0.54 | 0.55 | 0.55 | 0.55 |
| | | Landfill leachate treatment | kt-$N_2O$ | 0.03 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| | Total | | kt-$N_2O$ | 8.01 | 8.18 | 7.72 | 7.65 | 7.03 | 7.10 | 7.14 | 6.94 | 6.99 | 6.86 | 6.80 | 6.80 | 6.69 | 6.66 |
| | | | kt-$CO_2$ eq. | 2,387 | 2,439 | 2,301 | 2,280 | 2,094 | 2,115 | 2,129 | 2,069 | 2,082 | 2,045 | 2,027 | 2,028 | 1,992 | 1,983 |
| Total | | | kt-$CO_2$ eq. | 5,329 | 5,189 | 4,857 | 4,560 | 4,091 | 4,069 | 4,037 | 3,925 | 3,893 | 3,825 | 3,777 | 3,742 | 3,640 | 3,600 |

### 7.5.1. Domestic Wastewater (5.D.1.)

Domestic and commercial wastewater generated in Japan is treated at various wastewater treatment facilities (e.g., sewage treatment plants, Domestic sewage treatment plants, human-waste treatment plants) and greenhouse gas emissions from these sources are reported under "Domestic and Commercial Wastewater (5.D.1.)". Because the $CH_4$ and $N_2O$ emission characteristics differ from one wastewater treatment facility to another, a different emission estimation method is established for each facility.

The characteristics, effectiveness, and economic efficiency of wastewater treatment systems are thoroughly reviewed, and the most suitable systems are selected for each area in Japan with care also being taken to avoid excessive expenditure. As indicated in the *Waste Treatment in Japan* (MOE), public sewerage system is spreading from large cities to smaller municipalities and used by 79.4% of the population at the end of FY2018.

Domestic sewage treatment plants (e.g. current type *Johkasou*) are being promoted as an effective means of supplementing sewerage systems in smaller municipalities with low population densities and little flat land. In FY2018, *Johkasou* is used by 20.3% of the population, with the remainder being treated after collection or on-site.

"NA" is reported on the CRF table for activity data instead of reporting the amount of organic carbon based on BOD values because the activity data for this source are estimated using a country-specific method by each gas and each wastewater treatment facility.

#### 7.5.1.1. Sewage Treatment Plant (5.D.1.-)

##### *a) Category Description*

This category covers $CH_4$ and $N_2O$ emissions from treatment of wastewater at sewage treatment plants.

### *b) Methodological Issues*

- ***Estimation Method***

Emissions of $CH_4$ and $N_2O$ from this source are calculated using Japan's country-specific method in accordance with the decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of sewage treated at sewage treatment plants by the emission factor.

$$E = EF \times A$$

*E* : Amount of $CH_4$ or $N_2O$ emitted from sewage treatment plants in conjunction with domestic/commercial wastewater treatment [kg-$CH_4$], [kg-$N_2O$]
*EF* : Emission factor [kg-$CH_4/m^3$], [kg-$N_2O/m^3$]
*A* : Yearly amount of sewage treated at a sewage treatment plant [$m^3$]

- ***Emission Factors***

#### *1) $CH_4$*

Emission factors are established by adding the simple averages for each treatment process, having taken the actual volume of $CH_4$ released from sludge treatment and water treatment processes measured at sewage treatment plants from research studies at 8 plants conducted in Japan (MOE, 2006b).

$$EF_{CH4} = EF_{WWTT} + EF_{SSTT}$$
$$= 8.8 \times 10^{-4} \text{ [kg-}CH_4/m^3\text{]}$$

$EF_{CH4}$ : $CH_4$ Emission factor
$EF_{WWTT}$ : Average of emission factor for wastewater treatment processes (528.7 [mg-$CH_4/m^3$])
$EF_{SSTT}$ : Average of emission factor for sludge treatment processes (348.0 [mg-$CH_4/m^3$])

#### *2) $N_2O$*

Emission factors are established on the basis of measured values of $N_2O$ volume emitted from wastewater and sludge treatment processes at sewage treatment plants which is obtained from research studies at 42 plants conducted in the country. Since the research studies revealed that the amount of $N_2O$ emission varies according to the type of wastewater treatment process at sewage treatment plants, the $N_2O$ emission factor for each wastewater treatment type is developed based on the latest findings in the country (MOE, 2013b).

$$EF_{N2O} = EF_{WWTTi} + EF_{SSTT}$$

$EF_{N2O}$ : $N_2O$ Emission factor
$EF_{WWTTi}$ : Emission factor for wastewater treatment process *i* (Table 7-74)
$EF_{SSTT}$ : Average of emission factor for sludge treatment process (0.6 [mg-$N_2O/m^3$])

Table 7-74 $N_2O$ Emission factor by wastewater treatment process at sewage treatment plant

| Wastewater treatment process | $N_2O$ EF for wastewater treatment process[3)] [mg-$N_2O/m^3$] | $N_2O$ EF for sludge treatment process [mg-$N_2O/m^3$] |
|---|---|---|
| Standard activated sludge process[1)] | 142 | 0.6 |
| Anaerobic-aerobic activated sludge process | 29.2 | 0.6 |
| Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process[2)] | 11.7 | 0.6 |
| Recycled nitrification-denitrification membrane bioreactor | 0.5 | 0.6 |

Note:
1) Includes all the wastewater treatment processes other than indicated above.

2) Includes all the wastewater treatment processes which remove nitrogen the same level or greater than Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process, but excludes recycled nitrification-denitrification membrane bioreactor.
3) Since the main purpose of the "Standard activated sludge process" is to remove BOD from wastewater, the nitrification reaction cannot be completed during the process, resulting in more $N_2O$ generated. In the meanwhile, advanced treatment procedures such as "Anaerobic-aerobic activated sludge process", "Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process", and "Recycled nitrification-denitrification membrane bioreactor" allow sufficient nitrification reaction to occur for nitrogen removal etc, and accordingly generate less $N_2O$.

- ***Activity Data***

Activity data for $N_2O$ emissions by wastewater treatment process at sewage treatment plants are provided by MLIT. Total amount of wastewater treated used for $N_2O$ emission estimates are also used for the activity data for $CH_4$ emission estimates.

Table 7-75 Activity data for wastewater treated at sewage treatment plant

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard activated sludge process | $10^6$ m$^3$ | 9,761 | 10,780 | 10,686 | 11,405 | 11,552 | 11,358 | 11,288 | 10,485 | 10,736 | 10,699 | 10,401 | 10,394 | 9,648 | 9,648 |
| Anaerobic-aerobic activated sludge process | $10^6$ m$^3$ | 73 | 446 | 1,523 | 1,039 | 868 | 909 | 909 | 953 | 931 | 938 | 933 | 962 | 1,107 | 1,107 |
| Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process | $10^6$ m$^3$ | 23 | 89 | 487 | 1,374 | 2,049 | 2,181 | 2,308 | 2,355 | 2,629 | 2,684 | 2,819 | 3,033 | 2,998 | 2,998 |
| Recycled nitrification-denitrification membrane bioreactor | $10^6$ m$^3$ | NO | NO | NO | 0.1 | 1 | 2 | 20 | 20 | 15 | 0.1 | 0.2 | 5 | 0.4 | 0.4 |
| Total | $10^6$ m$^3$ | 9,857 | 11,316 | 12,696 | 13,818 | 14,470 | 14,450 | 14,525 | 13,813 | 14,311 | 14,320 | 14,153 | 14,393 | 13,754 | 13,754 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainties in emission factors for $CH_4$ and $N_2O$ in sewage treatment plant are evaluated by using the 95% confidence intervals of actual measurement data which are used for calculation of emission factors. As for the uncertainties in activity data, the uncertainties in sewage data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in Table 7-76.

Table 7-76 Uncertainty assessment for sewage treatment plant on the category "Domestic wastewater (5.D.1.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Sewage treatment plant | $CH_4$ | -31% | +31% | -5% | +5% | -31% | +31% | The uncertainty is assessed by using the 95% interval confidence of actual measurement data in MOE (2006b). | The uncertainty in sewage statistics based on expert judgment is used. | Combined by using the formula for propagation of errors |
| | $N_2O$ | -100% | +146% | -5% | +5% | -100% | +146% | | | |

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By updating the statistical data including emissions were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 7.5.1.2. Domestic Sewage Treatment Plant (Mainly *Johkasou*) (5.D.1.-)

### *a) Category Description*

A part of domestic and commercial wastewater not processed in the public sewerage in Japan is processed in community plants, current type *Johkasou*, the old type *Johkasou*, and vaults. The *Johkasou* means decentralized wastewater treatment facilities installed at an individual home.

Table 7-77 Type of sewage and sewage treatment

| Plant type | | | | Sewage type | Description | |
|---|---|---|---|---|---|---|
| Community plants | | | | Human waste and miscellaneous wastewater | Small-scale wastewater treatment facility regionally installed | |
| *Johkasou* | Current type | Advanced type | TN removal type | | Wastewater treatment unit installed at an individual household | Advanced type certified in performance under the amended Building Standards Act in effect FY2001 |
| | | | TN and TP removal type | | | |
| | | | BOD removal type | | | |
| | | | Other advanced type | | | |
| | | Standard type | | | | Standard type under former the Building Standards Act |
| | Old type | | | Human waste only | | Old type which is not allowed to be newly installed under the amended Purification Tank Act since FY2001 |
| Vaults toilet | | | | | Installed at an individual household | |

This category covers $CH_4$ and $N_2O$ emissions from domestic sewage treatment plants. Emissions from human waste within its residence time in vault toilets are reported under this category, whereas the emissions that occur after the waste is collected from vault toilets are accounted for under "Human waste treatment plant (5.D.1.-)".

### *b) Methodological Issues*

- ***Estimation Method***

Emissions of $CH_4$ and $N_2O$ from this source are calculated using Japan's country-specific method, in accordance with decision tree the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the annual population of treatment for each type of domestic sewage treatment plant by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

$E$ : Emissions of methane and nitrous oxide from the processing of domestic and commercial wastewater at domestic sewage treatment plants (i.e. household Johkasou) [kg-$CH_4$], [kg-$N_2O$]
$EF_i$ : Emission factor for domestic sewage treatment plant $i$ [kg-$CH_4$/person], [kg-$N_2O$/person]
$A_i$ : Population (persons) requiring waste processing at domestic sewage treatment plant $i$ per year

- ***Emission Factors***

$CH_4$ and $N_2O$ emission factors for this source are determined from domestic research studies. as shown on the Table 7-78:

Table 7-78 Emission factors for $CH_4$ and $N_2O$ from domestic wastewater treatment systems

| $CH_4$ emission factors (Unit: kg-$CH_4$ /person-year) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Plant type | | | FY1990 ~1995 | FY1996 ~2000 | FY2001~ 2004 | FY2005 ~ | Reference |
| Community plant[1)] | | | 0.195 | Interpolation | | 0.062 | 1990-1995: Tanaka (1998)<br>2005-: Ike and Soda (2010) |
| Current type *Johkasou* | Advanced type | TN removal type | NA[2)] | | 1.044 | | MOE (2012) and MOE (2013c) |
| | | TN and TP removal type | | | | | |
| | | BOD removal type | | | | | |
| | | Other advanced type | | | 1.984 | | |
| | Standard type [3)] | | 2.477 | | | | |
| Old type *Johkasou* [3)] | | | 0.46 | | | | |
| Vault toilet [3)] | | | 0.062 | | | | |
| $N_2O$ emission factors (Unit: kg-$N_2O$/person-year) | | | | | | | |
| Plant type | | | FY1990 ~1995 | FY1996 ~2000 | FY2001~ 2004 | FY2005 ~ | Reference |
| Community plant[1)] | | | 0.0394 | Interpolation | | 0.0048 | 1990~1995: Tanaka et al. (1995) [4)]<br>2005-: Ike and Soda (2010) |
| Current type *Johkasou* | Advanced type | TN removal type | NA[2)] | | 0.123 | | MOE (2012) and MOE (2013c) |
| | | TN and TP removal type | | | | | |
| | | BOD removal type | | | | | |
| | | Other advanced type | | | 0.055 | | |
| | Standard type [3)] | | 0.0717 | | | | |
| Old type *Johkasou* [3)] | | | 0.039 | | | | |
| Vault toilet [3)] | | | 0.000022 | | | | |

Note:

1) For the values from FY2005 onward, the emission factors are applied taking into account the performance improvement of the plants.
2) The installation of current advanced type *Johkasou* was started under the technical guidelines for *Johkasou* of the Building Standards Act revised in FY2001.
3) The same emission factor is applied for through the reporting years because there is no significant technological advancement
4) The simple mean values of the upper limit and the lower limit of actual measured values indicated in the reference is applied.

- ***Activity Data***

Annual treatment population by type of domestic sewage treatment plant for community plants, current type *Johkasou*, old type *Johkasou*, and vault toilets given in the *Waste Treatment in Japan* is used as the activity data for $CH_4$ and $N_2O$ emitted in association with domestic sewage treatment plants. Activity data for current type J*ohkasou* are classified as advanced type and standard type by using installation share derived from installation number of each type, which can be assumed as a share of annual treatment population, shown in the *Survey of guidance promotion of Johkasou* (MOE).

Table 7-79 Annual treatment population by type of domestic sewage treatment plant (1,000 persons)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Community plant | 1000 person | 493 | 398 | 414 | 552 | 297 | 293 | 286 | 289 | 304 | 302 | 294 | 286 | 320 | 336 |
| Current type *Johkasou* (Sub tatal) | 1000 person | 6,274 | 8,515 | 10,806 | 12,792 | 13,792 | 14,082 | 14,276 | 14,341 | 14,492 | 14,564 | 14,600 | 14,630 | 14,557 | 14,490 |
| Advanced type | | | | | | | | | | | | | | | |
| TN removal type | 1000 person | NO | NO | NO | 263 | 1,061 | 1,433 | 1,900 | 2,261 | 2,612 | 2,948 | 3,105 | 3,447 | 3,862 | 3,950 |
| TN and TP removal type | 1000 person | NO | NO | NO | 3 | 10 | 14 | 16 | 28 | 35 | 37 | 39 | 40 | 42 | 43 |
| BOD removal type | 1000 person | NO | NO | NO | 34 | 43 | 33 | 46 | 22 | 25 | 22 | 19 | 18 | 20 | 29 |
| Other advanced type | 1000 person | NO | NO | NO | 4,501 | 5,997 | 6,132 | 6,129 | 6,095 | 6,123 | 6,098 | 6,153 | 6,022 | 5,666 | 5,685 |
| Standard type | 1000 person | 6,274 | 8,515 | 10,806 | 7,991 | 6,682 | 6,471 | 6,184 | 5,935 | 5,697 | 5,459 | 5,284 | 5,103 | 4,968 | 4,783 |
| Old type *Johkasou* | 1000 person | 26,828 | 26,105 | 23,289 | 18,303 | 14,712 | 13,948 | 13,315 | 13,052 | 12,383 | 11,822 | 11,415 | 11,018 | 10,543 | 10,154 |
| Vault toilet | 1000 person | 38,920 | 29,409 | 20,358 | 13,920 | 10,671 | 9,984 | 9,348 | 8,849 | 8,242 | 7,727 | 7,197 | 6,871 | 6,528 | 6,099 |
| Total | 1000 person | 72,515 | 64,427 | 54,867 | 45,567 | 39,472 | 38,307 | 37,225 | 36,531 | 35,421 | 34,415 | 33,506 | 32,805 | 31,948 | 31,079 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainties in emission factors for $CH_4$ and $N_2O$ in current type *Johkasou*, old type *Johkasou*, and vault toilet are evaluated by using the 95% confidence intervals of actual measurement data which are used for calculation of emission factors. As for the uncertainties in emission factors for $CH_4$ and $N_2O$ in community plant, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-80.

Table 7-80 Uncertainty assessment for domestic sewage treatment plant on the category "Domestic wastewater (5.D.1.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Community Plant | $CH_4$ | -32% | +32% | -10% | +10% | -33% | +33% | The uncertainty is assessed based on expert judgment. (The uncertainty in current type *Johkasou* is substituted). | The uncertainty in municipal waste statistics based on expert judgment is used. | Combined by using the formula for propagation of errors |
| | $N_2O$ | -45% | +45% | -10% | +10% | -46% | +46% | | | |
| Current type *Johkasou* | $CH_4$ | -32% | +32% | -10% | +10% | -33% | +33% | Quoted from MOE (2013c) | | Combined by using the formula for propagation of errors |
| | $N_2O$ | -45% | +45% | -10% | +10% | -46% | +46% | | | |
| Old type *Johkasou* | $CH_4$ | -84% | +84% | -10% | +10% | -84% | +84% | | | Combined by using the formula for propagation of errors |
| | $N_2O$ | -87% | +87% | -10% | +10% | -88% | +88% | | | |
| Vault toilet | $CH_4$ | -49% | +49% | -10% | +10% | -50% | +50% | | | Combined by using the formula for propagation of errors |
| | $N_2O$ | -72% | +72% | -10% | +10% | -73% | +73% | | | |

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By re-examining emission factors for current advanced type *Johkasou*, $CH_4$ and $N_2O$ emission from this source from FY2001 onward were recalculated.

By updating the statistical data including emissions for FY2017 were recalculated.

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

### 7.5.1.3. Human-Waste Treatment Plant (5.D.1.-)

#### *a) Category Description*

This category covers emissions of $CH_4$ and $N_2O$ emissions from treatment of vault toilet human waste and *Johkasou* sludge collected at human waste treatment plants.

#### *b) Methodological Issues*

#### *1) $CH_4$*

- ***Estimation Method***

Emissions of $CH_4$ from this source are calculated using Japan's country-specific methodology in accordance with decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of domestic wastewater treated at human waste treatment plants by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

$E$ : Emission of methane from the processing of domestic and commercial wastewater at human waste treatment plants [kg-$CH_4$]

$EF_i$ : Emission factor for human waste treatment plants (for treatment process *i*) [kg-$CH_4$/$m^3$]

$A_i$ : Input volume of human waste and *Johkasou* sludge at human waste treatment plants (for treatment process *i*) [$m^3$]

- ***Emission Factors***

Emission factors for $CH_4$ are determined by treatment processes type, including anaerobic, aerobic, standard denitrification and high-load denitrification treatments as well as membrane separation systems, for each of the human waste treatment plants (MOE, 2006b).

Table 7-81 $CH_4$ emission factors by each treatment process

| Treatment method | $CH_4$ Emission factor [kg-$CH_4$/$m^3$] | Reference |
|---|---|---|
| Anaerobic treatment | 0.543 | Estimated by multiplying the actual methane emissions given in Japan Environmental Sanitation Center (1990) by the value of 1 – $CH_4$ recovery rate (90%). |
| Aerobic treatment | 0.00545 | Simple average value of standard de-nitrification and high-load de-nitrification since actual data on emissions is not available. |
| Standard de-nitrification treatment | 0.0059 | Tanaka et al. (1995) |
| High load de-nitrification treatment | 0.005 | Tanaka et al. (1995) |
| Membrane separation | 0.00545 | Because the current status of its emissions is not identified, substituted the emission factor for aerobic treatment. |
| Other | 0.00545 | Because the current status of its emissions is not identified, substituted the emission factor for aerobic treatment. |

- ***Activity Data***

Activity data for $CH_4$ emissions associated with the processing of wastewater at human waste treatment plants is determined from the calculated throughput volume for each of the treatment processes (Table 7-84), by multiplying the total volume of human waste and *Johkasou* sludge processed at human waste treatment plants that are indicated in *Waste Treatment in Japan* (Table 7-82) by the capacity of each treatment process (Table 7-83).

$$A_i = W_H \times C_i / C_T$$

$A_i$ : Activity data for human waste treatment method *i* [kl]
$W_H$ : Total amount of human waste and septic tank sludge [kl]
$C_i$ : Capacity of waste treatment method *i* [kl]
$C_T$ : Total capacity of all waste treatment methods [kl]

Table 7-82 Volume of human waste and *Johkasou* sludge treated at their treatment plants

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Human waste from vault toilet | 1000 kl/year | 20,406 | 18,049 | 14,673 | 10,400 | 8,353 | 7,917 | 7,365 | 7,018 | 6,771 | 6,375 | 6,153 | 5,890 | 5,627 | 5,823 |
| *Johkasou* sludge | 1000 kl/year | 9,224 | 11,545 | 13,234 | 13,790 | 13,989 | 13,760 | 13,547 | 13,519 | 13,726 | 13,562 | 13,537 | 13,648 | 13,536 | 13,518 |
| Total | 1000 kl/year | 29,630 | 29,594 | 27,907 | 24,190 | 22,342 | 21,677 | 20,912 | 20,537 | 20,497 | 19,937 | 19,690 | 19,538 | 19,163 | 19,341 |

Table 7-83 Trends in treatment capacity by treatment process

| Unit | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobic treatment | kl/day | 34,580 | 19,869 | 10,996 | 6,476 | 4,144 | 3,891 | 3,265 | 3,159 | 3,059 | 2,779 | 2,245 | 2,155 | 1,799 | 1,574 |
| Aerobic treatment | kl/day | 26,654 | 19,716 | 12,166 | 8,465 | 6,961 | 6,753 | 6,200 | 6,469 | 6,001 | 5,899 | 5,979 | 5,600 | 4,743 | 4,468 |
| Standard denitrification | kl/day | 25,196 | 30,157 | 31,908 | 29,655 | 27,748 | 26,173 | 25,694 | 25,608 | 25,153 | 24,663 | 24,023 | 22,812 | 21,544 | 21,113 |
| High-intensity denitrification | kl/day | 8,158 | 13,817 | 16,498 | 17,493 | 16,285 | 16,104 | 15,778 | 15,030 | 14,529 | 14,336 | 13,831 | 13,651 | 13,838 | 13,289 |
| Membrane separation | kl/day | NO | 1,616 | 2,375 | 3,055 | 3,573 | 3,684 | 3,684 | 4,062 | 4,074 | 2,204 | 3,373 | 3,184 | 2,853 | 2,404 |
| Other | kl/day | 13,777 | 20,028 | 25,917 | 30,277 | 34,654 | 34,577 | 34,622 | 33,556 | 33,975 | 34,983 | 33,940 | 36,074 | 37,430 | 40,223 |

Table 7-84 Activity Data for human waste by treatment types

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobic treatment | 1000 kl/year | 9,455 | 5,589 | 3,073 | 1,642 | 992 | 925 | 765 | 738 | 722 | 653 | 530 | 504 | 419 | 366 |
| Aerobic treatment | 1000 kl/year | 7,288 | 5,546 | 3,400 | 2,146 | 1,666 | 1,605 | 1,453 | 1,512 | 1,417 | 1,386 | 1,412 | 1,311 | 1,106 | 1,040 |
| Standard denitrification | 1000 kl/year | 6,889 | 8,483 | 8,917 | 7,518 | 6,640 | 6,222 | 6,021 | 5,984 | 5,940 | 5,794 | 5,672 | 5,339 | 5,022 | 4,916 |
| High-intensity denitrification | 1000 kl/year | 2,231 | 3,887 | 4,611 | 4,435 | 3,897 | 3,828 | 3,697 | 3,512 | 3,431 | 3,368 | 3,266 | 3,195 | 3,226 | 3,094 |
| Membrane separation | 1000 kl/year | NO | 455 | 664 | 774 | 855 | 876 | 863 | 949 | 962 | 518 | 796 | 745 | 665 | 560 |
| Other | 1000 kl/year | 3,767 | 5,634 | 7,243 | 7,676 | 8,293 | 8,220 | 8,113 | 7,841 | 8,024 | 8,219 | 8,014 | 8,443 | 8,725 | 9,365 |
| Total | 1000 kl/year | 29,630 | 29,594 | 27,907 | 24,190 | 22,342 | 21,677 | 20,912 | 20,537 | 20,497 | 19,937 | 19,690 | 19,538 | 19,163 | 19,341 |

### *2) $N_2O$*

- ***Estimation Method***

Emissions of $N_2O$ from this source are calculated using Japan's country-specific methodology, in accordance with decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of nitrogen treated at human waste treatment plants, by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

$E$ : Emission of nitrous oxide from the processing of domestic and commercial wastewater at human waste treatment plants [kg-$N_2O$]
$EF_i$ : Emission factor for human waste treatment plants (by treatment process *i*) [kg-$N_2O$/kg-N]
$A_i$ : Amount of nitrous oxide in human waste and Johkasou sludge input at human waste treatment plants (by treatment process *i*) [kg-N]

- ***Emission Factors***

The emission factors for $N_2O$ are determined for each treatment process including high-load denitrification treatment and membrane separation systems using the results of actual case studies in Japan (MOE, 2006b).

According to the survey study on the emission factors for human waste treatment facilities conducted in FY1994 (Tanaka et al., 1997) and FY2003 (Ohmura et al., 2004) in Japan, because of the advancement of the structure of human waste treatment facilities and the technology of operation and

maintenance, actual measurement results show the improvement in the emission factors for high load de-nitrification treatment and membrane separation; therefore, different emission factors are used for FY1994 or before and from FY2003 onwards.

Table 7-85 $N_2O$ emission factors by each treatment process

| Treatment method | $N_2O$ emission factors [kg-$N_2O$-N/kg-N] | | |
|---|---|---|---|
| | FY1990-1994 | FY1995-2002 | From FY2003 |
| High load de-nitrification treatment | 0.033 1) | Interpolation | 0.0029 2) |
| Membrane separation | 0.033 1) | Interpolation | 0.0024 2) |
| Other (including anaerobic treatment, aerobic treatment, standard de-nitrification treatment) | 0.0000045 3) | | |

Note:
1) Use median value of actual measurements at 13 plants given in Tanaka et al. (1998)
2) Use median value of actual measurements at 13 plants given in Omura et al. (2004)
3) Referred to Tanaka et al. (1995) (Calculated by dividing upper limit value for standard de-nitrification treatment ($1.0\times10^{-5}$ kg-$N_2O/m^3$) by treated nitrogen concentration in FY1994 (2,211 mg/l)).

- ***Activity Data***

The volume of nitrogen treated at human waste treatment plants is calculated by multiplying treated nitrogen concentration by the volume of human waste treated at these facilities (the sum of collected human waste and sewage in sewerage tank), given in the *Waste Treatment in Japan*. The treated nitrogen concentration is based on weighted average of the volume of nitrogen contained in collected human waste and sewage in sewerage tank derived using the volume of collected human waste and sewage in sewerage tank treated at human waste treatment plants.

$$A_i = (W_H \times N_H + W_J \times N_J) \times F_i / 1000$$

$A_i$ : Activity data for human waste treatment method *i* [kg-N]
$W_H$ : Input volume of human waste at human waste treatment plants [$m^3$]
$W_J$ : Input volume of *Johkasou* sludge at human waste treatment plants [$m^3$]
$N_H$ : Nitrogen concentration in human waste [mg-N/l]
$N_J$ : Nitrogen concentration in *Johkasou* sludge [mg-N/l]
$F_i$ : Percentage throughput of treatment process *i* [%]

- ***Input Volume of Human Waste and Johkasou sludge at Human Waste Treatment Plants:***

See the data used for the calculation of $CH_4$ emissions from human waste treatment plants (Table 7-82).

- ***Percentage Throughput of the Human Waste Treatment Processes:***

See the data used for the calculation of $CH_4$ emission from human waste treatment plants (Table 7-83).

- ***Nitrogen Concentration in Human Waste and Johkasou Sludge Input at Treatment Plants:***

For the nitrogen concentration in human waste and *Johkasou* sludge input at treatment plants, the values analyzed for the period FY1989 - FY1991, FY1992 - FY1994, FY1995 – FY1997, and FY1998 - FY2000, respectively, are used based on the research conducted by Okazaki (2001). The value of FY2000 is substituted for the values from FY2001 onward. (See Table 7-86).

Table 7-86 Concentration of nitrogen contained in collected human waste and *Johkasou* sludge

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Human waste from vault toilet | mg-N/l | 3,940 | 3,100 | 2,700 | 2,700 | 2,700 | 2,700 | 2,700 | 2,700 | 2,700 | 2,700 | 2,700 | 2,700 | 2,700 | 2,700 |
| *Johkasou* sludge | mg-N/l | 1,060 | 300 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 |
| Weighted average | mg-N/l | 3,043 | 2,008 | 1,695 | 1,491 | 1,373 | 1,354 | 1,327 | 1,304 | 1,280 | 1,258 | 1,242 | 1,219 | 1,203 | 1,218 |

Table 7-87 Activity data: Amount of nitrogen in human waste and *Johkasou* sludge processed at human waste treatment plants

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobic treatment | kt-N | 28.8 | 11.2 | 5.2 | 2.4 | 1.4 | 1.3 | 1.0 | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 | 0.4 |
| Aerobic treatment | kt-N | 22.2 | 11.1 | 5.8 | 3.2 | 2.3 | 2.2 | 1.9 | 2.0 | 1.8 | 1.7 | 1.8 | 1.6 | 1.3 | 1.3 |
| Standard denitrification | kt-N | 21.0 | 17.0 | 15.1 | 11.2 | 9.1 | 8.4 | 8.0 | 7.8 | 7.6 | 7.3 | 7.0 | 6.5 | 6.0 | 6.0 |
| High-intensity denitrification | kt-N | 6.8 | 7.8 | 7.8 | 6.6 | 5.3 | 5.2 | 4.9 | 4.6 | 4.4 | 4.2 | 4.1 | 3.9 | 3.9 | 3.8 |
| Membrane separation | kt-N | NO | 0.9 | 1.1 | 1.2 | 1.2 | 1.2 | 1.1 | 1.2 | 1.2 | 0.7 | 1.0 | 0.9 | 0.8 | 0.7 |
| Other | kt-N | 11.5 | 11.3 | 12.3 | 11.4 | 11.4 | 11.1 | 10.8 | 10.2 | 10.3 | 10.3 | 10.0 | 10.3 | 10.5 | 11.4 |
| Total | kt-N | 90.2 | 59.4 | 47.3 | 36.1 | 30.7 | 29.4 | 27.7 | 26.8 | 26.2 | 25.1 | 24.5 | 23.8 | 23.0 | 23.6 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

As for the uncertainties in emission factors for $CH_4$ and $N_2O$ in human waste treatment plant, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-88.

Table 7-88 Uncertainty assessment for human waste treatment plant on the category "Domestic wastewater (5.D.1.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Human waste treatment plant | $CH_4$ | -84% | +84% | -10% | +10% | -84% | +84% | The uncertainty is assessed based on expert judgment. (The uncertainty in Old type *Johkasou* is substituted). | The uncertainty in municipal waste statistics based on expert judgment is used. | Combined by using the formula for propagation of errors |
| | $N_2O$ | -87% | +87% | -10% | +10% | -88% | +88% | | | |

- ***Time-series Consistency***

For $N_2O$ emission factor, consistent data over the time series are constructed based on the actual measurement data by using the methods described in Table 7-85. For other parameters, data are constructed consistently for the entire time series. The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By updating the statistical data including emissions for FY2017 were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

### 7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)

#### *a) Category Description*

Although most of the domestic wastewater generated by Japanese households is processed at wastewater treatment plants, treated wastewater which is discharged into public waters contains residual nitrogen. Also, some miscellaneous wastewater is discharged into public waters without any treatment. The $CH_4$ and $N_2O$ emissions from untreated wastewater and sludge decomposing in public waters and the $N_2O$ from treated wastewater are reported under this category. The emission sources for this category are shown on Table 7-89.

Table 7-89 Emission sources of category "Natural Decomposition of Domestic Wastewater (5.D.1.-)"

| Emission source | Detail |
|---|---|
| Untreated wastewater ($CH_4$, $N_2O$) | Untreated miscellaneous wastewater from households using old type *Johkasou* |
| | Untreated miscellaneous wastewater from households using vault toilet |
| | Untreated miscellaneous wastewater from households using on-site disposal systems |
| Treated wastewater ($N_2O$) | Treated wastewater from sewage treatment plants |
| | Treated wastewater from community plants and current advanced/standard type *Johkasou* |
| | Treated wastewater derived from human waste in old type *Johkasou* |
| | Treated wastewater from treatment of human waste/*Johkasou* sludge in human waste treatment plants |
| Sludge ($CH_4$, $N_2O$) | Human waste and *Johkasou* sludge dumped into the ocean |
| | Sewage sludge dumped into the ocean |

#### *b) Methodological Issues*

- ***Estimation Method***

Estimation method is established in accordance with the method described in the *2006 IPCC Guidelines*. In the natural decomposition of wastewater, both the volume of organic matter extracted as sludge and recovered $CH_4$ are zero. Accordingly, $CH_4$ emissions are calculated by multiplying the volume of organic matter contained in the untreated domestic wastewater that is discharged into public waters by the emission factor. The $N_2O$ emission is calculated by multiplying the volume of nitrogen contained in the wastewater by the emission factor.

$$E = EF \times A$$

*E* : Emission of methane or nitrous oxide from the natural decomposition of domestic wastewater [kg-$CH_4$], [kg-$N_2O$]
*EF* : Emission factor [kg-$CH_4$/kg-BOD], [kg-$N_2O$/kg-N]
*A* : Volume of organic matter [kg-BOD] or nitrogen [kg-N] in domestic wastewater

- ***Emission Factors***

Emission factors are determined in accordance with the *2006 IPCC Guidelines*. The emission factor for $CH_4$ is established by multiplying the maximum $CH_4$ generation potential ($B_0$) by a $CH_4$ conversion factor (MCF). The maximum $CH_4$ generation potential is set to 0.6 kg-$CH_4$/kg-BOD, given in the *2006 IPCC Guidelines*, and the MCF is set to 0.1, a default value for "Sea, river and lake discharge" of "Untreated systems".

$$EF_{CH4} = B_0 \times MCF$$
$$= 0.6 \text{ [kg-CH}_4\text{/kg-BOD]} \times 0.1$$
$$= 0.06 \text{ [kg-CH}_4\text{/kg-BOD]}$$

The emission factor for $N_2O$ is calculated from the value of 0.005 kg $N_2O$-N/kg N after conversion of the units.

$EF_{N2O}$ = 0.005 [kg-$N_2O$-N/kg-N] × 44/28
= 0.0079 [kg-$N_2O$/kg-N]

- ***Activity Data***

➢ ***Untreated wastewater***

Activity data for $CH_4$ and $N_2O$ emissions from untreated wastewater are obtained from the following equation:

$$A = \sum_i P_i \times U$$

*A* : Activity data of untreated miscellaneous wastewater from households [g-BOD], [g-N]
$P_i$ : User population of treatment system type *i* (old type *Johkasou*, vault toilet, on-site disposal system) [1] [person]
*U* : Unit BOD effluent (40 [g-BOD/person-day][2]), or unit nitrogen effluent (2 [g-N/person-day][2]) from untreated miscellaneous wastewater

Reference:
1) *Waste Treatment in Japan* (MOE)
2) JSWA (1999)

Note that a portion of the human waste in on-site disposal systems is utilized as fertilizer on farmlands in Japan. The $N_2O$ emission from this is already included in the "Direct soil emission (3.D.1.)" category in the Agriculture sector, and therefore, not included in the calculation for this source.

➢ ***Treated wastewater***

Activity data for $N_2O$ emissions from treated wastewater are obtained from the following equations:

$$A = A_{sp} + A_{dp} + A_{hp}$$

*A* : Total nitrogen in treated domestic wastewater (activity data) [t-N]
$A_{sp}$ : Total nitrogen in treated wastewater from sewage treatment plants [t-N]
$A_{dp}$ : Total nitrogen in treated wastewater from domestic sewage treatment plants [t-N]
$A_{hp}$ : Total nitrogen in treated wastewater from human waste treatment plants [t-N]

- ***Sewage treatment plants***

Total nitrogen in treated wastewater from sewage treatment plants are obtained from the equation below:

$$A_{sp} = \sum_i (W_i \times D_i) \times 10^{-6}$$

$W_i$ : Amount of treated wastewater in sewage treatment plant *i* [$m^3$]
$D_i$ : Nitrogen concentration in treated wastewater from sewage treatment plant *i* [mg-N/l]

Reference: *Sewage Statistics* (JSWA) for both parameters

- ***Domestic sewage treatment plant***

Total nitrogen in treated wastewater from domestic sewage treatment plants (community plant, current advanced/standard type *Johkasou*, and old type *Johakasou*) are obtained from the equation below:

$$A_{dp} = \sum_i \{TN_i \times d \times P_i \times (1 - R_i)\} \times 10^{-6}$$

$TN_i$ : Unit total nitrogen effluent from domestic sewage plant type *i* [g-N/person-day] (see Table 7-90)
$P_i$ : User population of domestic sewage treatment plant type *i* [person] (see Table 7-79)
$R_i$ : Fraction of nitrogen removal in domestic sewage plant type *i* [%] (see Table 7-91)
$d$ : Annual days [days/year]

Unit nitrogen effluent from each domestic sewage plant type and fraction of nitrogen removal in these plants are shown in the following tables:

Table 7-90 Unit nitrogen effluent from domestic sewage plants

| Treatment system | Sewage type | Unit nitrogen effluent [g-N/person-day] | Reference |
|---|---|---|---|
| Community plant | Human waste and miscellaneous wastewater | 10 | MOE (2009) |
| Current type *Johkasou* (both advanced and standard type) | | | |
| Old type *Johkasou* | Human waste | 8 | |

Table 7-91 Fraction of nitrogen removal in domestic sewage plants

| Treatment system | | | Fraction of nitrogen removal [%] | Reference |
|---|---|---|---|---|
| Community plant | | | 20 | Expert judgement |
| Current type *Johkasou* | Advanced type | TN removal type | 60 | |
| | | TN and TP removal type | | |
| | | BOD removal type | 20 | |
| | | Other advanced type | | |
| | Standard type | | | |
| Old type *Johkasou* | | | | |

- ***Human waste treatment plant***

Total nitrogen in treated wastewater from human waste treatment plant are obtained from the equation below:

$$A_{hp} = W \times D \times 10^{-6}$$

$W$ : Amount of human waste and *Johkasou* sludge treated in human waste treatment plant[1)] [$m^3$]
$D$ : Nitrogen concentration in treated wastewater from human waste treatment plant [mg-N/l]

Sources:
1) *Waste Treatment in Japan* (MOE)

Nitrogen concentration in treated wastewater of this subcategory is obtained as weighted averages of those in discharged wastewater from each human waste treatment type (Table 7-92) weighted by treatment capacities by treatment process (Table 7-83).

Table 7-92 Nitrogen concentrations in discharged wastewater from each human waste treatment method

| Treatment method | Nitrogen concentration [mg-N/l] | Source |
|---|---|---|
| Anaerobic treatment | 98.0 | Okazaki et al. (2001) |
| Aerobic treatment | 32.5 | |
| Standard de-nitrification treatment | 5.5 | |
| High load de-nitrification treatment | 19.0 | |
| Membrane separation | 10.0 | |

- ***Sludge***

Activity data for $CH_4$ and $N_2O$ emissions from sludge dumped into ocean are obtained from the equations below:

- ***Human waste/Johkasou sludge***

$$A = V_H \times D_H + V_J \times D_J$$

$A$ : Activity data of human waste/*Jokasou* sludge dumped into ocean [g-BOD], [g-N]
$V_H$ : Human waste dumped in ocean [1)] [kl]
$D_H$ : BOD/Nitrogen concentration in human waste[2)] [mg-BOD/l], [mg-N/l]
$V_J$ : *Jokasou* sludge dumped in ocean [1)] [kl]
$D_J$ : BOD/Nitrogen concentration in *Jokasou* sludge [2)] [mg-BOD/l], [mg-N/l]

Reference:
1) *Waste Treatment in Japan* (MOE)
2) Okazaki et al. (2001)

- ***Sewage sludge***

$$A = V \times D$$

$A$ : Activity data of sewage sludge dumped into ocean [g-BOD], [g-N]
$V$ : Sewage sludge dumped into ocean [1)] [kl]
$D$ : BOD/Nitrogen concentration into sewage sludge [2)] [mg-BOD/l], [mg-N/l]

Reference:
1) *Sewage Statistics* (JSWA)
2) The value for *Johkasou* sludge is substituted by Expert judgement based on Okazaki et al. (2001).

Estimated activity data are shown in Table 7-93.

Table 7-93 Activity data: Amount of organic material and nitrogen in untreated domestic wastewater and discharged into public water zone

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Organic mater in: | | | | | | | | | | | | | | | |
| Untreated wastewater (from old type *Johkasou*) | kt-BOD | 392 | 381 | 341 | 267 | 215 | 204 | 194 | 191 | 181 | 173 | 167 | 161 | 154 | 148 |
| Untreated wastewater (from Vault toilet) | kt-BOD | 568 | 429 | 298 | 203 | 156 | 146 | 136 | 130 | 120 | 113 | 105 | 101 | 95 | 89 |
| Untreated wastewater (from On-site disposal) | kt-BOD | 46 | 21 | 9 | 4 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Human waste, *Johkasou* sludge (Ocean dumping) | kt-BOD | 22 | 14 | 9 | 4 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Sewege sludge (Ocean dumping) | kt-BOD | 1 | 1 | 0 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Total | kt-BOD | 1,029 | 846 | 658 | 478 | 373 | 351 | 333 | 322 | 302 | 287 | 273 | 263 | 250 | 238 |
| Nitrogen in: | | | | | | | | | | | | | | | |
| Untreated wastewater (from old type *Johkasou*) | kt-N | 19.6 | 19.1 | 17.0 | 13.4 | 10.7 | 10.2 | 9.7 | 9.6 | 9.0 | 8.6 | 8.3 | 8.1 | 7.7 | 7.4 |
| Untreated wastewater (from Vault toilet) | kt-N | 28.4 | 21.5 | 14.9 | 10.2 | 7.8 | 7.3 | 6.8 | 6.5 | 6.0 | 5.6 | 5.3 | 5.0 | 4.8 | 4.5 |
| Untreated wastewater (from on-site disposal) | kt-N | 2.3 | 1.1 | 0.5 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.05 | 0.05 | 0.06 |
| Treated wastewater | kt-N | 297.0 | 301.2 | 281.8 | 267.0 | 247.1 | 251.6 | 255.0 | 243.2 | 250.0 | 241.3 | 243.0 | 241.9 | 239.2 | 238.0 |
| Human waste, *Johkasou* sludge (Ocean dumping) | kt-N | 7.2 | 3.2 | 2.2 | 0.8 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Sewege sludge (Ocean dumping) | kt-N | 0.1 | 0.1 | 0.01 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Total | kt-N | 354.6 | 346.0 | 316.4 | 291.5 | 265.7 | 269.1 | 271.6 | 259.3 | 265.1 | 255.6 | 256.7 | 255.0 | 251.7 | 249.9 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

As for the uncertainties in emission factors for $CH_4$ and $N_2O$ in this category, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-94.

Table 7-94 Uncertainty assessment for natural decomposition of domestic wastewater on the category "Domestic wastewater (5.D.1.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Natural decomposition | $CH_4$ | -58% | +58% | -10% | +10% | -59% | +59% | Since the *2006 IPCC Guidelines* provide the emission factors as default value for this category, the uncertainty is assessed in accordance with the default method in the guidelines. | The uncertainty in municipal waste statistics based on expert judgment is used. | Combined by using the formula for propagation of errors |
| | $N_2O$ | -58% | +58% | -10% | +10% | -59% | +59% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in $CH_4$ is substituted based on expert judgment. | | |

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

By reconsidering the fraction of nitrogen removal of current advanced type *Johkasou*, $N_2O$ emission from treated wastewater from FY2001 onward were recalculated.

By updating the statistical data, emissions were recalculated.

See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

No improvements are planned.

### 7.5.2. Industrial Wastewater (5.D.2.)

$CH_4$ and $N_2O$ emissions from industrial effluent, which is treated by plants/facilities in accordance with the regulations based on the Water Pollution Prevention Law and the Sewerage Law, are allocated to "Industrial wastewater treatment (5.D.2.-)" , $CH_4$ and $N_2O$ emissions from untreated/treated industrial effluent discharged from plants/facilities and decomposed in public waters, are allocated to "Natural decomposition of Industrial wastewater (5.D.2.-)", and $CH_4$ and $N_2O$ emissions from landfill leachate treatment are allocated to "Landfill leachate treatment (5.D.2.-)" under the sub-category of "Industrial Wastewater (5.D.2.)".

#### 7.5.2.1. Industrial Wastewater Treatment (5.D.2.-)

***a) Category Description***

$CH_4$ and $N_2O$ emissions from industrial effluent, which is treated by factories and other facilities in accordance with the regulations based on the Water Pollution Prevention Law and the Sewerage Law, are allocated to "Industrial wastewater treatment (5.D.2.-)."

### *b) Methodological Issues*

- ***Estimation Method***

In accordance with the decision tree of the *2006 IPCC Guidelines* (Page 6.19, Fig. 6.3), $CH_4$ and $N_2O$ emissions are estimated for the industries that release organic-rich wastewater. Since default values given in the *2006 IPCC Guidelines* are considered to be unsuited to Japan's circumstances, $CH_4$ emissions are estimated based on Japan's country-specific methodology, namely, by multiplying the annual amount of organic matter in industrial wastewater subject to report (BOD basis) by the CH4 emission factor per unit BOD that is based on Japan's country-specific wastewater handling. Because $CH_4$ is emitted in wastewater biological treatment processes, BOD-based activity data (amount of organic matter in wastewater degraded through biological treatment) is thought to be preferable to COD-based data. For this reason, $CH_4$ emissions are calculated using BOD in Japan. With regard to $N_2O$ emissions, no estimation methodologies are given in the *2006 IPCC Guidelines*. Therefore, in the same manner for estimating $CH_4$ emissions, $N_2O$ emissions are estimated by multiplying the amount of nitrogen in industrial wastewater by Japan's country-specific $N_2O$ emission factor.

$$E = EF \times A$$

Where:

*E* : Amount of $CH_4$ or $N_2O$ emissions generated when treating industrial wastewater [kg-$CH_4$], [kg-$N_2O$]

*EF* : Emission factor [kg-$CH_4$/kg-BOD], [kg-$N_2O$/kg-N]

*A* : Amount of BOD or nitrogen in industrial wastewater [kg-BOD], [kg-N]

- ***Emission Factor***

Country-specific emission factors obtained from a set of actual measurement at 8 plants in summer and winter (MOE, 2018 a) are adopted (MOE, 2018 b).

Table 7-95 Emission Factors for industrial wastewater treatment facilities

| Category of Manufacturing | $CH_4$ Emission factor [g-$CH_4$/kg-BOD] | $N_2O$ Emission factor [g-$N_2O$/kg-N] |
|---|---|---|
| Manufacture of food | 1.2 | 0.47 |
| Manufacture of pulp, paper and paper products | 2.5 | 0.014 |
| Manufacture of chemical and allied product | 0.92 | 17 |
| Manufacture of iron and steel | 7.3 | 4.0 |
| Other manufactures (average emission factors for above categories) | 3.0 | 5.3 |

In Japan, $CH_4$ emissions generated by anaerobic wastewater treatment are entirely recovered. For a small amount of $CH_4$ emissions generated under partially anaerobic conditions created during aerobic treatment, a country-specific emission factor is applied for emission estimates because the condition for this particular $CH_4$ emission differs from that for the use of default value for the $CH_4$ emissions generated from anaerobic treatment defined in *the 2006 IPCC Guidelines*.

- ***Activity Data***

The activity data for $CH_4$ emission are estimated based on the amount of organic matter contained in wastewater using BOD concentrations. The emission estimates are conducted for the industries which generate large amount of CH4 emissions with high BOD concentrations from the treatment of wastewater referring to the industry types provided in the *Revised 1996 IPCC Guidelines* (Table 7-96). The amount of organic matter is obtained by sorting and aggregating by industry type according to the middle industrial classification provided by JSWA (2009).

The use of COD concentrations is required to report activity data on CRF; however, activity data are reported as "NE" because country-specific methodology is used for this source.

$$A_{CH4,i} = W_i \times \frac{BOD_i}{1000}$$

Where:

$$W_i = I_i \times F_{CH4,i} \times F_{onsite,i}$$

$A_{CH4,i}$ : Amount of BOD in industrial wastewater from industry type *i* (Activity data) [kg-BOD]
$W_i$ : Amount of industrial wastewater from industry type *i* flowing into wastewater treatment facilities [$m^3$]
$BOD_i$ : BOD concentration of runoff water from industry type *i* [mg-BOD/l]
$I_i$ : Amount of industrial wastewater from industry type *i* used for product processing and/or washing [$m^3$]
$F_{CH4,i}$ : Percentage of industrial wastewater from industry type *i* treated at treatment facilities emitting $CH_4$ [%]
$F_{onsite,i}$ : Percentage of industrial wastewater from industry type *i* treated on-site [%]

The activity data for $N_2O$ emissions are obtained based on the amount of nitrogen contained in industrial wastewater and aggregated by the same industrial sub-category as that applied to the estimation of $CH_4$ emissions.

$$A_{N2O,i} = W_i \times TN_i/1000$$

Where:

$$W_i = I_i \times F_{N2O,i} \times F_{onsite,i}$$

$A_{N2O,i}$ : Amount of nitrogen in industrial wastewater from industry type *i* (Activity data) [kg-N]
$W_i$ : Amount of industrial wastewater from industry type *i* flowing into wastewater treatment facilities [$m^3$]
$TN_i$ : Total nitrogen concentration of runoff water from industry type *i* [mg-N/l]
$I_i$ : Amount of industrial wastewater from industry type *i* used for product processing and/or washing [$m^3$]
$F_{N2O,i}$ : Percentage of industrial wastewater from industry type *i* treated at treatment facilities emitting $N_2O$ [%]
$F_{onsite,i}$ : Percentage of industrial wastewater from industry type *i* treated on-site [%]

- ***Amount of Industrial Wastewater Inflowed into Wastewater Treatment Facilities***

The amount of water used for the treatment of products by industrial sub-category and the volume of water used for washing given in the *Table of Industrial Statistics - Land and Water* (METI) are used for the amount of industrial wastewater treated at wastewater treatment facilities.

- ***Percentage of Industrial Wastewater Treated at Facilities Generating $CH_4$***

Emissions of $CH_4$ from industrial wastewater treatment are believed to be generated from the treatment of wastewater with the activated sludge method and from the anaerobic treatment. Industrial wastewater treatment percentages for each industry code are set from the percentages of reported wastewater amounts in total wastewater, as given under "active sludge", "other biological treatment", "membrane treatment", "nitrification and denitrification" and "other advanced treatment" in the *Study on the Control of Wastewater loading* (Water and Air Environment Bureau of MOE).

- ***Percentage of Industrial Wastewater Treated at Facilities Generating $N_2O$***

Emissions of $N_2O$ from industrial wastewater treatment are believed to be generated mainly from biological treatment processes such as denitrification. Data on the fraction of industrial wastewater treated at facilities generating $CH_4$ is also used for $N_2O$ emission estimates.

- ***Percentage of Industrial Wastewater Treated On-site***

Percentage of industrial wastewater treated on-site is set at 1.0 in all industrial sub-categories because there is no statistical information available making it possible to ascertain this percentage.

- ***BOD and Nitrogen Concentrations in Runoff Wastewater***

For the BOD concentrations for industrial sub-categories, the BOD raw water quality for industrial sub-categories given in JSWA (1999) is used. For the nitrogen concentrations for industrial sub-categories, emission intensities (TN: Total Nitrogen) provided by the same survey for industrial sub-categories are used.

Table 7-96 BOD and nitrogen concentrations by industry type used for emission estimates

| Industry code | Category of Manufacturing | mg-BOD/L | mg-N/L |
|---|---|---|---|
| 9 | Manufacture of food | 1,470 | 62 |
| 10 | Manufacture of beverages, tobacco and feed | 1,138 | 77 |
| 11 | Manufacture of textile products | 386 | 36 |
| 14 | Manufacture of pulp, paper and paper products | 556 | 37 |
| 16 | Manufacture of chemical and allied product | 1,093 | 191 |
| 17 | Manufacture of petroleum and coal products | 975 | 289 |
| 18 | Manufacture of plastic products | 268 | 11 |
| 19 | Manufacture of rubber products | 112 | 32 |
| 20 | Manufacture of leather tanning, leather products and fur skins | 1,810 | 60 |
| 22 | Manufacture of iron and steel | 246 | 310 |

Table 7-97 BOD load [kt-BOD] and TN load [kt-N] of industrial wastewater

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BOD load | | | | | | | | | | | | | | | |
| Manufacture of food | kt-BOD | 297.8 | 326.2 | 306.8 | 289.4 | 305.7 | 311.7 | 299.8 | 288.0 | 307.2 | 348.4 | 348.4 | 348.4 | 348.4 | 348.4 |
| Manufacture of beverages, tobacco and feed | kt-BOD | 88.7 | 100.5 | 92.0 | 71.5 | 62.6 | 58.0 | 56.9 | 55.7 | 52.8 | 62.0 | 62.0 | 62.0 | 62.0 | 62.0 |
| Manufacture of textile products | kt-BOD | 98.1 | 94.2 | 65.5 | 47.7 | 40.2 | 40.1 | 42.8 | 45.4 | 38.2 | 36.4 | 36.4 | 36.4 | 36.4 | 36.4 |
| Manufacture of pulp, paper and paper products | kt-BOD | 471.8 | 422.7 | 457.3 | 423.4 | 401.0 | 365.4 | 353.1 | 340.9 | 321.4 | 324.0 | 324.0 | 324.0 | 324.0 | 324.0 |
| Manufacture of chemical and allied product | kt-BOD | 110.2 | 95.3 | 103.0 | 160.1 | 151.8 | 162.9 | 157.1 | 151.3 | 154.2 | 146.1 | 146.1 | 146.1 | 146.1 | 146.1 |
| Manufacture of petroleum and coal products | kt-BOD | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Manufacture of plastic products | kt-BOD | 6.2 | 5.9 | 6.2 | 6.9 | 7.8 | 6.9 | 7.1 | 7.4 | 7.1 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 |
| Manufacture of rubber products | kt-BOD | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Manufacture of leather tanning, leather products and fur skins | kt-BOD | 1.3 | 1.1 | 0.8 | 0.5 | 0.3 | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Manufacture of iron and steel | kt-BOD | 1.2 | 1.3 | 1.3 | 1.5 | 1.8 | 1.8 | 1.7 | 1.7 | 1.6 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| TN load | | | | | | | | | | | | | | | |
| Manufacture of food | kt-N | 15.5 | 16.9 | 16.3 | 15.0 | 15.1 | 16.0 | 15.3 | 14.6 | 15.8 | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 |
| Manufacture of beverages, tobacco and feed | kt-N | 3.8 | 4.2 | 4.3 | 3.9 | 2.7 | 2.6 | 2.5 | 2.4 | 2.8 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 |
| Manufacture of textile products | kt-N | 10.8 | 10.5 | 7.4 | 5.2 | 4.5 | 4.4 | 4.8 | 5.3 | 4.3 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 |
| Manufacture of pulp, paper and paper products | kt-N | 18.4 | 16.5 | 17.7 | 16.2 | 20.2 | 14.4 | 13.8 | 13.2 | 11.8 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| Manufacture of chemical and allied product | kt-N | 40.0 | 38.8 | 30.1 | 48.5 | 47.3 | 50.8 | 50.7 | 50.6 | 50.8 | 49.8 | 49.8 | 49.8 | 49.8 | 49.8 |
| Manufacture of petroleum and coal products | kt-N | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Manufacture of plastic products | kt-N | 0.2 | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| Manufacture of rubber products | kt-N | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Manufacture of leather tanning, leather products and fur skins | kt-N | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Manufacture of iron and steel | kt-N | 57.7 | 53.9 | 55.5 | 54.7 | 42.3 | 45.6 | 53.4 | 61.2 | 58.9 | 57.5 | 57.5 | 57.5 | 57.5 | 57.5 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

The uncertainty in emission factors are evaluated according to the survey for EFs (MOE, 2018a). As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-98.

Table 7-98 Uncertainty assessment for industrial wastewater treatment on the category "Industrial wastewater (5.D.2.-)"

| Item | GHGs | Emission /removal factor uncertainty [%] | | Activity data uncertainty [%] | | Emission/removal uncertainty [%] | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Industrial wastewater treatment | $CH_4$ | -60% | +60% | -30% | +30% | -67% | +67% | The uncertainty is evaluated according to the survey for EFs (MOE, 2018a) | The uncertainty in industrial waste statistics based on expert judgment is used. | Combined by using the formula for propagation of errors |
| | $N_2O$ | -95% | +95% | -30% | +30% | -100% | +100% | | | |

- ***Time-series Consistency***

Data on the percentage of industrial wastewater treated at $CH_4$- and $N_2O$-generating facilities since FY2001 are available only for FY2004. Therefore, data are interpolated and extrapolated for the remaining years. The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

No recalculations are conducted.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 7.5.2.2. Natural Decomposition of Industrial Wastewater (5.D.2.-)

### *a) Category Description*

Although most of the industrial wastewater in Japan generated in industrial plants and facilities is processed at industrial wastewater treatment plants, treated wastewater which is discharged into public waters contains residual nitrogen. Also, some industrial wastewater is discharged into public waters without any treatment. The $CH_4$ and $N_2O$ emissions from untreated wastewater decomposing in public waters and the $N_2O$ from treated wastewater are reported under this category.

### *b) Methodological Issues*

- ***Estimation Method***

$CH_4$ and $N_2O$ emissions from untreated/treated industrial wastewater discharged into public waters are estimated in accordance with the method in the *2006 IPCC Guidelines*, as shown below.

$$E = EF \times A$$

*E* : Emission of methane or nitrous oxide from the natural decomposition of industrial wastewater [kg-$CH_4$], [kg-$N_2O$]

*EF* : Emission factor [kg-$CH_4$/kg-BOD], [kg-$N_2O$/kg-N]

*A* : Volume of organic matter [kg-BOD] or nitrogen [kg-N] in industrial wastewater

- ***Emission Factor***

As for $CH_4$ and $N_2O$ emission factors for both of untreated and treated wastewater discharged into public waters, the default values of the *2006 IPCC Guidelines* are applied in a similar way of the category "7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)".

Table 7-99 $CH_4$ and $N_2O$ emission factors for the category natural decomposition of industrial wastewater

| Gas | Unit | Emission foctor | Reference |
|---|---|---|---|
| $CH_4$ | kg-$CH_4$/ kg-BOD | 0.06 | *2006 IPCC Guidelines* |
| $N_2O$ | kg-$N_2O$/ kg-N | 0.0079 | *2006 IPCC Guidelines* |

- ***Activity Data***

Activity data for this category cover 10 middle industrial classification shown on the Table 7-96 of "7.5.2.1. Industrial Wastewater Treatment (5.D.2.-).

➢ ***Untreated wastewater***

Activity data for this category are defined as a sum up of BOD or TN loadings from industrial plants/facilities which directly discharge untreated wastewater into public waters. The BOD or TN loadings in wastewater from each plant/facility are calculated by multiplying amount of wastewater and BOD or TN concentration in wastewater from each plant/facility, which data are obtained from the *Comprehensive Survey on Water Pollutant Discharge* (MOE).

$$A = \sum (V_i \times Q_i)$$

*A* : Activity data of untreated wastewater (BOD or TN loadings) [kg-BOD/L], [kg-N/L]

$V_i$ : Amount of untreated industrial wastewater discharged into public waters from industrial plant/facility *i* [$m^3$]

$Q_i$ : BOD or TN concentration of untreated industrial wastewater discharged from industrial plant/facility *i* [g-BOD/L], [g-N/L]

Table 7-100 BOD and TN loadings in untreated wastewater discharged into public waters (Activity data)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BOD load | | | | | | | | | | | | | | | |
| Manufacture of food | kt-BOD | 8.0 | 8.5 | 9.0 | 16.3 | 6.0 | 6.2 | 6.3 | 5.3 | 4.3 | 4.6 | 5.0 | 5.3 | 5.5 | 5.5 |
| Manufacture of beverages, tobacco and feed | kt-BOD | 0.6 | 0.6 | 0.6 | 0.6 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 | 0.4 | 0.4 |
| Manufacture of textile products | kt-BOD | 3.4 | 2.9 | 2.2 | 2.2 | 4.4 | 4.4 | 4.5 | 4.8 | 5.1 | 3.8 | 2.5 | 2.9 | 3.3 | 3.3 |
| Manufacture of pulp, paper and paper products | kt-BOD | 9.4 | 8.9 | 8.9 | 8.4 | 3.7 | 3.6 | 3.6 | 5.3 | 6.9 | 5.2 | 3.4 | 3.7 | 4.1 | 4.1 |
| Manufacture of chemical and allied product | kt-BOD | 49.5 | 50.6 | 44.9 | 46.7 | 28.2 | 28.3 | 28.4 | 25.9 | 23.4 | 25.3 | 27.2 | 24.0 | 20.8 | 20.8 |
| Manufacture of petroleum and coal products | kt-BOD | 25.4 | 20.8 | 24.6 | 26.9 | 12.3 | 11.3 | 10.2 | 9.3 | 8.5 | 9.8 | 11.2 | 10.2 | 9.1 | 9.1 |
| Manufacture of plastic products | kt-BOD | 0.6 | 0.6 | 0.6 | 0.8 | 0.7 | 0.7 | 0.7 | 0.6 | 0.5 | 0.6 | 0.6 | 0.4 | 0.1 | 0.1 |
| Manufacture of rubber products | kt-BOD | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.04 | 0.1 | 0.1 | 0.1 | 0.04 | 0.04 |
| Manufacture of leather tanning, leather products and fur skins | kt-BOD | 0.3 | 0.3 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Manufacture of iron and steel | kt-BOD | 39.7 | 37.3 | 40.3 | 36.5 | 25.7 | 26.1 | 26.4 | 22.8 | 19.1 | 22.5 | 26.0 | 22.2 | 18.5 | 18.5 |
| TN load | | | | | | | | | | | | | | | |
| Manufacture of food | kt-N | 5.0 | 5.3 | 5.6 | 5.3 | 3.1 | 3.2 | 3.3 | 3.3 | 3.3 | 2.9 | 2.6 | 2.5 | 2.4 | 2.4 |
| Manufacture of beverages, tobacco and feed | kt-N | 0.6 | 0.6 | 0.6 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 |
| Manufacture of textile products | kt-N | 0.8 | 0.7 | 0.5 | 0.4 | 1.7 | 1.7 | 1.7 | 1.8 | 1.8 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 |
| Manufacture of pulp, paper and paper products | kt-N | 0.7 | 0.7 | 0.7 | 0.5 | 0.6 | 0.6 | 0.6 | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Manufacture of chemical and allied product | kt-N | 31.4 | 32.2 | 28.5 | 28.2 | 22.1 | 21.3 | 20.6 | 18.3 | 16.1 | 15.8 | 15.5 | 15.9 | 16.2 | 16.2 |
| Manufacture of petroleum and coal products | kt-N | 19.6 | 16.0 | 18.9 | 8.8 | 7.6 | 7.6 | 7.6 | 7.4 | 7.2 | 7.0 | 6.7 | 6.5 | 6.3 | 6.3 |
| Manufacture of plastic products | kt-N | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.2 | 0.1 | 0.1 |
| Manufacture of rubber products | kt-N | 0.3 | 0.3 | 0.2 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Manufacture of leather tanning, leather products and fur skins | kt-N | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Manufacture of iron and steel | kt-N | 33.3 | 31.2 | 33.7 | 41.8 | 17.6 | 17.6 | 17.6 | 16.3 | 14.9 | 14.6 | 14.2 | 14.7 | 15.2 | 15.2 |

- ***Treated wastewater***

Activity data are defined as a sum up of TN loadings from industrial plants/facilities which discharge treated wastewater into public waters. The TN loadings in wastewater from each plant/facility are calculated by multiplying amount of wastewater and TN concentration for each plant/facility, which data are obtained from the *Comprehensive Survey on Water Pollutant Discharge* (MOE).

$$A = \sum \left(V_i \times TN_i\right)$$

$A$ : Activity data of treated wastewater (TN loadings) [kg-N/L]

$V_i$ : Amount of treated industrial wastewater discharged into public water from industrial plant/facility i [$m^3$]

$TN_i$ : TN concentration in treated industrial wastewater discharged from industrial plant/facility *i* [g-BOD/L], [g-N/L]

Table 7-101 TN loadings in treated industrial wastewater discharged into public waters (Activity data)

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Manufacture of food | kt-N | 5.8 | 6.2 | 6.5 | 7.0 | 3.9 | 4.0 | 4.2 | 6.0 | 7.9 | 6.6 | 5.3 | 5.3 | 5.4 | 5.4 |
| Manufacture of beverages, tobacco and feed | kt-N | 1.1 | 1.1 | 1.1 | 0.7 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.4 | 0.4 | 0.7 | 1.1 | 1.1 |
| Manufacture of textile products | kt-N | 2.5 | 2.1 | 1.6 | 2.1 | 1.7 | 1.7 | 1.7 | 1.6 | 1.5 | 1.3 | 1.1 | 1.2 | 1.4 | 1.4 |
| Manufacture of pulp, paper and paper products | kt-N | 8.4 | 8.0 | 8.0 | 8.0 | 5.4 | 5.4 | 5.4 | 4.6 | 3.8 | 4.1 | 4.4 | 5.6 | 6.8 | 6.8 |
| Manufacture of chemical and allied product | kt-N | 17.0 | 17.4 | 15.5 | 14.2 | 16.5 | 15.9 | 15.4 | 14.6 | 13.7 | 13.2 | 12.7 | 11.2 | 9.7 | 9.7 |
| Manufacture of petroleum and coal products | kt-N | 2.2 | 1.8 | 2.1 | 1.1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Manufacture of plastic products | kt-N | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Manufacture of rubber products | kt-N | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Manufacture of leather tanning, leather products and fur skins | kt-N | 0.28 | 0.23 | 0.18 | 0.09 | 0.04 | 0.04 | 0.04 | 0.03 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| Manufacture of iron and steel | kt-N | 5.3 | 5.0 | 5.4 | 4.1 | 3.1 | 3.1 | 3.1 | 2.6 | 2.1 | 2.4 | 2.7 | 2.8 | 2.9 | 2.9 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

As for the uncertainties in emission factors for $CH_4$ and $N_2O$ in this category, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-102.

Table 7-102 Uncertainty assessment for natural decomposition of industrial wastewater on the category "Industrial wastewater (5.D.2.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Natural decomposition | $CH_4$ | -58% | +58% | -30% | +30% | -66% | +66% | Since the *2006 IPCC Guidelines* provide the emission factors as default value for this category, the uncertainty is assessed in accordance with the default method in the guidelines. | The uncertainty in industrial waste statistics based on expert judgment is used. | Combined by using the formula for propagation of errors |
| | $N_2O$ | -58% | +58% | -30% | +30% | -66% | +66% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in $CH_4$ is substituted based on expert judgment. | | |

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

No recalculations are conducted.

### *f) Category-specific Planned Improvements*

No improvements are planned.

### 7.5.2.3. Landfill Leachate Treatment (5.D.2.-)

#### *a) Category Description*

$CH_4$ and $N_2O$ emissions from landfill leachate treatment in MSW and IW landfill sites are estimated and allocated to "Landfill leachate treatment (5.D.2.-)."

#### *b) Methodological Issues*

- ***Estimation Method***

Potential BOD load [kg-BOD/year] and TN load [kg-N/year] to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites are applied for its activity data, and the methodology for the natural decomposition of domestic wastewater given in *the 2006 IPCC Guidelines* is applied to estimate $CH_4$ and $N_2O$ emissions from this source as described below:

$$E = EF \times L_i$$

*E* : $CH_4$ and $N_2O$ emissions
*EF* : $CH_4$ and $N_2O$ emission factor
$L_i$ : Potential BOD load [kg-BOD/year] and TN load [kg-N/year] to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites

- ***Emission Factors***

Emission factors for $CH_4$ and $N_2O$ are determined in accordance with the methodology for the natural decomposition of domestic wastewater given in the *2006 IPCC Guidelines* as described below.

*$CH_4$ Emission factor*

According to the *2006 IPCC Guidelines*, the emission factor for $CH_4$ is established by multiplying the maximum $CH_4$ generation potential ($B_0$) by a $CH_4$ conversion factor (MCF). The maximum $CH_4$ generation potential ($B_0$) is determined to be 0.6 kg-$CH_4$/kg-BOD which is a default value for "Domestic waste water" given in the *2006 IPCC Guidelines*, and MCF is determined to be 0.8 which is also a default value for "Anaerobic reactor" of "Treated systems" given in the *2006 IPCC Guidelines*.

$$\begin{aligned} EF_{CH4} &= B_0 \times MCF \\ &= 0.6 \quad [\text{kg-CH}_4/\text{kg-BOD}] \quad \times 0.8 \\ &= 0.48 \quad [\text{kg-CH}_4/\text{kg-BOD}] \end{aligned}$$

$B_0$ : Maximum $CH_4$ generation potential [kg-$CH_4$/kg-BOD], (IPCC default value:0.6)
*MCF* : $CH_4$ conversion factor (IPCC default value: 0.8)

*$N_2O$ Emission Factor*

The emission factor for $N_2O$ is determined from a default value of 0.005 (kg $N_2O$-N/kg N) given in the *2006 IPCC Guidelines* after unit conversion.

$$\begin{aligned} EF_{N2O} &= 0.005 \ [\text{kg-N}_2\text{O-N/kg-N}] \quad \times 44/28 \\ &= 0.0079 \ [\text{kg-N}_2\text{O /kg-N}] \end{aligned}$$

- ***Activity Data***

Based on MOE (2010), the activity data for $CH_4$ and $N_2O$ emission estimates are determined by establishing the ratio of organic and nitrogen contents to be remained in leachate for the amount of

organic waste disposed of in MSW and IW landfill sites to obtain potential BOD load [kg-BOD/year] and TN load [kg-N/year].

*$CH_4$ activity data*

$$L_{BODi} = F_{BOD} \times W \times T_i$$

$L_{BODi}$ : Potential BOD load to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites [kg-BOD/year]
$F_{BOD}$ : Ratio of organic contents for the amount of organic waste landfilled [kg-BOD/t] determined to be 0.188 [kg-BOD/t] based on MOE (2010)
$W$ : Amount of organic waste landfilled with or without intermediate treatments including incineration ash [t/year] obtained by the Cyclical Use of Waste Report
$T_i$ : Ratio of leachate to be biologically treated in landfill site [%] determined to be 87.6% based on MOE (2010)

*$N_2O$ activity data*

$$L_{TNi} = F_{TN} \times W \times T_i$$

$L_{TNi}$ : Potential TN load to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites [kg-N/year]
$F_{TN}$ : Ratio of nitrogen contents for the amount of organic waste landfilled [kg-N/t] determined to be 0.254 [kg-N/t] based on MOE (2010)
$W$ : Amount of organic waste landfilled with or without intermediate treatments including incineration ash [t/year] obtained by the Cyclical Use of Waste Report
$T_i$ : Ratio of leachate to be biologically treated in landfill site [%] determined to be 87.6% based on MOE (2010)

Table 7-103 BOD load [kt-BOD] and TN load [kt-N] of landfill leachate

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BOD load | kt-BOD | 2.6 | 2.5 | 2.2 | 1.6 | 0.8 | 0.8 | 0.7 | 0.8 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 |
| TN load | kt-N | 3.5 | 3.3 | 3.0 | 2.2 | 1.1 | 1.1 | 0.9 | 1.0 | 0.8 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainties***

As for the uncertainties in emission factors for $CH_4$ and $N_2O$ in landfill leachate treatment, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-104.

Table 7-104 Uncertainty assessment for landfill leachate treatment on the category "Industrial wastewater (5.D.2.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Landfill leachate treatment | $CH_4$ | -39% | +39% | -100% | +100% | -107% | +107% | The uncertainty is quoted from MOE (2010), a source of emission factors. | Due to the lack of information for the uncertainty of the activity data, the uncertainty is assessed by expert judgment. | Combined by using the formula for propagation of errors |
| | $N_2O$ | -39% | +39% | -100% | +100% | -107% | +107% | Due to the lack of information for the uncertainty of the emission factor, the uncertainty in the EF of CH4 in this category is substituted based on expert judgment. | | |

- ***Time-series Consistency***

As described in detail in the preceding sections, emissions are calculated in a consistent manner.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

By updating the statistical data, emissions were recalculated. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

No improvements are planned.

## 7.6. Other (5.E.)

In this category, $CO_2$ emissions as a result of the decomposition of petroleum-derived surfactants are calculated. Estimated greenhouse gas emissions from category 'Other' are shown in Table 7-106.

Table 7-105 Categories whose emissions are estimated for Other (5.E.)

| Category | Waste type | Treatment type | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|
| 5.E.1. (7.6.1) | Petroleum-Derived Surfactants | Decomposition at wastewater treatment facilities and/or the environment | ○ | NA | NA |

In FY2018, emissions from this source category are 673 kt-$CO_2$ eq. and accounted for 0.05% of the national total emissions (excluding LULUCF). The emissions from this source category had decreased by 4.2% compared to those in FY1990. This emission decrease is primarily due to the decrease in $CO_2$ emissions from the use of alkylbenzenes by introduction of the Pollutant Release and Transfer Register (PRTR).

Table 7-106 GHG emissions from category 'Other' (5.E.)

| Gas | Category | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 5.E. Other (Decomposition of petroleum-derived surfactants) | kt-$CO_2$ | 703 | 668 | 656 | 507 | 514 | 527 | 524 | 528 | 605 | 617 | 625 | 619 | 637 | 673 |

### 7.6.1. Decomposition of Petroleum-Derived Surfactants (5.E.-)

***a) Category Description***

Surfactants are used for various cleaning activities at home and factories in Japan. Petroleum-derived surfactants discharged into wastewater treatment facilities and into the environment, and emit $CO_2$. As this emission source did not correspond to any of the existing waste categories (5.A. to 5.D.), it is included in the "Other (5.E.)" section. Because "$CH_4$ and $N_2O$ emissions from wastewater treatment" and "$CO_2$ emissions from the decomposition of petroleum-derived surfactants" concern different types of gas, they are unrelated to each other and pose no duplicate inventory issues.

***b) Methodological Issues***

- ***Estimation Method***

As neither the *2006 IPCC Guidelines* specified a method for determining $CO_2$ emissions, a method specifically established in Japan is applied to the calculation. Because carbon contained in surfactants

that emitted into wastewater treatment facilities and into the environment is eventually oxidized to $CO_2$ and emitted into the atmosphere as a result of surfactants decomposition, $CO_2$ emissions are estimated based on the amount of carbon contained in surfactants that emitted into wastewater treatment facilities and into the environment.

Based on the facts stated above, the $CO_2$ emissions are calculated by multiplying the volume of the petroleum-derived surfactant for each type of raw material by the carbon content of each of the materials. The calculation covered synthetic alcohols, alkylbenzenes, alkylphenols, and ethylene oxide. Some of the carbon contained in surfactants discharged into wastewater treatment facilities are adsorbed and assimilated by sludge. However, this portion of carbon is not decomposed biologically. It is released into the atmosphere as $CO_2$ through incineration and landfilling of sludge. Therefore, the emission is included in $CO_2$ emission estimates.

- ***Emission Factor***

Emission factor is determined for each type of material by calculating the amount of $CO_2$, expressed in kg that is emitted from the decomposition of 1 t of a surfactant using the average carbon content in the molecules.

$EF_i = C_i \times 1{,}000 \times 44/12$

$EF_i$ : Emission factor for petroleum-derived raw material *i* used in a surfactant
$C_i$ : Average carbon content of petroleum-derived raw material *i* used in a surfactant

Table 7-107 Average carbon content of surfactants, by petroleum-derived raw material

| Raw material | Carbon number | Molecular weight | Carbon content | Basis for determination |
|---|---|---|---|---|
| Synthetic alcohol | 12 | 186 | 77.4% | C12-alcohol as the main constituent. |
| Alkylbenzene | 18 | 250 | 86.4% | C12-alkylbenzene as the main constituent. |
| Alkylphenol | 15 | 210 | 85.7% | C9-alkylphenol as the main constituent. |
| Ethylene oxide | 2 | 44 | 54.5% | Based on ethylene oxide molecules ($C_2H_4O$) |

- ***Activity Data***

Activity data is the amount of raw materials consumed for petroleum-derived surfactants. As some of the surfactants produced in Japan are exported, the activity data are determined by multiplying the volume of raw materials used in the surfactants obtained from the statistical data for surfactant use by an import/export adjustment factor.

- ***Volume of Surfactants Used***

The volumes of the use of surfactant by material are obtained from the consumption of raw materials for surfactants indicated in the *Current Production Statistics - Chemical Industry*. As there is no compilation of usage since FY2002, the volume of use is estimated using the simple averages (k value) of ratio of consumption and production in the period from FY1990 to FY2001.

- ***Export/import Correction Factor***

Correction factor is calculated from the export/import statistics in *International Trade Statistics* by the Ministry of Finance (MOF) for categories of anionic surfactants, cationic surfactants, non-ionic surfactants, and other organic surfactants and the volume of surfactants used. As some of the materials for surfactants are used in several types of surfactants, an average of the export/import correction factor

is weighted by surfactant production volume as necessary to calculate the correction factor for each classification of surfactant.

$$F_{corr.} = (P + I - E)/P$$

$F_{corr.}$ : Export/Import correction factor
$P$ : Surfactants production [t]
$I$ : Surfactants imported [t]
$E$ : Surfactants exported [t]

Table 7-108 Activity data associated with decomposition of petroleum-based surfactants

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Synthetic alcohol | t | 29,239 | 16,253 | 28,285 | 31,609 | 32,872 | 33,750 | 34,870 | 36,193 | 43,324 | 42,947 | 44,299 | 45,551 | 45,601 | 47,839 |
| Alkyl benzene | t | 105,432 | 102,794 | 80,832 | 47,349 | 50,206 | 50,519 | 46,369 | 44,502 | 44,980 | 47,494 | 44,044 | 39,485 | 42,769 | 44,565 |
| Alkyl phenol | t | 10,141 | 8,798 | 7,454 | 3,448 | 2,044 | 2,054 | 2,263 | 2,910 | 4,318 | 4,885 | 4,873 | 4,638 | 5,661 | 6,208 |
| Ethylene oxide | t | 124,984 | 132,175 | 146,509 | 127,150 | 126,301 | 131,148 | 134,532 | 136,679 | 161,969 | 163,777 | 171,380 | 174,243 | 176,247 | 187,717 |

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

The uncertainty in emission factor for $CO_2$ is evaluated by using molecular weight which is used for calculation of emission factors, based on expert judgment. As for activity data, the same assessment as municipal waste statistics is applied based on expert judgment since information on the uncertainty is not available.

Table 7-109 Uncertainty assessment for decomposition of petroleum-derived surfactants on the category "Other (5.E.-)"

| Item | GHGs | Emission /removal factor uncertainty | | Activity data uncertainty | | Emission /removal uncertainty | | The method of evaluating uncertainty in emission factor | The method of evaluating uncertainty in activity data | The method of evaluating uncertainty in emissions/ removals |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (-) | (+) | (-) | (+) | (-) | (+) | | | |
| Decomposition of petroleum-derived surfactants | $CO_2$ | -1% | +1% | -10% | +10% | -10% | +10% | The uncertainty is assessed by using molecular weight data based on expert judgment. | Due to the lack of information for the uncertainty of the activity data, the uncertainty in municipal waste statistics is substituted by expert judgment. | Combined by using the formula for propagation of errors |

- ***Time-series Consistency***

Consistent methodology is used in the estimation. However, data on the amount of raw materials consumed for surfactants have become not available since FY2002 and activity data are estimated from the production amount of the surfactants.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By revisioning the statistical data, emissions were recalculated. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

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# Chapter 8. Other

## 8.1. Overview of Sector

*UNFCCC Reporting Guidelines (Decision 24/CP.19)* paragraph 29 indicates that Annex I Parties should report and explicitly describe the details of emissions from each country-specific source of gases which are not part of the *IPCC Guidelines*. According to this requirement, emissions from the Other sector (CRF sector 6) are indicated below.

## 8.2. $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, and $NF_3$

Among $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$ and $NF_3$, no emissions or removals are reported in the Other sector.

## 8.3. $NO_x$, CO, NMVOC, and $SO_x$

Among precursors ($NO_x$, CO, NMVOC) and $SO_x$, CO emissions from smoking are reported in the Other sector (see Annex 3).

# Chapter 9. Indirect $CO_2$ and Nitrous Oxide Emissions

## 9.1. Overview of Sector

### *a) Category Description*

Since Parties may now choose to report indirect $CO_2$, in accordance with paragraph 29 of the UNFCCC Inventory Reporting Guidelines, and since the estimation method reflecting Japanese actual status has been established, Japan elects to report indirect $CO_2$ emissions from the atmospheric oxidation of $CH_4$, CO, and NMVOCs, and not to report indirect $N_2O$ emissions arising from sources other than those in the agriculture and LULUCF sectors.

Indirect $CO_2$ emissions originating from the use and/or evaporation of NMVOCs and $CH_4$ from the sub-categories indicated in Table 9-1 are estimated. Other than evaporation of $CH_4$ and NMVOCs, $CH_4$, CO, and NMVOCs originating from fuel combustion, evaporative fuel emissions from vehicles[1], and $CH_4$, CO, and NMVOCs from the incineration of fossil-fuel derived waste are oxidized to $CO_2$ in the atmosphere; these indirect $CO_2$ emissions are not reported, because these emissions are included in $CO_2$ emissions from fuel combustion (1.A), and $CO_2$ emissions from incineration and open burning of Waste (5.C) [2], respectively. According to the *2006 IPCC Guidelines*, indirect $CO_2$ emissions originating from biogenic $CH_4$, CO, and NMVOC emissions from the agriculture sector, LULUCF sector, waste sector, and the Other sector were not reported from the viewpoint of carbon-neutrality.

Table 9-1 Source sub-categories of indirect $CO_2$

| Sub-category | Originated from $CH_4$ | Originated from CO | Originated from NMVOCs |
|---|---|---|---|
| 1.B Fugitive emissions from Fuels | ○ | NE, NO | ○ |
| 2. Industrial process and product use | ○ | NE | ○ |

### *b) Methodological Issues*

- ***Estimation Method***

$CO_2$ emissions occurring from the oxidation of evaporative NMVOCs and $CH_4$ in the atmosphere are estimated with the following conversion formulae which are mentioned in the *2006 IPCC Guidelines*;

$$E_{CO2} = E_{CH4} \times \frac{44}{16}$$

$$E_{CO2} = E_{NMVOC} \times C \times \frac{44}{12}$$

$E_{CO2}$ : Indirect $CO_2$ emissions [kt]

$E_{CH4}$ : $CH_4$ emissions [kt]

$E_{NMVOC}$: NMVOC emissions [kt]

$C$ : Average carbon content of NMVOCs

- ***Parameters***

The average carbon content is calculated by weighting it by the composition rate of each NMVOC

[1] Emissions are reported in 3. Transport in 1.A. Fuel Combustion

[2] Japan assumes 100% oxidation during the combustion of fuel in 1.A Fuel Combustion and in 5 Waste

substance emitted from each source. The carbon contents of each substance are obtained from molecular formulae, and the type of substance and composition rate of NMVOCs were estimated based on the national emission inventory for volatile organic compounds (VOC) by the Ministry of Environment and other information. The average carbon content is calculated for each emission source until FY2014. The average carbon content across all emission sources in FY2014 of 0.73 is applied from FY2015 onward for all emission sources, because the yearly fluctuation of the carbon content is small. But for emission sources such as removers, that started to be reported from the 2018 submission, 0.73 is applied for years FY1990 and onward.

- ***Activity Data***

Refer to Chapter 3 for information on $CH_4$ emissions from fugitive emissions from fuels (1.B.). Refer to Chapter 4 for information on $CH_4$ emissions from the chemical industry (2.B) and metal industry (2.C). Refer to Annex 3 for information on carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs).

### *c) Uncertainties and Time-series Consistency*

- ***Uncertainty***

Refer to Annex 2.

- ***Time-series Consistency***

For average carbon content of NMVOCs, the composition for each substance is calculated using statistics which are consistent throughout the time-series. Refer to the relevant chapter for activity data.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

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# Chapter 10. Recalculation and Improvements

## 10.1. Explanations and Justifications for Recalculations

This section explains improvements on estimation of emissions and removals in the inventory submitted in 2020.

In accordance with the *UNFCCC Reporting Guidelines* and the *2006 IPCC Guidelines*, Annex I Parties should recalculate their inventories for the base year and all subsequent years of the times series in the cases of 1) application of new estimation methods, 2) addition of new categories for emissions and removals, and 3) data refinement. Major changes from the previous inventory are indicated below.

### 10.1.1. General Issues

As Japan's own specific circumstance, it can generally be said that activity data for the latest year available at the time when the inventory is compiled are often revised in the year following the submission year because of such as the publication of data in the fiscal year basis. In the national inventory submitted this year, activity data in many sources for FY2017 have been changed and as a result, the emissions from those sources for the inventory year have been recalculated.

### 10.1.2. Recalculations in Each Sector

The information of recalculation for sectors (energy; industrial processes and product use; agriculture; land use, land-use change and forestry; and waste), occurring due to Japan's own specific circumstance and needs, is described separately under sections named as "Category-specific Recalculations" in Chapters 3 to 7.

## 10.2. Implications for Emission Levels

The following shows the changes made to the overall emission estimates due to the recalculations indicated in "Section 10.1. Explanations and Justifications for Recalculations".

### 10.2.1. GHG Inventory

Compared to the values reported in the previous year's inventory, total emissions (excluding the LULUCF sector, and including indirect $CO_2$) in the base year (FY 1990) under the UNFCCC increased by 0.004%, and the total emissions in year FY 2017 decreased by 0.03% (Table 10-1).

Comparisons with the previous year's inventory for each sector, by category and by gas are as shown in Table 10-2 to Table 10-6. See each category for details on the reasons of recalculations.

# Table 10-1 Comparison of emissions and removals in the inventories submitted in 2019 and 2020

[Mt-$CO_2$ eq.]

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | JNGI 2019 | 1,095.7 | 1,099.2 | 1,105.9 | 1,095.8 | 1,151.0 | 1,162.4 | 1,169.9 | 1,160.7 | 1,119.6 | 1,155.9 | 1,176.8 | 1,161.6 | 1,189.4 | 1,187.4 | 1,186.2 | 1,198.7 | 1,181.0 | 1,221.7 | 1,161.2 | 1,095.7 | 1,143.6 | 1,194.4 | 1,232.8 | 1,248.7 | 1,200.1 | 1,164.7 | 1,151.4 | 1,130.4 |
| with LULUCF | JNGI 2020 | 1,095.9 | 1,099.5 | 1,106.1 | 1,095.9 | 1,151.1 | 1,162.5 | 1,169.8 | 1,160.7 | 1,119.6 | 1,156.0 | 1,176.8 | 1,161.7 | 1,189.4 | 1,187.4 | 1,186.2 | 1,198.6 | 1,180.8 | 1,221.1 | 1,160.7 | 1,095.5 | 1,143.4 | 1,194.2 | 1,232.4 | 1,248.4 | 1,198.4 | 1,163.1 | 1,148.6 | 1,128.8 |
| (excl. Indirect $CO_2$) | *difference* | *0.01%* | *0.02%* | *0.02%* | *0.01%* | *0.01%* | *0.01%* | *0.00%* | *0.00%* | *0.00%* | *0.01%* | *0.00%* | *0.00%* | *0.01%* | *0.00%* | *-0.01%* | *-0.01%* | *-0.02%* | *-0.05%* | *-0.05%* | *-0.02%* | *-0.02%* | *-0.01%* | *-0.03%* | *-0.02%* | *-0.14%* | *-0.13%* | *-0.24%* | *-0.14%* |
| $CO_2$ | JNGI 2019 | 1,158.5 | 1,170.0 | 1,179.8 | 1,172.7 | 1,227.6 | 1,240.0 | 1,252.1 | 1,245.3 | 1,205.6 | 1,242.2 | 1,265.0 | 1,250.3 | 1,279.6 | 1,287.8 | 1,283.0 | 1,290.3 | 1,267.2 | 1,302.9 | 1,232.2 | 1,163.0 | 1,214.4 | 1,264.5 | 1,305.9 | 1,315.1 | 1,264.9 | 1,224.5 | 1,206.2 | 1,188.1 |
| without LULUCF | JNGI 2020 | 1,158.4 | 1,170.1 | 1,179.7 | 1,172.6 | 1,227.6 | 1,239.9 | 1,251.9 | 1,245.1 | 1,205.4 | 1,242.0 | 1,264.8 | 1,250.2 | 1,279.5 | 1,287.6 | 1,282.9 | 1,290.1 | 1,266.8 | 1,302.5 | 1,231.9 | 1,162.6 | 1,214.1 | 1,264.2 | 1,305.4 | 1,314.7 | 1,263.0 | 1,222.8 | 1,203.2 | 1,187.7 |
| (excl. Indirect $CO_2$) | *difference* | *-0.01%* | *0.00%* | *0.00%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.02%* | *-0.02%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.02%* | *-0.03%* | *-0.03%* | *-0.03%* | *-0.03%* | *-0.03%* | *-0.03%* | *-0.03%* | *-0.03%* | *-0.03%* | *-0.14%* | *-0.14%* | *-0.25%* | *-0.04%* |
| $CH_4$ | JNGI 2019 | 44.4 | 43.3 | 44.1 | 40.1 | 43.4 | 41.9 | 40.8 | 40.0 | 38.2 | 38.0 | 38.0 | 37.2 | 36.4 | 34.9 | 36.0 | 35.7 | 35.1 | 35.3 | 35.0 | 34.1 | 34.6 | 33.6 | 32.7 | 32.4 | 31.7 | 30.9 | 30.6 | 30.2 |
| with LULUCF | JNGI 2020 | 44.5 | 43.4 | 44.2 | 40.1 | 43.5 | 42.0 | 40.8 | 40.1 | 38.2 | 38.1 | 38.1 | 37.2 | 36.5 | 35.1 | 36.1 | 35.9 | 35.3 | 35.6 | 35.3 | 34.4 | 34.9 | 33.9 | 33.0 | 32.6 | 32.0 | 31.1 | 30.8 | 30.3 |
| | *difference* | *0.19%* | *0.21%* | *0.20%* | *0.21%* | *0.18%* | *0.18%* | *0.16%* | *0.14%* | *0.14%* | *0.12%* | *0.11%* | *0.20%* | *0.29%* | *0.38%* | *0.46%* | *0.53%* | *0.67%* | *0.77%* | *0.86%* | *0.88%* | *0.85%* | *0.84%* | *0.82%* | *0.78%* | *0.75%* | *0.78%* | *0.78%* | *0.59%* |
| $CH_4$ | JNGI 2019 | 44.3 | 43.2 | 44.0 | 40.0 | 43.3 | 41.9 | 40.7 | 39.9 | 38.1 | 38.0 | 38.0 | 37.1 | 36.3 | 34.9 | 35.9 | 35.7 | 35.0 | 35.3 | 34.9 | 34.0 | 34.5 | 33.5 | 32.6 | 32.3 | 31.7 | 30.8 | 30.5 | 30.1 |
| without LULUCF | JNGI 2020 | 44.4 | 43.3 | 44.1 | 40.0 | 43.4 | 41.9 | 40.7 | 40.0 | 38.1 | 38.0 | 38.0 | 37.1 | 36.4 | 35.0 | 36.0 | 35.8 | 35.3 | 35.5 | 35.2 | 34.3 | 34.8 | 33.8 | 32.9 | 32.5 | 31.9 | 31.1 | 30.7 | 30.2 |
| | *difference* | *0.16%* | *0.17%* | *0.17%* | *0.18%* | *0.15%* | *0.15%* | *0.13%* | *0.11%* | *0.10%* | *0.09%* | *0.08%* | *0.17%* | *0.26%* | *0.35%* | *0.43%* | *0.50%* | *0.64%* | *0.74%* | *0.84%* | *0.86%* | *0.83%* | *0.82%* | *0.80%* | *0.76%* | *0.73%* | *0.76%* | *0.76%* | *0.57%* |
| $N_2O$ | JNGI 2019 | 32.0 | 31.7 | 31.9 | 31.8 | 33.0 | 33.4 | 34.5 | 35.3 | 33.7 | 27.6 | 30.1 | 26.5 | 26.0 | 25.8 | 25.7 | 25.2 | 25.1 | 24.5 | 23.7 | 23.1 | 22.5 | 22.0 | 21.7 | 21.8 | 21.4 | 21.0 | 20.4 | 20.6 |
| with LULUCF | JNGI 2020 | 32.1 | 31.8 | 32.0 | 31.8 | 33.1 | 33.4 | 34.5 | 35.3 | 33.7 | 27.6 | 30.1 | 26.5 | 25.9 | 25.8 | 25.6 | 25.2 | 25.0 | 24.4 | 23.6 | 22.9 | 22.4 | 22.0 | 21.7 | 21.7 | 21.3 | 20.9 | 20.4 | 20.6 |
| | *difference* | *0.28%* | *0.22%* | *0.18%* | *0.15%* | *0.11%* | *0.06%* | *0.03%* | *0.06%* | *0.07%* | *0.10%* | *0.10%* | *-0.01%* | *-0.08%* | *-0.16%* | *-0.21%* | *-0.34%* | *-0.40%* | *-0.47%* | *-0.57%* | *-0.55%* | *-0.38%* | *-0.34%* | *-0.28%* | *-0.42%* | *-0.47%* | *-0.32%* | *-0.32%* | *-0.21%* |
| $N_2O$ | JNGI 2019 | 31.8 | 31.5 | 31.7 | 31.6 | 32.8 | 33.2 | 34.3 | 35.1 | 33.5 | 27.4 | 29.9 | 26.3 | 25.8 | 25.6 | 25.5 | 25.0 | 24.9 | 24.3 | 23.5 | 22.9 | 22.3 | 21.9 | 21.5 | 21.6 | 21.2 | 20.8 | 20.3 | 20.5 |
| without LULUCF | JNGI 2020 | 31.9 | 31.6 | 31.8 | 31.6 | 32.9 | 33.2 | 34.3 | 35.1 | 33.5 | 27.4 | 29.9 | 26.3 | 25.7 | 25.6 | 25.4 | 25.0 | 24.8 | 24.2 | 23.4 | 22.7 | 22.2 | 21.8 | 21.5 | 21.5 | 21.1 | 20.7 | 20.2 | 20.4 |
| | *difference* | *0.28%* | *0.21%* | *0.17%* | *0.15%* | *0.11%* | *0.05%* | *0.03%* | *0.06%* | *0.07%* | *0.09%* | *0.10%* | *-0.01%* | *-0.09%* | *-0.17%* | *-0.21%* | *-0.35%* | *-0.41%* | *-0.48%* | *-0.58%* | *-0.56%* | *-0.39%* | *-0.35%* | *-0.29%* | *-0.43%* | *-0.48%* | *-0.33%* | *-0.33%* | *-0.21%* |
| HFCs | JNGI 2019 | 15.9 | 17.3 | 17.8 | 18.1 | 21.1 | 25.2 | 24.6 | 24.4 | 23.7 | 24.4 | 22.9 | 19.5 | 16.2 | 16.2 | 12.4 | 12.8 | 14.6 | 16.7 | 19.3 | 20.9 | 23.3 | 26.1 | 29.4 | 32.1 | 35.8 | 39.3 | 42.6 | 44.9 |
| | JNGI 2020 | 15.9 | 17.3 | 17.8 | 18.1 | 21.1 | 25.2 | 24.6 | 24.4 | 23.7 | 24.4 | 22.9 | 19.5 | 16.2 | 16.2 | 12.4 | 12.8 | 14.6 | 16.7 | 19.3 | 20.9 | 23.3 | 26.1 | 29.4 | 32.1 | 35.8 | 39.3 | 42.6 | 44.9 |
| | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.01%* | *0.01%* | *0.01%* |
| PFCs | JNGI 2019 | 6.5 | 7.5 | 7.6 | 10.9 | 13.4 | 17.6 | 18.3 | 20.0 | 16.6 | 13.1 | 11.9 | 9.9 | 9.2 | 8.9 | 9.2 | 8.6 | 9.0 | 7.9 | 5.7 | 4.0 | 4.2 | 3.8 | 3.4 | 3.3 | 3.4 | 3.3 | 3.4 | 3.5 |
| | JNGI 2020 | 6.5 | 7.5 | 7.6 | 10.9 | 13.4 | 17.6 | 18.3 | 20.0 | 16.6 | 13.1 | 11.9 | 9.9 | 9.2 | 8.9 | 9.2 | 8.6 | 9.0 | 7.9 | 5.7 | 4.0 | 4.2 | 3.8 | 3.4 | 3.3 | 3.4 | 3.3 | 3.4 | 3.5 |
| | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| $SF_6$ | JNGI 2019 | 12.9 | 14.2 | 15.6 | 15.7 | 15.0 | 16.4 | 17.0 | 14.5 | 13.2 | 9.2 | 7.0 | 6.1 | 5.7 | 5.4 | 5.3 | 5.1 | 5.2 | 4.7 | 4.2 | 2.4 | 2.4 | 2.2 | 2.2 | 2.1 | 2.1 | 2.2 | 2.2 | 2.1 |
| | JNGI 2020 | 12.9 | 14.2 | 15.6 | 15.7 | 15.0 | 16.4 | 17.0 | 14.5 | 13.2 | 9.2 | 7.0 | 6.1 | 5.7 | 5.4 | 5.3 | 5.0 | 5.2 | 4.7 | 4.2 | 2.4 | 2.4 | 2.2 | 2.2 | 2.1 | 2.0 | 2.1 | 2.2 | 2.1 |
| | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.51%* | *-0.51%* | *-0.54%* | *-0.63%* | *-1.10%* | *-1.06%* | *-1.13%* | *-1.22%* | *-1.26%* | *-1.27%* | *-3.61%* | *-3.53%* | *-3.05%* |
| $NF_3$ | JNGI 2019 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 1.5 | 1.4 | 1.6 | 1.5 | 1.4 | 1.5 | 1.8 | 1.5 | 1.6 | 1.1 | 0.6 | 0.6 | 0.4 |
| | JNGI 2020 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 1.5 | 1.4 | 1.6 | 1.5 | 1.4 | 1.5 | 1.8 | 1.5 | 1.6 | 1.1 | 0.6 | 0.6 | 0.4 |
| | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| Indirect $CO_2$ | JNGI 2019 | 5.5 | 5.3 | 5.0 | 4.8 | 4.8 | 4.7 | 4.7 | 4.5 | 4.2 | 4.1 | 4.2 | 3.8 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 2.7 | 2.5 | 2.4 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 |
| | JNGI 2020 | 5.5 | 5.3 | 5.1 | 4.8 | 4.8 | 4.7 | 4.7 | 4.6 | 4.2 | 4.2 | 4.2 | 3.8 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 2.7 | 2.5 | 2.4 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 |
| | *difference* | *0.16%* | *0.16%* | *0.17%* | *0.18%* | *0.19%* | *0.20%* | *0.22%* | *0.24%* | *0.26%* | *0.28%* | *0.30%* | *0.30%* | *0.30%* | *0.30%* | *0.29%* | *0.26%* | *0.24%* | *0.17%* | *0.19%* | *0.25%* | *0.17%* | *0.14%* | *0.13%* | *0.13%* | *0.09%* | *0.00%* | *0.26%* | *-1.95%* |
| Total | JNGI 2019 | 1,270.0 | 1,283.8 | 1,296.5 | 1,289.1 | 1,353.4 | 1,374.5 | 1,387.1 | 1,379.4 | 1,330.9 | 1,354.5 | 1,374.8 | 1,349.4 | 1,373.2 | 1,379.2 | 1,371.8 | 1,379.0 | 1,357.4 | 1,393.4 | 1,321.4 | 1,248.6 | 1,302.7 | 1,353.8 | 1,396.6 | 1,408.1 | 1,360.1 | 1,321.5 | 1,305.8 | 1,289.6 |
| without LULUCF | JNGI 2020 | 1,270.0 | 1,284.0 | 1,296.7 | 1,289.1 | 1,353.4 | 1,374.5 | 1,387.0 | 1,379.3 | 1,330.8 | 1,354.4 | 1,374.8 | 1,349.3 | 1,373.2 | 1,379.1 | 1,371.7 | 1,378.8 | 1,357.2 | 1,393.2 | 1,321.2 | 1,248.4 | 1,302.5 | 1,353.6 | 1,396.3 | 1,407.8 | 1,358.3 | 1,319.8 | 1,302.8 | 1,289.2 |
| excl. Indirect $CO_2$ | *difference* | *0.00%* | *0.01%* | *0.01%* | *0.00%* | *0.00%* | *0.00%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *0.00%* | *0.00%* | *-0.01%* | *-0.01%* | *-0.02%* | *-0.02%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.02%* | *-0.02%* | *-0.13%* | *-0.13%* | *-0.22%* | *-0.03%* |
| Total | JNGI 2019 | 1,207.5 | 1,213.3 | 1,222.9 | 1,212.4 | 1,277.1 | 1,297.2 | 1,305.2 | 1,295.1 | 1,245.2 | 1,268.4 | 1,286.9 | 1,261.0 | 1,283.3 | 1,279.1 | 1,275.2 | 1,287.6 | 1,271.5 | 1,312.5 | 1,250.7 | 1,181.6 | 1,232.2 | 1,283.9 | 1,323.7 | 1,341.9 | 1,295.5 | 1,261.9 | 1,251.2 | 1,232.2 |
| with LULUCF | JNGI 2020 | 1,207.8 | 1,213.7 | 1,223.4 | 1,212.7 | 1,277.3 | 1,297.4 | 1,305.3 | 1,295.2 | 1,245.2 | 1,268.6 | 1,287.0 | 1,261.1 | 1,283.5 | 1,279.1 | 1,275.3 | 1,287.6 | 1,271.4 | 1,312.0 | 1,250.3 | 1,181.5 | 1,232.1 | 1,283.9 | 1,323.6 | 1,341.8 | 1,294.0 | 1,260.4 | 1,248.6 | 1,230.7 |
| excl. Indirect $CO_2$ | *difference* | *0.02%* | *0.03%* | *0.03%* | *0.02%* | *0.02%* | *0.02%* | *0.00%* | *0.00%* | *0.01%* | *0.02%* | *0.01%* | *0.01%* | *0.01%* | *0.00%* | *0.00%* | *0.00%* | *-0.01%* | *-0.03%* | *-0.03%* | *-0.01%* | *-0.01%* | *0.00%* | *-0.01%* | *-0.01%* | *-0.12%* | *-0.12%* | *-0.21%* | *-0.12%* |
| Total | JNGI 2019 | 1,275.5 | 1,289.1 | 1,301.6 | 1,293.9 | 1,358.2 | 1,379.2 | 1,391.8 | 1,384.0 | 1,335.0 | 1,358.6 | 1,379.1 | 1,353.2 | 1,376.7 | 1,382.6 | 1,375.1 | 1,382.1 | 1,360.5 | 1,396.4 | 1,324.1 | 1,251.1 | 1,305.1 | 1,356.1 | 1,398.8 | 1,410.3 | 1,362.2 | 1,323.6 | 1,307.9 | 1,291.7 |
| without LULUCF | JNGI 2020 | 1,275.5 | 1,289.3 | 1,301.7 | 1,293.9 | 1,358.2 | 1,379.2 | 1,391.7 | 1,383.9 | 1,334.9 | 1,358.5 | 1,379.0 | 1,353.1 | 1,376.7 | 1,382.5 | 1,375.0 | 1,382.0 | 1,360.3 | 1,396.2 | 1,323.9 | 1,250.9 | 1,305.0 | 1,355.9 | 1,398.6 | 1,410.1 | 1,360.5 | 1,322.0 | 1,305.0 | 1,291.3 |
| incl. Indirect $CO_2$ | *difference* | *0.004%* | *0.01%* | *0.01%* | *0.00%* | *0.00%* | *0.00%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.01%* | *-0.02%* | *-0.02%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.02%* | *-0.02%* | *-0.13%* | *-0.13%* | *-0.22%* | *-0.03%* |
| Total | JNGI 2019 | 1,213.0 | 1,218.6 | 1,228.0 | 1,217.3 | 1,281.9 | 1,301.9 | 1,309.9 | 1,299.7 | 1,249.3 | 1,272.6 | 1,291.2 | 1,264.7 | 1,286.8 | 1,282.4 | 1,278.5 | 1,290.8 | 1,274.6 | 1,315.4 | 1,253.4 | 1,184.1 | 1,234.6 | 1,286.2 | 1,326.0 | 1,344.1 | 1,297.7 | 1,264.0 | 1,253.3 | 1,234.3 |
| with LULUCF | JNGI 2020 | 1,213.3 | 1,219.0 | 1,228.4 | 1,217.5 | 1,282.1 | 1,302.1 | 1,310.0 | 1,299.8 | 1,249.4 | 1,272.8 | 1,291.2 | 1,264.9 | 1,287.0 | 1,282.5 | 1,278.6 | 1,290.8 | 1,274.5 | 1,315.0 | 1,253.0 | 1,184.0 | 1,234.5 | 1,286.3 | 1,325.8 | 1,344.0 | 1,296.2 | 1,262.6 | 1,250.7 | 1,232.8 |
| incl. Indirect $CO_2$ | *difference* | *0.02%* | *0.04%* | *0.03%* | *0.02%* | *0.02%* | *0.02%* | *0.00%* | *0.01%* | *0.01%* | *0.02%* | *0.01%* | *0.01%* | *0.01%* | *0.01%* | *0.00%* | *0.00%* | *-0.01%* | *-0.03%* | *-0.03%* | *-0.01%* | *-0.01%* | *0.00%* | *-0.01%* | *-0.01%* | *-0.12%* | *-0.12%* | *-0.21%* | *-0.12%* |

## Table 10-2 Comparison of emissions and removals in the inventories submitted in 2019 and 2020 (Energy sector)

1. Energy [Mt-$CO_2$ eq.]

| Category | Gas | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Fuel Combustion | $CO_2$ | JNGI 2019 | 368.5 | 369.4 | 374.3 | 357.0 | 391.5 | 378.9 | 381.2 | 377.5 | 365.0 | 386.9 | 395.5 | 386.6 | 413.4 | 432.5 | 430.2 | 449.7 | 440.7 | 490.9 | 471.7 | 441.4 | 473.8 | 534.8 | 581.5 | 582.0 | 552.8 | 526.9 | 522.1 | 507.1 |
| 1. Energy Industries | | JNGI 2020 | 368.5 | 369.4 | 374.3 | 357.0 | 391.5 | 378.9 | 381.2 | 377.5 | 365.0 | 386.9 | 395.5 | 386.6 | 413.4 | 432.5 | 430.2 | 449.7 | 440.7 | 490.9 | 471.7 | 441.4 | 473.8 | 534.8 | 581.5 | 583.4 | 552.9 | 527.3 | 522.7 | 508.8 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.24%* | *0.02%* | *0.08%* | *0.13%* | *0.33%* |
| | $CH_4$ | JNGI 2019 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | JNGI 2020 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.02%* | *0.04%* | *0.05%* | *0.11%* | *0.07%* | *0.06%* | *-0.03%* | *-0.02%* | *0.30%* | *-0.76%* |
| | $N_2O$ | JNGI 2019 | 0.9 | 0.9 | 0.9 | 0.9 | 1.0 | 1.4 | 1.4 | 1.4 | 1.5 | 1.6 | 1.6 | 1.8 | 1.8 | 1.9 | 1.9 | 2.1 | 2.1 | 2.2 | 2.1 | 2.1 | 2.1 | 2.3 | 2.3 | 2.4 | 2.3 | 2.3 | 2.2 | 2.3 |
| | | JNGI 2020 | 0.9 | 0.9 | 0.9 | 0.9 | 1.0 | 1.4 | 1.4 | 1.4 | 1.5 | 1.6 | 1.6 | 1.8 | 1.8 | 1.9 | 1.9 | 2.1 | 2.1 | 2.2 | 2.1 | 2.1 | 2.1 | 2.3 | 2.3 | 2.4 | 2.3 | 2.3 | 2.2 | 2.3 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.01%* | *0.02%* | *0.05%* | *0.06%* | *0.11%* | *0.08%* | *0.12%* | *0.03%* | *0.05%* | *0.25%* | *0.21%* |
| A. Fuel Combustion | $CO_2$ | JNGI 2019 | 349.7 | 346.2 | 341.1 | 342.0 | 350.8 | 357.6 | 360.5 | 356.8 | 332.2 | 336.6 | 346.6 | 340.6 | 346.3 | 344.2 | 343.7 | 334.2 | 331.6 | 329.7 | 300.8 | 283.8 | 300.4 | 299.3 | 299.0 | 306.6 | 299.2 | 290.4 | 275.9 | 272.7 |
| 2. Manufacturing Industries | | JNGI 2020 | 349.7 | 346.2 | 341.1 | 342.0 | 350.8 | 357.6 | 360.5 | 356.8 | 332.2 | 336.6 | 346.6 | 340.6 | 346.3 | 344.2 | 343.7 | 334.2 | 331.6 | 329.7 | 300.8 | 283.8 | 300.4 | 299.3 | 299.0 | 304.1 | 296.6 | 287.5 | 273.6 | 269.8 |
| and Construction | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.79%* | *-0.88%* | *-0.98%* | *-0.80%* | *-1.04%* |
| | $CH_4$ | JNGI 2019 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | | JNGI 2020 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.74%* | *-0.90%* | *-0.97%* | *-0.77%* | *-0.62%* |
| | $N_2O$ | JNGI 2019 | 1.3 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 1.8 | 1.8 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | 1.9 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 |
| | | JNGI 2020 | 1.3 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 1.8 | 1.8 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | 1.9 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.8 | 1.7 | 1.7 | 1.7 | 1.6 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.01%* | *0.00%* | *-0.30%* | *-0.34%* | *-0.37%* | *-0.31%* | *-0.47%* |
| A. Fuel Combustion | $CO_2$ | JNGI 2019 | 201.0 | 212.7 | 219.4 | 223.2 | 232.6 | 242.0 | 248.8 | 250.7 | 248.9 | 253.0 | 252.7 | 256.8 | 253.2 | 249.2 | 243.2 | 237.8 | 235.1 | 232.4 | 224.8 | 221.5 | 222.0 | 217.1 | 218.0 | 215.1 | 210.1 | 208.9 | 207.0 | 205.2 |
| 3. Transport | | JNGI 2020 | 201.0 | 212.7 | 219.4 | 223.2 | 232.6 | 242.0 | 248.8 | 250.7 | 248.9 | 253.0 | 252.7 | 256.8 | 253.2 | 249.2 | 243.2 | 237.8 | 235.1 | 232.4 | 224.8 | 221.5 | 222.0 | 217.1 | 218.0 | 215.1 | 210.1 | 208.9 | 206.9 | 205.4 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.08%* |
| | $CH_4$ | JNGI 2019 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | JNGI 2020 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.11%* | *-0.52%* | *-0.92%* | *-1.29%* | *-1.64%* | *-1.98%* | *-2.28%* | *-2.53%* | *-2.83%* | *-3.12%* | *-3.47%* | *-3.75%* | *-4.46%* |
| | $N_2O$ | JNGI 2019 | 3.7 | 3.9 | 4.0 | 3.9 | 4.0 | 4.1 | 4.2 | 4.2 | 4.1 | 4.1 | 4.0 | 3.8 | 3.6 | 3.3 | 3.0 | 2.8 | 2.6 | 2.5 | 2.3 | 2.2 | 2.0 | 1.9 | 1.9 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 |
| | | JNGI 2020 | 3.7 | 3.9 | 4.0 | 3.9 | 4.0 | 4.1 | 4.2 | 4.2 | 4.1 | 4.1 | 4.0 | 3.8 | 3.6 | 3.3 | 3.0 | 2.8 | 2.6 | 2.5 | 2.3 | 2.2 | 2.1 | 1.9 | 1.9 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.02%* | *0.08%* | *0.14%* | *0.19%* | *0.25%* | *0.31%* | *0.37%* | *0.42%* | *0.45%* | *0.44%* | *0.39%* | *0.34%* | *-0.14%* |
| A. Fuel Combustion | $CO_2$ | JNGI 2019 | 159.6 | 160.9 | 163.2 | 170.2 | 168.5 | 176.4 | 175.3 | 176.1 | 181.4 | 187.3 | 191.2 | 190.0 | 193.5 | 189.7 | 194.3 | 196.4 | 187.9 | 178.4 | 166.9 | 156.4 | 157.1 | 153.0 | 146.2 | 148.5 | 141.0 | 138.2 | 142.0 | 143.4 |
| 4. Other Sectors | | JNGI 2020 | 159.6 | 160.9 | 163.2 | 170.2 | 168.5 | 176.4 | 175.3 | 176.1 | 181.4 | 187.3 | 191.2 | 190.0 | 193.5 | 189.7 | 194.3 | 196.4 | 187.9 | 178.4 | 166.9 | 156.4 | 157.1 | 153.0 | 146.2 | 149.6 | 142.2 | 139.3 | 141.0 | 144.4 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.01%* | *0.01%* | *0.01%* | *0.01%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.76%* | *0.78%* | *0.81%* | *-0.76%* | *0.71%* |
| | $CH_4$ | JNGI 2019 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | JNGI 2020 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.49%* | *0.29%* | *0.30%* | *0.03%* | *-0.08%* |
| | $N_2O$ | JNGI 2019 | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 0.8 | 0.7 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| | | JNGI 2020 | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 0.8 | 0.7 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.26%* | *0.20%* | *0.22%* | *-0.59%* | *0.20%* |
| B. Fugitive Emissions | $CO_2$ | JNGI 2019 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1. Solid Fuels | | JNGI 2020 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | $CH_4$ | JNGI 2019 | 4.8 | 4.2 | 3.8 | 3.1 | 2.7 | 2.4 | 2.1 | 1.9 | 1.7 | 1.7 | 1.6 | 1.3 | 0.8 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | | JNGI 2020 | 4.8 | 4.2 | 3.8 | 3.1 | 2.7 | 2.4 | 2.1 | 1.9 | 1.7 | 1.7 | 1.6 | 1.3 | 0.8 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| B. Fugitive Emissions | $CO_2$ | JNGI 2019 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 |
| 2. Oil and Natural Gas | | JNGI 2020 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.5 | 0.4 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.01%* | *0.01%* | *0.00%* | *0.00%* | *-8.51%* |
| | $CH_4$ | JNGI 2019 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | | JNGI 2020 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.05%* | *0.05%* | *0.05%* | *0.05%* | *-0.22%* |
| | $N_2O$ | JNGI 2019 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | JNGI 2020 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.03%* |
| 1. Total | GHG | JNGI 2019 | 1,091.9 | 1,102.2 | 1,110.6 | 1,104.5 | 1,155.3 | 1,167.4 | 1,178.2 | 1,173.4 | 1,139.4 | 1,176.0 | 1,198.0 | 1,185.7 | 1,217.4 | 1,226.1 | 1,221.8 | 1,228.5 | 1,205.6 | 1,241.8 | 1,174.2 | 1,112.6 | 1,162.5 | 1,213.2 | 1,253.7 | 1,261.1 | 1,211.9 | 1,173.0 | 1,155.4 | 1,137.0 |
| | | JNGI 2020 | 1,091.9 | 1,102.2 | 1,110.6 | 1,104.5 | 1,155.3 | 1,167.4 | 1,178.2 | 1,173.4 | 1,139.4 | 1,176.0 | 1,198.0 | 1,185.7 | 1,217.4 | 1,226.1 | 1,221.8 | 1,228.5 | 1,205.7 | 1,241.8 | 1,174.2 | 1,112.6 | 1,162.6 | 1,213.3 | 1,253.7 | 1,261.1 | 1,210.5 | 1,171.6 | 1,152.7 | 1,137.0 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.01%* | *-0.11%* | *-0.11%* | *-0.23%* | *0.00%* |

*Excluding Indirect $CO_2$

# Table 10-3 Comparison of emissions and removals in the inventories submitted in 2019 and 2020 (Industrial processes and product use sector) (1/2)

2. Industrial Processes and Product Use
(1/2) [Mt-$CO_2$ eq.]

| Category | Gas | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Mineral Products | $CO_2$ | JNGI 2019 | 49.2 | 50.5 | 51.0 | 50.3 | 51.3 | 51.1 | 51.5 | 48.8 | 43.9 | 43.6 | 43.9 | 43.0 | 40.5 | 40.1 | 39.8 | 41.2 | 41.2 | 40.2 | 37.4 | 32.8 | 32.8 | 33.1 | 33.7 | 35.1 | 34.8 | 33.7 | 33.6 | 34.1 |
| | | JNGI 2020 | 49.2 | 50.5 | 51.0 | 50.3 | 51.3 | 51.1 | 51.5 | 48.8 | 43.9 | 43.6 | 43.9 | 43.0 | 40.5 | 40.1 | 39.8 | 41.2 | 41.2 | 40.2 | 37.4 | 32.8 | 32.8 | 33.1 | 33.6 | 35.0 | 34.7 | 33.7 | 33.5 | 34.0 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.02%* | *-0.10%* | *-0.15%* | *-0.19%* | *-0.23%* | *-0.26%* | *-0.27%* |
| B. Chemical Industry | $CO_2$ | JNGI 2019 | 7.0 | 7.0 | 6.8 | 6.4 | 6.8 | 7.0 | 7.1 | 7.1 | 6.4 | 6.9 | 6.8 | 6.3 | 6.2 | 6.1 | 6.1 | 5.8 | 5.9 | 6.0 | 5.1 | 4.9 | 5.4 | 5.1 | 4.7 | 4.8 | 4.7 | 4.6 | 4.3 | 4.5 |
| | | JNGI 2020 | 7.0 | 7.0 | 6.8 | 6.4 | 6.8 | 7.0 | 7.1 | 7.1 | 6.4 | 6.9 | 6.8 | 6.3 | 6.2 | 6.1 | 6.1 | 5.8 | 5.9 | 6.0 | 5.1 | 4.9 | 5.4 | 5.1 | 4.7 | 4.8 | 4.7 | 4.6 | 4.3 | 4.5 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.03%* | *-0.03%* | *-0.01%* | *0.00%* | *0.00%* |
| | $CH_4$ | JNGI 2019 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | | JNGI 2020 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | $N_2O$ | JNGI 2019 | 9.6 | 9.1 | 9.0 | 8.7 | 9.8 | 9.7 | 10.7 | 11.3 | 10.0 | 3.8 | 6.3 | 3.0 | 2.8 | 2.9 | 3.1 | 2.6 | 2.7 | 2.0 | 2.2 | 2.4 | 1.8 | 1.5 | 1.3 | 1.3 | 1.0 | 0.8 | 0.7 | 0.6 |
| | | JNGI 2020 | 9.6 | 9.1 | 9.0 | 8.7 | 9.8 | 9.7 | 10.7 | 11.3 | 10.0 | 3.8 | 6.3 | 3.0 | 2.8 | 2.9 | 3.1 | 2.6 | 2.7 | 2.0 | 2.2 | 2.4 | 1.8 | 1.5 | 1.3 | 1.3 | 1.0 | 0.8 | 0.7 | 0.6 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | HFCs | JNGI 2019 | 15.9 | 17.3 | 17.6 | 17.1 | 18.9 | 22.0 | 20.3 | 19.0 | 17.7 | 18.0 | 16.0 | 12.2 | 8.1 | 6.9 | 1.9 | 1.0 | 1.2 | 0.6 | 0.9 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 |
| | | JNGI 2020 | 15.9 | 17.3 | 17.6 | 17.1 | 18.9 | 22.0 | 20.3 | 19.0 | 17.7 | 18.0 | 16.0 | 12.2 | 8.1 | 6.9 | 1.9 | 1.0 | 1.2 | 0.6 | 0.9 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | PFCs | JNGI 2019 | 0.3 | 0.4 | 0.4 | 0.6 | 0.7 | 0.9 | 1.2 | 1.7 | 1.6 | 1.6 | 1.7 | 1.3 | 1.3 | 1.2 | 1.1 | 1.0 | 1.1 | 1.0 | 0.6 | 0.5 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | JNGI 2020 | 0.3 | 0.4 | 0.4 | 0.6 | 0.7 | 0.9 | 1.2 | 1.7 | 1.6 | 1.6 | 1.7 | 1.3 | 1.3 | 1.2 | 1.1 | 1.0 | 1.1 | 1.0 | 0.6 | 0.5 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | $SF_6$ | JNGI 2019 | 3.5 | 3.9 | 4.3 | 4.3 | 4.1 | 4.5 | 4.0 | 2.5 | 2.0 | 1.5 | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.9 | 1.3 | 1.1 | 1.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.04 |
| | | JNGI 2020 | 3.5 | 3.9 | 4.3 | 4.3 | 4.1 | 4.5 | 4.0 | 2.5 | 2.0 | 1.5 | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.9 | 1.3 | 1.1 | 1.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.04 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | $NF_3$ | JNGI 2019 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.02 | 0.03 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 1.2 | 1.1 | 1.2 | 1.2 | 1.1 | 1.3 | 1.6 | 1.3 | 1.5 | 1.0 | 0.4 | 0.4 | 0.2 |
| | | JNGI 2020 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.02 | 0.03 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 1.2 | 1.1 | 1.2 | 1.2 | 1.1 | 1.3 | 1.6 | 1.3 | 1.5 | 1.0 | 0.4 | 0.4 | 0.2 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| C. Metal Production | $CO_2$ | JNGI 2019 | 7.2 | 7.1 | 6.8 | 6.7 | 6.7 | 6.8 | 6.9 | 6.8 | 6.5 | 6.5 | 6.7 | 6.8 | 6.6 | 6.4 | 6.5 | 6.5 | 6.6 | 6.7 | 6.2 | 5.5 | 6.1 | 6.0 | 6.1 | 6.2 | 6.1 | 5.9 | 5.8 | 5.7 |
| | | JNGI 2020 | 7.2 | 7.1 | 6.8 | 6.7 | 6.7 | 6.8 | 6.9 | 6.8 | 6.5 | 6.5 | 6.7 | 6.8 | 6.6 | 6.4 | 6.5 | 6.5 | 6.6 | 6.7 | 6.2 | 5.5 | 6.1 | 6.0 | 6.1 | 6.2 | 6.1 | 5.9 | 5.8 | 5.7 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.01%* | *0.04%* | *0.14%* | *0.24%* | *0.40%* | *0.59%* | *0.40%* |
| | $CH_4$ | JNGI 2019 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | JNGI 2020 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.01%* |
| | HFCs | JNGI 2019 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | JNGI 2020 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | *difference* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | PFCs | JNGI 2019 | 0.20 | 0.17 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.09 | 0.07 | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.00 | NO | NO | NO |
| | | JNGI 2020 | 0.20 | 0.17 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.09 | 0.07 | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.00 | NO | NO | NO |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *NA* | *NA* | *NA* |
| | $SF_6$ | JNGI 2019 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.4 | 0.6 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 0.6 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 |
| | | JNGI 2020 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.4 | 0.6 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 0.6 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| D. Non-energy Products from Fuels and Solvent Use | $CO_2$ | JNGI 2019 | 2.2 | 2.1 | 2.1 | 2.2 | 2.4 | 2.4 | 2.7 | 2.8 | 2.6 | 2.8 | 2.8 | 2.9 | 3.0 | 2.9 | 3.0 | 3.2 | 3.4 | 3.4 | 3.1 | 3.2 | 3.1 | 3.1 | 3.0 | 3.1 | 2.9 | 2.8 | 2.9 | 2.9 |
| | | JNGI 2020 | 2.0 | 2.1 | 2.1 | 2.1 | 2.3 | 2.4 | 2.5 | 2.6 | 2.5 | 2.6 | 2.7 | 2.7 | 2.8 | 2.8 | 2.9 | 2.9 | 3.1 | 3.0 | 2.8 | 2.9 | 2.7 | 2.7 | 2.6 | 2.7 | 2.5 | 2.5 | 2.6 | 2.7 |
| | | *difference* | *-5.73%* | *0.86%* | *-0.54%* | *-3.40%* | *-2.89%* | *-2.87%* | *-7.44%* | *-7.34%* | *-6.62%* | *-6.31%* | *-4.79%* | *-4.68%* | *-3.50%* | *-4.81%* | *-5.66%* | *-9.07%* | *-10.31%* | *-11.39%* | *-10.92%* | *-10.23%* | *-11.67%* | *-12.29%* | *-15.32%* | *-14.06%* | *-13.87%* | *-10.31%* | *-10.18%* | *-7.51%* |

*Excluding Indirect $CO_2$

Table 10-3 Comparison of emissions and removals in the inventories submitted in 2019 and 2020 (Industrial processes and product use sector) (2/2)

2. Industrial Processes and Product Use
(2/2) [Mt-$CO_2$ eq.]

| Category | Gas | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E. Electronic Industry | HFCs | JNGI 2019 | 0.00 | NO | 0.02 | 0.14 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | JNGI 2020 | 0.00 | NO | 0.02 | 0.14 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | *difference* | *0.00%* | *NA* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | PFCs | JNGI 2019 | 1.5 | 1.7 | 1.7 | 2.5 | 3.1 | 4.0 | 4.7 | 6.0 | 6.1 | 6.5 | 7.0 | 5.3 | 5.4 | 5.3 | 5.6 | 4.7 | 5.1 | 4.5 | 3.4 | 2.1 | 2.3 | 1.9 | 1.7 | 1.6 | 1.7 | 1.7 | 1.8 | 1.9 |
| | | JNGI 2020 | 1.5 | 1.7 | 1.7 | 2.5 | 3.1 | 4.0 | 4.7 | 6.0 | 6.1 | 6.5 | 7.0 | 5.3 | 5.4 | 5.3 | 5.6 | 4.7 | 5.1 | 4.5 | 3.4 | 2.1 | 2.3 | 1.9 | 1.7 | 1.6 | 1.7 | 1.7 | 1.8 | 1.9 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | $SF_6$ | JNGI 2019 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.8 | 1.1 | 1.2 | 1.4 | 1.5 | 1.3 | 1.4 | 1.4 | 1.4 | 1.3 | 1.0 | 0.8 | 0.6 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.4 |
| | | JNGI 2020 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.8 | 1.1 | 1.2 | 1.4 | 1.5 | 1.3 | 1.4 | 1.4 | 1.4 | 1.3 | 1.0 | 0.8 | 0.6 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.4 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | $NF_3$ | JNGI 2019 | 0.03 | 0.03 | 0.03 | 0.04 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.2 | 0.3 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | JNGI 2020 | 0.03 | 0.03 | 0.03 | 0.04 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.2 | 0.3 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| F. Product Uses as ODS Substitutes | HFCs | JNGI 2019 | 0.00 | NO | 0.1 | 0.9 | 1.9 | 2.9 | 4.1 | 5.1 | 5.7 | 6.1 | 6.6 | 7.0 | 7.9 | 9.1 | 10.3 | 11.5 | 13.2 | 15.8 | 18.2 | 20.5 | 23.0 | 25.8 | 29.1 | 31.8 | 35.5 | 39.0 | 42.3 | 44.6 |
| | | JNGI 2020 | 0.00 | NO | 0.1 | 0.9 | 1.9 | 2.9 | 4.1 | 5.1 | 5.7 | 6.1 | 6.6 | 7.0 | 7.9 | 9.1 | 10.3 | 11.5 | 13.2 | 15.8 | 18.2 | 20.5 | 23.0 | 25.8 | 29.1 | 31.8 | 35.5 | 39.0 | 42.3 | 44.6 |
| | | *difference* | *0.00%* | *NA* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.01%* | *0.01%* | *0.01%* |
| | PFCs | JNGI 2019 | 4.5 | 5.3 | 5.4 | 7.8 | 9.6 | 12.6 | 12.2 | 12.3 | 8.8 | 5.0 | 3.2 | 3.2 | 2.6 | 2.3 | 2.5 | 2.8 | 2.8 | 2.4 | 1.6 | 1.4 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| | | JNGI 2020 | 4.5 | 5.3 | 5.4 | 7.8 | 9.6 | 12.6 | 12.2 | 12.3 | 8.8 | 5.0 | 3.2 | 3.2 | 2.6 | 2.3 | 2.5 | 2.8 | 2.8 | 2.4 | 1.6 | 1.4 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| G. Other Product Manufacture and Use | $N_2O$ | JNGI 2019 | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.6 | 0.4 | 0.4 | 0.4 |
| | | JNGI 2020 | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.6 | 0.4 | 0.4 | 0.4 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *1.12%* |
| | PFCs | JNGI 2019 | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | NA,NO | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |
| | | JNGI 2020 | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | NA,NO | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | NA,NO | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |
| | | *difference* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *NA* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | $SF_6$ | JNGI 2019 | 8.8 | 9.7 | 10.7 | 10.8 | 10.3 | 11.3 | 12.1 | 10.8 | 9.6 | 5.7 | 3.7 | 2.9 | 2.4 | 2.2 | 2.0 | 1.8 | 1.8 | 1.8 | 1.7 | 1.6 | 1.4 | 1.5 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| | | JNGI 2020 | 8.8 | 9.7 | 10.7 | 10.8 | 10.3 | 11.3 | 12.1 | 10.8 | 9.6 | 5.7 | 3.7 | 2.9 | 2.4 | 2.2 | 2.0 | 1.7 | 1.8 | 1.7 | 1.7 | 1.5 | 1.4 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.4 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-1.45%* | *-1.43%* | *-1.45%* | *-1.54%* | *-1.71%* | *-1.78%* | *-1.66%* | *-1.73%* | *-1.77%* | *-1.80%* | *-5.18%* | *-5.18%* | *-4.38%* |
| H. Other | $CO_2$ | JNGI 2019 | 0.06 | 0.07 | 0.07 | 0.06 | 0.07 | 0.07 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.08 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 |
| | | JNGI 2020 | 0.06 | 0.07 | 0.07 | 0.06 | 0.07 | 0.07 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.08 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.07 | 0.07 | 0.08 | 0.09 | 0.10 | 0.09 | 0.09 | 0.10 | 0.11 | 0.11 |
| | | *difference* | *0.54%* | *0.04%* | *0.15%* | *0.20%* | *0.46%* | *0.43%* | *0.22%* | *0.31%* | *0.28%* | *0.27%* | *0.19%* | *0.78%* | *0.99%* | *1.02%* | *0.97%* | *0.20%* | *0.32%* | *0.64%* | *1.32%* | *1.25%* | *1.24%* | *16.23%* | *30.75%* | *13.60%* | *12.64%* | *16.49%* | *34.68%* | *30.05%* |
| 2. Total | GHG | JNGI 2019 | 111.1 | 115.4 | 117.3 | 119.5 | 127.0 | 137.2 | 139.5 | 136.5 | 123.8 | 111.1 | 109.2 | 98.1 | 91.2 | 89.8 | 86.4 | 87.7 | 90.6 | 89.7 | 85.3 | 77.8 | 81.1 | 83.1 | 85.7 | 90.0 | 92.6 | 93.6 | 96.6 | 99.3 |
| | | JNGI 2020 | 110.9 | 115.4 | 117.3 | 119.4 | 127.0 | 137.1 | 139.3 | 136.3 | 123.6 | 110.9 | 109.0 | 98.0 | 91.1 | 89.7 | 86.3 | 87.4 | 90.2 | 89.3 | 84.9 | 77.5 | 80.7 | 82.7 | 85.2 | 89.5 | 92.1 | 93.2 | 96.2 | 99.0 |
| | | *difference* | *-0.11%* | *0.02%* | *-0.01%* | *-0.06%* | *-0.05%* | *-0.05%* | *-0.15%* | *-0.15%* | *-0.14%* | *-0.16%* | *-0.12%* | *-0.14%* | *-0.11%* | *-0.16%* | *-0.20%* | *-0.36%* | *-0.42%* | *-0.46%* | *-0.43%* | *-0.45%* | *-0.48%* | *-0.48%* | *-0.58%* | *-0.56%* | *-0.52%* | *-0.43%* | *-0.41%* | *-0.32%* |

*Excluding Indirect $CO_2$

Table 10-4 Comparison of emissions and removals in the inventories submitted in 2019 and 2020 (Agriculture sector)

| 3. Agriculture | | [Mt-$CO_2$ eq.] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | Gas | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| A. Enteric Fermentation | $CH_4$ | JNGI 2019 | 9.4 | 9.5 | 9.6 | 9.5 | 9.4 | 9.3 | 9.2 | 9.1 | 9.1 | 9.0 | 8.9 | 9.0 | 8.9 | 8.8 | 8.6 | 8.5 | 8.5 | 8.5 | 8.4 | 8.2 | 8.0 | 7.9 | 7.7 | 7.5 | 7.3 | 7.3 | 7.3 | 7.3 |
| | | JNGI 2020 | 9.4 | 9.6 | 9.7 | 9.6 | 9.4 | 9.3 | 9.2 | 9.2 | 9.1 | 9.1 | 9.0 | 9.0 | 8.9 | 8.9 | 8.7 | 8.7 | 8.6 | 8.7 | 8.6 | 8.5 | 8.2 | 8.2 | 8.0 | 7.7 | 7.5 | 7.5 | 7.5 | 7.5 |
| | | *difference* | *0.77%* | *0.79%* | *0.78%* | *0.74%* | *0.70%* | *0.66%* | *0.57%* | *0.50%* | *0.44%* | *0.38%* | *0.35%* | *0.56%* | *0.79%* | *1.03%* | *1.30%* | *1.53%* | *1.99%* | *2.36%* | *2.79%* | *2.88%* | *2.95%* | *2.90%* | *2.85%* | *2.82%* | *2.79%* | *2.78%* | *2.83%* | *2.90%* |
| B. Manure Management | $CH_4$ | JNGI 2019 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 | 3.0 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 |
| | | JNGI 2020 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 | 3.0 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 | 2.8 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.05%* |
| | $N_2O$ | JNGI 2019 | 4.1 | 4.1 | 4.2 | 4.1 | 4.0 | 3.9 | 3.9 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | 3.9 | 3.9 | 3.9 | 4.0 | 4.1 | 4.2 | 4.3 | 4.3 | 4.2 | 4.1 | 4.0 | 4.0 | 3.9 | 3.9 | 3.9 | 3.9 |
| | | JNGI 2020 | 4.2 | 4.2 | 4.2 | 4.2 | 4.1 | 4.0 | 3.9 | 3.9 | 3.9 | 3.8 | 3.9 | 3.9 | 3.9 | 3.9 | 4.0 | 4.0 | 4.1 | 4.2 | 4.2 | 4.2 | 4.1 | 4.1 | 4.0 | 3.9 | 3.9 | 3.8 | 3.8 | 3.9 |
| | | *difference* | *2.27%* | *1.91%* | *1.69%* | *1.57%* | *1.41%* | *1.07%* | *0.88%* | *1.08%* | *1.06%* | *1.06%* | *1.22%* | *0.68%* | *0.45%* | *0.21%* | *0.09%* | *-0.46%* | *-0.66%* | *-0.88%* | *-1.29%* | *-1.20%* | *-0.52%* | *-0.48%* | *-0.29%* | *-1.01%* | *-1.24%* | *-1.57%* | *-1.65%* | *0.26%* |
| C. Rice Cultivation | $CH_4$ | JNGI 2019 | 12.8 | 12.0 | 13.3 | 10.2 | 14.4 | 13.6 | 13.1 | 13.0 | 11.8 | 12.2 | 12.7 | 12.5 | 12.7 | 11.8 | 13.3 | 13.4 | 13.3 | 13.9 | 14.2 | 13.9 | 15.0 | 14.7 | 14.3 | 14.6 | 14.4 | 13.9 | 13.9 | 13.6 |
| | | JNGI 2020 | 12.8 | 12.0 | 13.3 | 10.2 | 14.4 | 13.6 | 13.1 | 13.0 | 11.8 | 12.2 | 12.7 | 12.5 | 12.7 | 11.8 | 13.3 | 13.4 | 13.3 | 13.9 | 14.2 | 13.9 | 15.0 | 14.7 | 14.3 | 14.6 | 14.4 | 13.9 | 13.9 | 13.6 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| D. Agricultural Soils | $N_2O$ | JNGI 2019 | 7.1 | 7.0 | 6.9 | 7.0 | 6.9 | 6.6 | 6.5 | 6.4 | 6.3 | 6.3 | 6.3 | 6.2 | 6.1 | 6.1 | 6.0 | 5.9 | 5.9 | 6.2 | 5.5 | 5.2 | 5.6 | 5.4 | 5.4 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 |
| | | JNGI 2020 | 7.1 | 7.0 | 6.9 | 7.0 | 6.9 | 6.6 | 6.5 | 6.4 | 6.3 | 6.3 | 6.3 | 6.1 | 6.1 | 6.0 | 5.9 | 5.9 | 5.8 | 6.2 | 5.4 | 5.2 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 |
| | | *difference* | *-0.08%* | *-0.17%* | *-0.21%* | *-0.25%* | *-0.31%* | *-0.36%* | *-0.37%* | *-0.33%* | *-0.26%* | *-0.23%* | *-0.26%* | *-0.35%* | *-0.43%* | *-0.54%* | *-0.57%* | *-0.69%* | *-0.75%* | *-0.78%* | *-0.98%* | *-1.02%* | *-0.83%* | *-0.83%* | *-0.77%* | *-0.83%* | *-0.83%* | *0.01%* | *0.03%* | *0.58%* |
| F. Field Burning of Agricultural Residues | $CH_4$ | JNGI 2019 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | JNGI 2020 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-3.73%* |
| | $N_2O$ | JNGI 2019 | 0.04 | 0.04 | 0.04 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | JNGI 2020 | 0.04 | 0.04 | 0.04 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-3.73%* |
| G. Liming | $CO_2$ | JNGI 2019 | 0.6 | 0.5 | 0.5 | 0.5 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| | | JNGI 2020 | 0.6 | 0.5 | 0.5 | 0.5 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-28.62%* | *-30.20%* | *-19.02%* |
| H. Urea Application | $CO_2$ | JNGI 2019 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | JNGI 2020 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *6.17%* | *2.02%* | *2.02%* |
| 3. Total | GHG | JNGI 2019 | 37.3 | 36.5 | 37.8 | 34.6 | 38.2 | 36.9 | 36.1 | 35.8 | 34.5 | 34.7 | 35.2 | 34.7 | 35.0 | 33.9 | 35.1 | 35.2 | 34.9 | 36.0 | 35.4 | 34.7 | 35.7 | 35.2 | 34.6 | 34.6 | 34.1 | 33.6 | 33.4 | 33.2 |
| | | JNGI 2020 | 37.4 | 36.7 | 37.9 | 34.7 | 38.3 | 37.0 | 36.2 | 35.9 | 34.5 | 34.7 | 35.3 | 34.8 | 35.0 | 34.0 | 35.1 | 35.2 | 35.0 | 36.1 | 35.5 | 34.8 | 35.9 | 35.3 | 34.8 | 34.8 | 34.2 | 33.6 | 33.5 | 33.4 |
| | | *difference* | *0.43%* | *0.39%* | *0.34%* | *0.34%* | *0.27%* | *0.21%* | *0.17%* | *0.19%* | *0.18%* | *0.17%* | *0.17%* | *0.16%* | *0.18%* | *0.19%* | *0.23%* | *0.20%* | *0.28%* | *0.32%* | *0.35%* | *0.38%* | *0.47%* | *0.47%* | *0.48%* | *0.37%* | *0.32%* | *0.15%* | *0.11%* | *0.56%* |

# Table 10-5 Comparison of emissions and removals in the inventories submitted in 2019 and 2020 (Land use, land-use change and forestry sector)

4. Land Use, Land-Use Change and Forestry

[Mt-$CO_2$ eq.]

| Category | Gas | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Forest Land | $CO_2$ | JNGI 2019 | -79.1 | -86.2 | -86.6 | -86.9 | -87.3 | -87.6 | -91.3 | -91.1 | -91.0 | -90.8 | -90.6 | -90.5 | -90.3 | -99.0 | -98.5 | -92.7 | -86.8 | -85.5 | -80.8 | -75.9 | -76.4 | -78.1 | -77.7 | -70.0 | -68.3 | -63.1 | -58.6 | -60.9 |
| | | JNGI 2020 | -79.1 | -86.2 | -86.6 | -86.9 | -87.3 | -87.6 | -91.3 | -91.1 | -91.0 | -90.8 | -90.6 | -90.5 | -90.3 | -99.0 | -98.5 | -92.7 | -86.8 | -85.5 | -80.8 | -75.9 | -76.4 | -78.1 | -77.7 | -70.0 | -68.3 | -63.1 | -58.6 | -60.8 |
| | | *difference* | *-0.02%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *-0.01%* | *0.00%* | *-0.01%* | *0.00%* | *0.00%* | *0.00%* | *-0.02%* | *-0.02%* | *-0.04%* | *-0.03%* | *-0.06%* | *-0.03%* | *-0.03%* | *-0.02%* | *-0.02%* | *-0.02%* | *-0.02%* | *-0.01%* |
| | $CH_4$ | JNGI 2019 | 0.01 | 0.01 | 0.01 | 0.03 | 0.02 | 0.01 | 0.03 | 0.04 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.03 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.02 |
| | | JNGI 2020 | 0.01 | 0.01 | 0.01 | 0.03 | 0.02 | 0.01 | 0.03 | 0.04 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.03 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.02 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| | $N_2O$ | JNGI 2019 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.13 | 0.12 | 0.13 | 0.13 |
| | | JNGI 2020 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.13 | 0.12 | 0.13 | 0.13 |
| | | *difference* | *0.11%* | *0.11%* | *0.11%* | *0.11%* | *0.11%* | *0.12%* | *0.11%* | *0.11%* | *0.12%* | *0.12%* | *0.12%* | *0.12%* | *0.12%* | *0.12%* | *0.12%* | *0.12%* | *0.12%* | *0.12%* | *0.12%* | *0.13%* | *0.13%* | *0.13%* | *0.13%* | *0.12%* | *0.11%* | *0.04%* | *0.02%* | *0.04%* |
| B. Cropland | $CO_2$ | JNGI 2019 | 11.7 | 10.6 | 7.2 | 5.5 | 6.3 | 5.5 | 3.8 | 3.2 | 3.2 | 2.0 | 0.1 | 0.0 | 0.1 | -0.6 | 2.7 | 2.3 | 1.5 | 5.0 | 10.5 | 8.0 | 5.5 | 5.9 | 5.0 | 3.7 | 4.4 | 4.3 | 4.8 | 4.5 |
| | | JNGI 2020 | 11.7 | 10.6 | 7.1 | 5.4 | 6.2 | 5.4 | 3.8 | 3.2 | 3.1 | 2.0 | 0.0 | 0.0 | 0.1 | -0.7 | 2.6 | 2.3 | 1.4 | 5.0 | 10.4 | 8.0 | 5.5 | 5.9 | 4.9 | 3.7 | 4.4 | 4.3 | 4.8 | 4.0 |
| | | *difference* | *-0.18%* | *-0.21%* | *-0.30%* | *-0.40%* | *-0.94%* | *-0.90%* | *-1.11%* | *-1.04%* | *-1.00%* | *-2.80%* | *-52.99%* | *-150.62%* | *-16.18%* | *3.59%* | *-0.93%* | *-1.57%* | *-3.13%* | *-0.69%* | *-0.31%* | *0.05%* | *-0.02%* | *-0.17%* | *-0.74%* | *-0.63%* | *-0.31%* | *0.30%* | *0.40%* | *-12.51%* |
| | $CH_4$ | JNGI 2019 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | | JNGI 2020 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.01%* | *0.03%* |
| | $N_2O$ | JNGI 2019 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | JNGI 2020 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | *difference* | *0.16%* | *0.17%* | *0.18%* | *0.19%* | *0.19%* | *0.19%* | *0.18%* | *0.16%* | *0.15%* | *0.14%* | *0.13%* | *0.14%* | *0.15%* | *0.16%* | *0.19%* | *0.16%* | *0.12%* | *0.08%* | *0.04%* | *0.10%* | *0.10%* | *0.08%* | *0.04%* | *0.11%* | *0.18%* | *0.31%* | *0.44%* | *0.43%* |
| C. Grassland | $CO_2$ | JNGI 2019 | 1.1 | 0.8 | 0.1 | -0.2 | 0.1 | 0.7 | 0.3 | 0.1 | 0.02 | -0.4 | 0.04 | -0.3 | -0.5 | -1.2 | -0.9 | -1.0 | -0.4 | -0.7 | -1.0 | -0.13 | 0.03 | 0.25 | -0.03 | -0.09 | 0.09 | -0.04 | -0.10 | -0.16 |
| | | JNGI 2020 | 1.1 | 0.8 | 0.1 | -0.2 | 0.1 | 0.7 | 0.3 | 0.1 | 0.03 | -0.4 | 0.05 | -0.3 | -0.5 | -1.2 | -0.9 | -1.0 | -0.4 | -0.7 | -0.9 | -0.04 | 0.12 | 0.26 | -0.02 | -0.04 | 0.15 | -0.01 | -0.07 | -0.18 |
| | | *difference* | *0.88%* | *0.97%* | *8.58%* | *-2.35%* | *4.54%* | *0.71%* | *1.52%* | *14.08%* | *34.59%* | *-1.86%* | *18.43%* | *-2.72%* | *-1.50%* | *-0.68%* | *-1.13%* | *-5.86%* | *-13.45%* | *-12.00%* | *-9.43%* | *-73.01%* | *289.66%* | *2.21%* | *-24.70%* | *-62.66%* | *69.25%* | *-70.59%* | *-29.98%* | *15.55%* |
| | $CH_4$ | JNGI 2019 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 |
| | | JNGI 2020 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.03%* |
| | $N_2O$ | JNGI 2019 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | JNGI 2020 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* |
| D. Wetlands | $CO_2$ | JNGI 2019 | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 | 0.4 | 0.6 | 0.1 | 0.5 | 0.5 | 0.4 | 0.4 | 0.09 | 0.06 | 0.06 | 0.04 | 0.04 | 0.08 | 0.09 | 0.11 | 0.11 | 0.05 | 0.06 | 0.02 | 0.02 | 0.05 | 0.05 | 0.05 |
| | | JNGI 2020 | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 | 0.4 | 0.6 | 0.1 | 0.5 | 0.5 | 0.4 | 0.4 | 0.09 | 0.06 | 0.06 | 0.04 | 0.04 | 0.08 | 0.09 | 0.12 | 0.11 | 0.06 | 0.07 | 0.02 | 0.02 | 0.06 | 0.06 | 0.02 |
| | | *difference* | *0.13%* | *0.13%* | *0.13%* | *0.13%* | *0.12%* | *0.12%* | *0.13%* | *0.18%* | *0.18%* | *0.18%* | *0.19%* | *0.17%* | *0.17%* | *0.18%* | *0.19%* | *6.97%* | *6.92%* | *10.46%* | *10.45%* | *6.91%* | *6.92%* | *13.81%* | *13.77%* | *0.40%* | *0.44%* | *21.97%* | *21.98%* | *-63.03%* |
| E. Settlements | $CO_2$ | JNGI 2019 | 2.6 | 3.3 | 3.7 | 2.1 | 1.3 | 1.1 | 0.4 | 0.2 | 0.1 | -0.3 | -0.6 | -0.8 | -1.4 | -1.5 | -1.5 | -1.0 | -1.0 | 0.09 | 0.41 | -0.21 | -0.30 | -0.90 | -0.66 | -0.50 | -0.34 | -0.08 | 0.01 | -0.11 |
| | | JNGI 2020 | 2.9 | 3.5 | 3.9 | 2.4 | 1.5 | 1.3 | 0.6 | 0.4 | 0.2 | -0.1 | -0.4 | -0.7 | -1.3 | -1.4 | -1.4 | -1.0 | -0.9 | -0.24 | 0.03 | -0.30 | -0.38 | -0.81 | -0.57 | -0.44 | -0.28 | 0.11 | 0.20 | -0.16 |
| | | *difference* | *8.32%* | *7.07%* | *6.71%* | *9.98%* | *15.64%* | *17.86%* | *45.56%* | *98.26%* | *295.38%* | *-58.27%* | *-24.89%* | *-17.12%* | *-8.42%* | *-7.24%* | *-6.83%* | *-6.96%* | *-7.33%* | *-379.10%* | *-92.33%* | *40.05%* | *27.88%* | *-9.65%* | *-13.77%* | *-11.06%* | *-17.93%* | *-241.22%* | *1292.81%* | *40.62%* |
| F. Other Land | $CO_2$ | JNGI 2019 | 1.2 | 1.3 | 1.0 | 1.3 | 1.1 | 1.0 | 0.9 | 1.2 | 0.9 | 0.9 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.2 | 0.2 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | JNGI 2020 | 1.2 | 1.3 | 1.0 | 1.3 | 1.2 | 1.0 | 0.9 | 1.2 | 0.9 | 1.0 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | | *difference* | *2.16%* | *1.67%* | *1.74%* | *2.27%* | *2.54%* | *2.76%* | *2.16%* | *1.78%* | *2.13%* | *3.90%* | *3.23%* | *2.30%* | *2.28%* | *2.11%* | *3.41%* | *21.34%* | *4.28%* | *8.64%* | *8.96%* | *19.86%* | *19.58%* | *81.88%* | *24.93%* | *14.17%* | *19.41%* | *8.64%* | *14.68%* | *-12.10%* |
| | $N_2O$ | JNGI 2019 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | JNGI 2020 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | *difference* | *0.04%* | *0.09%* | *0.13%* | *0.18%* | *0.23%* | *0.27%* | *0.31%* | *0.37%* | *0.41%* | *0.47%* | *0.53%* | *0.59%* | *0.66%* | *0.72%* | *0.79%* | *0.85%* | *0.93%* | *1.12%* | *1.34%* | *1.78%* | *2.11%* | *2.42%* | *2.74%* | *3.09%* | *3.50%* | *3.76%* | *4.02%* | *3.96%* |
| G. Harvested Wood Products | $CO_2$ | JNGI 2019 | -0.4 | -0.6 | 0.5 | 1.2 | 1.7 | 1.5 | 3.0 | 1.8 | 0.4 | 1.7 | 1.8 | 1.7 | 1.2 | 1.4 | 0.9 | 0.6 | 0.4 | -0.4 | -0.4 | 0.6 | 0.1 | 2.5 | 0.1 | 0.3 | -0.9 | -1.2 | -1.2 | -1.4 |
| | | JNGI 2020 | -0.4 | -0.6 | 0.5 | 1.2 | 1.7 | 1.5 | 3.0 | 1.8 | 0.4 | 1.9 | 1.8 | 1.7 | 1.2 | 1.4 | 0.9 | 0.6 | 0.4 | -0.4 | -0.4 | 0.6 | 0.1 | 2.5 | 0.1 | 0.3 | -0.8 | -1.2 | -1.2 | -1.8 |
| | | *difference* | *1.22%* | *0.27%* | *3.32%* | *-0.83%* | *-0.07%* | *-0.36%* | *-0.13%* | *-0.02%* | *-0.08%* | *8.63%* | *-0.49%* | *1.77%* | *4.16%* | *-0.15%* | *-0.17%* | *0.37%* | *1.03%* | *-1.15%* | *-3.65%* | *-0.31%* | *-21.91%* | *-2.36%* | *4.58%* | *-0.07%* | *-3.55%* | *5.73%* | *3.49%* | *29.74%* |
| H. Other (Organic soil in settlements converted from other land-use categories) | $CH_4$ | JNGI 2019 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | JNGI 2020 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | *difference* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | $N_2O$ | JNGI 2019 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | JNGI 2020 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | *difference* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| (IV) Indirect $N_2O$ emissions from managed soils | $N_2O$ | JNGI 2019 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | | JNGI 2020 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | | *difference* | *0.13%* | *0.14%* | *0.14%* | *0.14%* | *0.15%* | *0.15%* | *0.15%* | *0.15%* | *0.15%* | *0.15%* | *0.15%* | *0.15%* | *0.16%* | *0.16%* | *0.17%* | *0.16%* | *0.16%* | *0.16%* | *0.17%* | *0.19%* | *0.20%* | *0.20%* | *0.20%* | *0.21%* | *0.21%* | *0.14%* | *0.15%* | *0.15%* |
| 4. Total | GHG | JNGI 2019 | -62.5 | -70.5 | -73.6 | -76.6 | -76.3 | -77.3 | -81.9 | -84.3 | -85.7 | -86.1 | -87.9 | -88.4 | -89.9 | -100.1 | -96.5 | -91.3 | -85.9 | -81.0 | -70.7 | -67.0 | -70.5 | -69.9 | -72.9 | -66.2 | -64.5 | -59.6 | -54.5 | -57.5 |
| | | JNGI 2020 | -62.2 | -70.3 | -73.3 | -76.4 | -76.1 | -77.1 | -81.7 | -84.1 | -85.5 | -85.7 | -87.8 | -88.3 | -89.7 | -100.0 | -96.4 | -91.2 | -85.8 | -81.2 | -70.9 | -66.9 | -70.4 | -69.7 | -72.7 | -66.0 | -64.3 | -59.4 | -54.3 | -58.5 |
| | | *difference* | *-0.41%* | *-0.37%* | *-0.39%* | *-0.31%* | *-0.25%* | *-0.25%* | *-0.23%* | *-0.23%* | *-0.23%* | *-0.36%* | *-0.17%* | *-0.20%* | *-0.21%* | *-0.12%* | *-0.13%* | *-0.16%* | *-0.15%* | *0.25%* | *0.30%* | *-0.16%* | *-0.14%* | *-0.30%* | *-0.20%* | *-0.21%* | *-0.30%* | *-0.34%* | *-0.45%* | *1.88%* |

Table 10-6 Comparison of emissions and removals in the inventories submitted in 2019 and 2020 (Waste sector)

| 5. Waste | | [Mt-$CO_2$ eq.] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | Gas | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| A. Solid Waste Disposal | $CH_4$ | JNGI 2019 | 9.6 | 9.5 | 9.5 | 9.3 | 9.2 | 9.0 | 8.7 | 8.5 | 8.2 | 7.9 | 7.6 | 7.3 | 7.0 | 6.7 | 6.4 | 6.1 | 5.8 | 5.5 | 5.1 | 4.8 | 4.5 | 4.3 | 4.1 | 3.9 | 3.6 | 3.4 | 3.2 | 3.1 |
| | | JNGI 2020 | 9.6 | 9.5 | 9.5 | 9.3 | 9.2 | 9.0 | 8.7 | 8.5 | 8.2 | 7.9 | 7.6 | 7.3 | 7.0 | 6.7 | 6.4 | 6.1 | 5.8 | 5.5 | 5.1 | 4.8 | 4.5 | 4.3 | 4.1 | 3.9 | 3.6 | 3.4 | 3.2 | 3.1 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.13%* | *0.14%* | *0.40%* |
| B. Biological Treatment of Solid Waste | $CH_4$ | JNGI 2019 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | JNGI 2020 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-13.23%* |
| | $N_2O$ | JNGI 2019 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | | JNGI 2020 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-13.31%* |
| C. Incineration and Open Burning of Waste | $CO_2$ | JNGI 2019 | 12.4 | 12.5 | 13.5 | 13.3 | 15.8 | 16.0 | 16.5 | 17.1 | 17.1 | 16.8 | 17.0 | 15.8 | 15.2 | 15.2 | 14.6 | 14.1 | 13.2 | 13.4 | 14.5 | 12.1 | 12.3 | 11.5 | 12.2 | 12.1 | 11.6 | 11.5 | 10.9 | 10.8 |
| | | JNGI 2020 | 12.4 | 12.5 | 13.5 | 13.3 | 15.8 | 16.0 | 16.5 | 17.1 | 17.1 | 16.8 | 17.0 | 15.8 | 15.2 | 15.2 | 14.6 | 14.1 | 13.2 | 13.4 | 14.5 | 12.1 | 12.3 | 11.5 | 12.2 | 12.1 | 11.6 | 11.5 | 11.0 | 10.7 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.07%* | *0.05%* | *0.05%* | *0.03%* | *0.03%* | *0.02%* | *0.03%* | *0.05%* | *0.07%* | *0.03%* | *0.02%* | *0.47%* | *-1.17%* |
| | $CH_4$ | JNGI 2019 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | JNGI 2020 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.74%* | *6.73%* |
| | $N_2O$ | JNGI 2019 | 1.4 | 1.5 | 1.6 | 1.6 | 1.8 | 1.9 | 2.0 | 2.1 | 2.1 | 2.2 | 2.2 | 2.1 | 1.9 | 1.9 | 1.9 | 2.0 | 1.8 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.5 | 1.3 | 1.4 |
| | | JNGI 2020 | 1.4 | 1.5 | 1.6 | 1.6 | 1.8 | 1.9 | 2.0 | 2.1 | 2.1 | 2.2 | 2.2 | 2.1 | 1.9 | 1.9 | 1.9 | 2.0 | 1.8 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.5 | 1.3 | 1.4 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.18%* |
| D. Waste Water Treatment and Discharge | $CH_4$ | JNGI 2019 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.5 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 | 2.1 | 2.0 | 1.9 | 1.9 | 1.9 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 |
| | | JNGI 2020 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 | 2.8 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.5 | 2.4 | 2.4 | 2.3 | 2.3 | 2.2 | 2.1 | 2.1 | 2.0 | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 | 1.7 | 1.7 | 1.6 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.50%* | *0.99%* | *1.44%* | *1.86%* | *2.21%* | *2.68%* | *3.04%* | *3.03%* | *2.96%* | *2.88%* | *2.63%* | *2.45%* | *2.29%* | *2.08%* | *2.05%* | *1.75%* | *-1.50%* |
| | $N_2O$ | JNGI 2019 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.2 | 2.1 | 2.1 | 2.2 | 2.1 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 |
| | | JNGI 2020 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *-0.30%* | *-0.58%* | *-0.81%* | *-1.01%* | *-1.19%* | *-1.42%* | *-1.55%* | *-1.48%* | *-1.38%* | *-1.24%* | *-1.00%* | *-0.85%* | *-0.68%* | *-0.52%* | *-0.47%* | *-0.25%* | *-2.07%* |
| E. Other | $CO_2$ | JNGI 2019 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 0.7 | 0.6 | 0.7 | 0.7 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| | | JNGI 2020 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 0.7 | 0.6 | 0.7 | 0.7 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.02%* |
| 5. Total | GHG | JNGI 2019 | 29.7 | 29.7 | 30.9 | 30.4 | 32.9 | 33.1 | 33.3 | 33.7 | 33.3 | 32.7 | 32.5 | 30.8 | 29.7 | 29.4 | 28.4 | 27.6 | 26.3 | 25.9 | 26.6 | 23.5 | 23.3 | 22.3 | 22.6 | 22.4 | 21.5 | 21.3 | 20.3 | 20.1 |
| | | JNGI 2020 | 29.7 | 29.7 | 30.9 | 30.4 | 32.9 | 33.1 | 33.3 | 33.7 | 33.3 | 32.7 | 32.5 | 30.8 | 29.7 | 29.4 | 28.5 | 27.7 | 26.3 | 26.0 | 26.6 | 23.5 | 23.3 | 22.4 | 22.7 | 22.4 | 21.5 | 21.3 | 20.4 | 19.9 |
| | | *difference* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.00%* | *0.02%* | *0.04%* | *0.05%* | *0.07%* | *0.11%* | *0.12%* | *0.13%* | *0.13%* | *0.13%* | *0.13%* | *0.14%* | *0.15%* | *0.15%* | *0.14%* | *0.15%* | *0.39%* | *-1.18%* |

### 10.2.2. KP-LULUCF Inventory

Compared to the values reported in the previous year's inventory, total emissions/removals arising from KP-LULUCF activities in FY2017 were resulted to be an increase of removals by 1.86% (Table 10-7).

Table 10-7 Comparison of emissions and removals in the inventories submitted in 2019 and 2020 for KP-LULUCF activities

KP-LULUCF activities [Mt-$CO_2$ eq.]

| Activity | Gas | | 1990 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| Afforestation and Reforestation | $CO_2$ | JNGI 2019 | - | -1.6 | -1.6 | -1.6 | -1.6 | -1.6 |
| | | JNGI 2020 | - | -1.6 | -1.6 | -1.6 | -1.6 | -1.5 |
| | | *difference* | - | *-3.03%* | *-2.95%* | *-2.59%* | *-2.29%* | *-2.13%* |
| | $CH_4$ | JNGI 2019 | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | JNGI 2020 | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | *difference* | - | *-2.97%* | *-2.88%* | *-2.58%* | *-2.28%* | *-2.22%* |
| | $N_2O$ | JNGI 2019 | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | JNGI 2020 | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | *difference* | - | *-2.97%* | *-2.88%* | *-2.58%* | *-2.28%* | *-2.22%* |
| Deforestation | $CO_2$ | JNGI 2019 | - | 2.0 | 2.0 | 2.1 | 2.1 | 1.8 |
| | | JNGI 2020 | - | 2.0 | 2.1 | 2.3 | 2.3 | 1.6 |
| | | *difference* | - | *1.33%* | *1.43%* | *6.53%* | *6.71%* | *-12.50%* |
| | $CH_4$ | JNGI 2019 | - | NO | NO | NO | NO | NO |
| | | JNGI 2020 | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | *difference* | - | *NA* | *NA* | *NA* | *NA* | *NA* |
| | $N_2O$ | JNGI 2019 | - | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | JNGI 2020 | - | -0.00 | -0.00 | -0.00 | -0.00 | 0.00 |
| | | *difference* | - | *-109.61%* | *-115.71%* | *-106.27%* | *-109.66%* | *-84.57%* |
| Forest Management | $CO_2$ | JNGI 2019 | - | -51.2 | -51.5 | -49.1 | -46.6 | -46.3 |
| | | JNGI 2020 | - | -51.2 | -51.6 | -49.3 | -46.7 | -46.6 |
| | | *difference* | - | *0.16%* | *0.11%* | *0.43%* | *0.40%* | *0.72%* |
| | $CH_4$ | JNGI 2019 | - | 0.00 | 0.02 | 0.00 | 0.00 | 0.02 |
| | | JNGI 2020 | - | 0.00 | 0.02 | 0.00 | 0.00 | 0.02 |
| | | *difference* | - | *0.02%* | *0.02%* | *0.02%* | *0.01%* | *0.01%* |
| | $N_2O$ | JNGI 2019 | - | 0.09 | 0.10 | 0.10 | 0.10 | 0.10 |
| | | JNGI 2020 | - | 0.09 | 0.10 | 0.10 | 0.10 | 0.10 |
| | | *difference* | - | *0.13%* | *0.12%* | *0.02%* | *0.01%* | *0.02%* |
| Cropland Management | $CO_2$ | JNGI 2019 | 10.2 | 3.6 | 4.3 | 4.2 | 4.7 | 4.5 |
| | | JNGI 2020 | 10.2 | 3.6 | 4.4 | 4.4 | 4.9 | 4.1 |
| | | *difference* | *-0.16%* | *1.90%* | *2.45%* | *2.89%* | *3.25%* | *-8.44%* |
| | $CH_4$ | JNGI 2019 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | | JNGI 2020 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | | *difference* | *0.00%* | *0.09%* | *0.20%* | *0.32%* | *0.42%* | *0.56%* |
| | $N_2O$ | JNGI 2019 | 0.04 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | JNGI 2020 | 0.04 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | *difference* | *0.16%* | *0.07%* | *-0.05%* | *-0.79%* | *-1.94%* | *0.63%* |
| Grazing Land Managemen | $CO_2$ | JNGI 2019 | 0.8 | -0.3 | -0.1 | -0.2 | -0.2 | -0.3 |
| | | JNGI 2020 | 0.8 | -0.2 | 0.0 | -0.1 | -0.1 | -0.1 |
| | | *difference* | *-0.13%* | *-29.87%* | *-102.68%* | *-54.14%* | *-44.87%* | *-49.29%* |
| | $CH_4$ | JNGI 2019 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | JNGI 2020 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | *difference* | *0.00%* | *8.18%* | *15.36%* | *22.84%* | *41.82%* | *51.43%* |
| | $N_2O$ | JNGI 2019 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | JNGI 2020 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | *difference* | *-0.13%* | *-0.44%* | *-0.42%* | *-0.40%* | *-0.37%* | *-0.38%* |
| Revegetation | $CO_2$ | JNGI 2019 | -0.1 | -1.2 | -1.2 | -1.3 | -1.3 | -1.3 |
| | | JNGI 2020 | -0.1 | -1.2 | -1.2 | -1.3 | -1.3 | -1.3 |
| | | *difference* | *3.75%* | *0.40%* | *0.44%* | *0.44%* | *0.42%* | *1.38%* |
| Total | | JNGI 2019 | 11.0 | -48.5 | -47.9 | -45.6 | -42.7 | -42.9 |
| | | JNGI 2020 | 11.0 | -48.4 | -47.7 | -45.4 | -42.4 | -43.7 |
| | | *difference* | *-0.18%* | *-0.27%* | *-0.46%* | *-0.37%* | *-0.55%* | *1.86%* |

## 10.3. Implication for Emission Trends, including Time Series Consistency

Table 10-8 shows the changes made to the emission trends due to the recalculations indicated in "Section 10.1. Explanation and Justification for Recalculations". The comparison between the 2019 submission and the 2020 submission is made through the comparison of values between FY1990 and FY2017.

### 10.3.1. GHG Inventory

The change between FY1990 and FY2017 total emissions (excluding the LULUCF sector and including indirect $CO_2$) in the 2020 submission decreased by approximately 0.5 million tonnes (in $CO_2$ equivalents) and decreased by 0.04 percentage points, compared to the data reported in the previous submission.

Table 10-8 Comparison of change between 1990 and 2017 total emissions (excluding the LULUCF sector, and including indirect $CO_2$) between the inventories submitted in 2019 and 2020

| | Emissions (2017) - Emissions (1990) [Mt-$CO_2$ eq.] | | | Emissions (2017) / Emissions (1990) - 1 [%] | | |
|---|---|---|---|---|---|---|
| | JNGI 2019 | JNGI 2020 | Difference | JNGI 2019 | JNGI 2020 | Difference |
| $CO_2$ | 29.6 | 29.3 | -0.3 | 2.6% | 2.5% | 0.0% |
| $CH_4$ | -14.3 | -14.2 | 0.1 | -32.2% | -31.9% | 0.3% |
| $N_2O$ | -11.3 | -11.5 | -0.1 | -35.6% | -35.9% | -0.3% |
| HFCs | 29.0 | 29.0 | 0.0 | 181.7% | 181.8% | 0.0% |
| PFCs | -3.0 | -3.0 | 0.0 | -46.3% | -46.3% | 0% |
| $SF_6$ | -10.7 | -10.8 | -0.1 | -83.4% | -83.9% | -0.5% |
| $NF_3$ | 0.4 | 0.4 | 0.0 | 1279.3% | 1279.3% | 0% |
| Indirect $CO_2$ | -3.4 | -3.4 | 0.0 | -61.3% | -62.1% | -1% |
| Total | 16.3 | 15.8 | -0.5 | 1.28% | 1.24% | -0.04% |

## 10.4. Recalculations and improvement plan, including response to the review process

### 10.4.1. Improvements after submission of the inventory

The major improvements carried out after the submission of the 2019 inventory are listed below.

#### 10.4.1.1. Methodology for estimating emissions and removals of GHGs

Changed calculation methods are provided in Table 10-9.

### 10.4.1.1.a. GHG Inventory

Table 10-9 Changes in estimation methods

| Sector and category | | Changes in estimation methods |
|---|---|---|
| 1.A | $CO_2$ emissions from fuel combustion | The carbon emission factors of FY2018 were established. |
| 1.A | GHG emissions from fuel combustion | The calorific values of FY2018 were established. |
| 1.A.3.b | $CH_4$ and $N_2O$ emissions from road transportation | New measurements of raw emission factors for vehicles were provided by JAMA. In response to the issue identified by QAWG in FY2017, additional measurements were provided by MOE, Bureau of Environment of Tokyo Metropolitan Government, NIES, NTSEL, and JPEC. The 2016 Regulation for diesel heavy-duty trucks and the 2018 Regulation for passenger vehicles were reflected into the estimation method. Therefore, the emission factors were revised for gasoline hybrid passenger vehicles after FY2003, light passenger vehicles, gasoline passenger vehicles, gasoline small cargo trucks and diesel small cargo trucks, and diesel regular cargo trucks after FY2005, and light cargo trucks after FY2007. The 3rd Regulation is reflected into the estimation method of motorcycles. |
| 2.D.3.- | NMVOC Incineration | Updates were made to the methods of establishment of domestic supply of solvents for paint. |
| 2.D.3 | Use of Synthetic Leather | Updates were made to the method of estimating activity data for use of synthetic leather. |
| 2.D.3 | Use of Dampening Solutions | NMVOC emissions were newly estimated. |
| 2.G.2 | Accelerators | The $SF_6$ EFs for university/research facilities were revised. |
| 2.H.2 | Food and beverage industry | Update were made to the ethyl alcohol content for spirits and liqueurs. |
| 2.H.3 | Emissions from imported carbonated gas | Emissions from imported carbonated gas were newly estimated. |
| 3.A.1 | Enteric Fermentation/ Cattle | The categorization of cattle types for calculation methods were revised for all year. |
| 3.B.1<br>3.B.5<br><br><br>3.D.a.2<br><br>3.D.b.1 | Manure Management/ Cattle<br>Manure Management/ Indirect $N_2O$ Emissions/ Atmospheric Deposition<br>Agricultural Soils/ Direct $N_2O$ Emissions/ Organic Fertilizer<br>Agricultural Soils/ Indirect $N_2O$ Emissions/ | The calculation method of nitrogen content in excretion for non-dairy cattle has been revised. |
| 3.B.2<br>3.B.5<br><br><br>3.D.a.2<br><br>3.D.b.1 | Manure Management/ Cattle<br>Manure Management/ Indirect $N_2O$ Emissions/ Atmospheric Deposition<br>Agricultural Soils/ Direct $N_2O$ Emissions/ Organic Fertilizer<br>Agricultural Soils/ Indirect $N_2O$ Emissions/ | The calculation method of nitrogen content in excretion for swine has been revised. |
| 3.D.a.5 | Agricultural Soils/ Direct $N_2O$ Emissions/ Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter Cultivation of organic soils | The estimation method for mineral soil area associated with land use conversion in LULUCF sector was changed. |
| 3.D.a.6 | Agricultural Soils/ Direct $N_2O$ Emissions/ Plowing organic soils | The estimation method for organic soil area associated with land use conversion in LULUCF sector was changed. |
| 4.B.1 | Cropland remaining cropland | Due to correction of carbon stock per unit area in mineral soil in upland fields for FY2017, carbon stock changes in cropland remaining cropland were recalculated for FY2017.<br>Since organic carbon stock from biochar amendments in cropland were estimated in this submission, carbon stock change in mineral soil in |

| Sector and category | | Changes in estimation methods |
|---|---|---|
| | | cropland remaining cropland were calculated for all years. |
| 4.B.2 | Land converted to cropland | Since biomass growth of annual crops in cropland (after conversion) were corrected, carbon stock changes in living biomass in land converted to cropland were recalculated for all years. |
| 4.A.2<br>4.C.2<br>4.D.2<br>4.E.2<br>4.F.2 | Land converted to forest land, grassland, wetlands, settlements and other land | Due to correction of biomass carbon stocks of annual crops in cropland before conversion, carbon stock change in living biomass in other land use converted from cropland were recalculated for all years. |
| 4.E.2 | Land converted to settlements | Since emission from organic soils in settlements converted from other land use categories were estimated in this submission, $CO_2$ emissions from organic soils in settlements converted from other land use categories were calculated for all years. |
| 4.G | Harvested Wood Products Buildings and Wood used for other than buildings | The outflow values were also recalculated for all years due to the correction of the equation for calculating the domestic wood rate in demolition materials and input amount of demolition material per unit area. According to the change of the domestic wood rate in demolition materials, the inflow values of wood boards were also recalculated for all years. |
| 4.G | Harvested Wood Products Paper and paperboard | The inflow value of consumption of raw materials for pulp products were recalculated for all years due to the correction of the domestic wood rate in demolition materials. Because of this inflow recalculation, the outflow which is calculated based on first order decay function were also recalculated. |
| 4.(II) | Emissions from Drainage of Organic and Mineral soils | Since area of deforestation (D area) were revised, emissions in this category were recalculated for all years.<br>In addition, since $CH_4$ and $N_2O$ emissions from organic soils drainage activities in settlements converted from other land use categories were estimated from this submission, $CH_4$ and $N_2O$ from this category were recalculated for all years. |
| 5.D.1 | Domestic wastewater (domestic sewage treatment plant) | By re-examining emission factors for current advanced type *Johkasou*, $CH_4$ and $N_2O$ emissions from this source from FY2001 onward were recalculated. |
| 5.D.1 | Domestic wastewater (natural decomposition of domestic wastewater) | By reconsidering the fraction of nitrogen removal of current advanced type *Johkasou*, $N_2O$ emissions from treated wastewater from FY2001 onward were recalculated. |

#### 10.4.1.1.b. KP-LULUCF Inventory

Table 10-10 Changes in estimation methods

| Sector and category | Changes in estimation methods |
|---|---|
| Afforestation (A), Reforestation (R), Deforestation (D) | Due to adding a new estimation of carbon stock changes in living biomass associated with conversion from cropland for annual crops and pasture land to forest land were reported under AR as well as those from forest land to cropland for annual crops were reported under D, carbon stock changes in living biomass under AR and D for FY2013 - 2017 were recalculated. Moreover, a new estimation of $CO_2$ and $CH_4$ emissions associated with drainage from organic soils in the case that the land conversion to settlements occurred was added under each category of activity. With this revision, $CO_2$ and $CH_4$ emissions associated with drainage from organic soils for FY2013 - 2017 were recalculated. |
| Forest Management (FM) | Carbon stock change in HWP for FY2013 - FY2017 were also recalculated due to revision of both activity data and parameters used for the estimation. |
| Cropland Management (CM) | Emissions and removals associated with carbon stock changes in living biomass, organic soils and mineral soils in CM for FY1990 and FY2013 - FY2017 were recalculated due to adding a new estimation of carbon stock loss and gain in the biomass associated with conversion at cropland for annual crops in CM mentioned above. Moreover, a new estimation of $CO_2$ and $CH_4$ emissions associated with drainage from organic soils in the case that the land conversion to settlements occurred was added under each category of activity. With this revision, $CO_2$ and $CH_4$ emissions associated with drainage from organic soils for FY2013 - 2017 were recalculated. |
| Grazing Land Management (GM) | Emissions associated with carbon stock changes in living biomass and mineral soils and from organic soils in GM for FY1990 and FY2013 - FY2017 were recalculated due to adding a new estimation of carbon stock changes in living biomass associated with conversion from pasture land mentioned above in GM. Moreover, a new estimation of $CO_2$ and $CH_4$ emissions associated with drainage from organic soils in the case that the land conversion to settlements occurred was added under each category of activity. With this revision, $CO_2$ and $CH_4$ emissions associated with drainage from organic soils for FY2013 - 2017 were recalculated. |
| Revegetation (RV) | Carbon stock changes in all carbon pools under the RV activities for FY 1990, FY 2013 - FY 2017 were recalculated, due to the revision of allocation in biomass loss due to conversion which became reported under each activity before conversion. |

### 10.4.1.2. National Greenhouse Gas Inventory Report

No major changes since the previous submission.

### 10.4.1.3. Improvements by following UNFCCC-ERT recommendations

Actions taken in response to recommendations from UNFCCC review are summarized below. See relative sections for details.

The Committee for Greenhouse Gas Estimation Methods (see “Committee for Greenhouse Gas Estimation Methods” (Chapter 1.2.1.2.) address all the recommendations raised by ERT, and efforts have been made to tackle the issues and improve the national GHG inventory with due consideration of the priority.

Table 10-11 Summary of improvements made to the national inventory in response to recommendations from UNFCCC review

| Sector/Category | Recommendations by ERT | Actions taken | NIR/CRF |
|---|---|---|---|
| Energy/ Reference approach | Include in the NIR detailed information on the conversion factors used to convert GCV to NCV for all fuels. (ARR 2018 E.1) | The conversion factors are provided in the NIR | NIR Annex 4 (A4.4) |
| Energy/ Non-energy use of fuels | Provide greater transparency in the NIR and CRF tables (e.g. documentation boxes) and justification for the application of the "NE" notation key when fuels are used for non-energy purposes to demonstrate that there are no omissions of any potential emissions (ARR 2018 E.4) | The notation key of other oil is changed from "NE" to "NO" because it is known that refinery gas is used as feedstock of BTX (benzene, toluene and xylene). No "NE" is reported in CRF Table 1.A(d) in this submission. | CRF Table 1.A(d) |
| Energy/ Public electricity and heat production (1.A.1.a) | Increase the transparency of its reporting regarding the composition of other fuels for public electricity and heat production in order to justify the $CO_2$ IEF and ensure comparability of reporting. (ARR 2018 E.5) | The reason of the difficulty to distinguish the activity data on calorie basis between biomass faction and the fossil-fuel derived fraction is described in NIR table 3-57 footnote 8 and 9. | NIR Chapter 3 (3.2.12) |
| Energy/ Natural gas (1.B.2.b) | Clarify the text of the NIR regarding fugitive emissions from natural gas distribution to industrial consumers. (ARR 2018 E.10) | A figure is newly provided with explanation in the NIR. | NIR Chapter 3 (3.3.2.2)/ Figure 3-7 |
| Energy/ Reference approach | Report emissions from the non-biomass fraction of waste in the reference approach (CRF table 1.A(b)). (ARR 2018 E.11) | The emissions from waste are reported in the reference approach. | CRF table 1.A(b) |
| Energy/ Petroleum refining (1.A.1.b) | Explain in the NIR that the reported $CH_4$ and $N_2O$ IEFs from 2012 to 2015 increased when the new data from the *General Survey of the Emissions of Air Pollutants* (conducted in 2014) were implemented in the inventory because the survey identified an increase in the number of furnaces with higher EFs (based on furnace type and fuel consumption) for the period 2012–2015.<br>Explain in the NIR the reasons for the significant decline observed in the $CH_4$ and $N_2O$ IEF between 2010 and 2011.<br>(ARR 2018 E.12) | An explanation is provided in the NIR. | NIR Chapter 3 (3.2.5.b) |
| IPPU/ General | Reallocate emissions from the consumption of reducing agents for the production of soda ash, iron and steel, ferroalloys, lead and zinc to the categories 2.B.7, 2.C.1, 2.C.2, 2.C.5 and 2.C.6, respectively, in line with the UNFCCC Annex I inventory reporting guidelines and the 2006 IPCC Guidelines.(ARR 2018 I.1) | An explanation is provided in the NIR. | NIR Chapter 4 (4.3.7,4.4.1,4.4.2,4.4.5,4.4.6) |
| IPPU/ Lime production (2.A.2) | Provide a justification for the information that lime production does not lead to $CO_2$ emissions in sugar mills owing to subsequent recarbonation (ARR 2018 I.3) | An explanation is provided in the NIR. | NIR Chapter 4 (4.2.2.b) |
| IPPU/ Lime production (2.A.2) | Work with the aluminium industry to obtain information to confirm that lime is not produced by aluminium manufacturers (ARR 2018 I.4) | An explanation is provided in the NIR. | NIR Chapter 4 (4.2.2.b) |
| IPPU/Glass production (2.A.3) | Estimate and include in the inventory the $CO_2$ emissions associated with the consumption of minor $CO_2$-emitting raw materials for glass manufacturing (ARR 2018 I.5). | The $CO_2$ emissions were included in the inventory. An explanation is provided in the NIR. | NIR Chapter 4 (4.2.3.)/Table2 (I).A-Hs1 |
| IPPU/Petrochemical and carbon black production (2.B.8) | Justify that the country-specific $CO_2$ EF has been developed in a manner consistent with the 2006 IPCC Guidelines, covering the total $CO_2$ emissions from the steam cracking process, and is considered to be more accurate than the IPCC default EF (ARR 2018 I.8). | An explanation is provided in the NIR. | NIR Chapter 4 (4.3.8.2.b) |
| IPPU/Ammonia | Include in the NIR the reasons for the inter- | The explanation is provided in the | NIR Chapter 4 |

| Sector/Category | Recommendations by ERT | Actions taken | NIR/CRF |
|---|---|---|---|
| production (2.B.1) | annual variation in the $CO_2$ IEF for 2004/2005 (–9.6 per cent), 2011/2012 (8.0 per cent) and 2015/2016 (–11.1 per cent) (ARR 2018 I.23). | NIR. | (4.3.1.b) |
| IPPU/Titanium dioxide production (2.B.6) | Add a sentence to the NIR clarifying that the $CO_2$ EF for rutile $TiO_2$ is lower than the IPCC default (ARR 2018 I.24) | The explanation is provided in the NIR. | NIR Chapter 4 (4.3.6.b) |
| IPPU/Petrochemical and carbon black (2.B.8) | Include in the NIR the reasons for the lower $CH_4$ IEF (compared with the IPCC default) for production of ethylene dichloride and for vinyl chloride monomer (ARR 2018 I.25) | The explanation is provided in the NIR. | NIR Chapter 4 (4.3.8.3.b) |
| IPPU/ Iron and steel production (2.C.1) | Include in the NIR the sum of $CO_2$ emissions from categories 1.A.2.a and 2.C.1 and provide a qualitative explanation on how this sum is comparable to the emissions that are calculated in line with the 2006 IPCC Guidelines.<br>Include in the NIR an explanation on why the country-specific $CO_2$ EF for category 2.C.1 is higher than the IPCC default values (ARR 2018 I.27) | The explanation is provided in the NIR. | NIR Chapter 4 (4.4.1,4.4.1.2. b) |
| IPPU/ Iron and steel production (2.C.1.c) | Correct the notation key from "NA" to "NO" for the AD in CRF table 2(I).A-Hs2 (production/consumption quantity) for category 2.C.1.c (ARR 2018 I.28) | The notation key in the CRF table is corrected. | CRF Table2(I).A-Hs2 |
| IPPU/ Iron and steel production (2.C.1) | Include in the NIR a description (or table) indicating all reducing agents used in iron and steel production and make a cross reference to the NIR sections where information about the reducing agents can be found (ARR2018 I.29) | The explanation and the cross reference are provided in the NIR. | NIR Chapter 3 (3.2.3) /NIR Chapter 4 (4.4.1) |
| IPPU/2.C.1 Iron and steel production (2.C.1) | Include information on pulverized coal injection in NIR table 3-10 to demonstrate its use as fuel for non-energy purposes (e.g. as feedstock) (ARR 2018 I.30) | The explanation is provided in the NIR. | NIR Chapter 3 (3.2.3) |
| IPPU/2.C.2 Ferroalloys production | Estimate $CO_2$ emissions related to the other carbon-containing materials (such as ore and slag forming) (ARR 2018 I.31) | The explanation is provided in the NIR. | NIR Chapter 4 (4.4.2.a) |
| IPPU/2.C.2 Ferroalloys production | Provide a more detailed explanation of how $CH_4$ emissions and the country-specific $CH_4$ EF are calculated and explain the reasons for not producing a country-specific EF on the basis of t $CH_4$/t ferroalloy produced (as in CRF table 2(I).A-Hs2 and in the 2006 IPCC Guidelines) (ARR 2018 I.32). | The explanation is provided in the NIR. | NIR Chapter 4 (4.4.2.b) |
| IPPU/Direct Lubricant use (2.D.1) | Verify and correct the units reported in CRF table 2(I).A-Hs2 (ARR2018 I.33). | The units in the CRF table is corrected. | CRF Table2(I).A-Hs2 |
| IPPU/ Semiconductor manufacturing (2.E.1) | Report in the NIR information about the "use rate" per specific gas and "by-production rate" of $C_2F_6$. (ARR2018 I.10) | Tables for use rates and by-production rates were added. | NIR Chapter 4 (4.6.1) |
| IPPU/ Liquid Crystal manufacturing (2.E.2) | Report in the NIR information about the "use rate" per specific gas and "by-production rate" of $CHF_3$. (ARR2018 I.13) | Tables for use rates and by-production rates were added. | NIR Chapter 4 (4.6.2) |
| IPPU/ Refrigeration and air conditioning (2.F.1) | Report in the NIR that the parameters "refrigerant contained per operated device" and "refrigerant contained per disposed device" are equal to "refrigerant charged per device at production" since these types of equipment are sealed tight. (ARR2018 I.17) | Descriptions were added to the Note under the table in the NIR. | NIR Chapter 4 (4.7.1.1) below Table 4-63 |
| IPPU/ Refrigeration and air conditioning (2.F.1) | Provide documentation in the NIR to support the claim that PFC emissions from the manufacturing, stocks and disposal of commercial refrigeration are not occurring at any time during the time series (ARR2018 I.34) | Additional explanation on PFC use is provided. | NIR Chapter 4 (4.7.1.2.a) |

| Sector/Category | Recommendations by ERT | Actions taken | NIR/CRF |
|---|---|---|---|
| IPPU/ Refrigeration and air conditioning (2.F.1) | Reallocate the AD and emissions relating to railways and vessels from commercial refrigeration to transport refrigeration. (ARR2018 I.35) | Allocation was changed. | NIR Chapter 4 (4.7.1.3) and CRF Table2(II).B-Hs2 |
| IPPU/ Foam blowing agents (2.F.2) | Improve the transparency of the reporting of AD for foam blowing agents in open and closed cells in CRF table 2(II)B-Hs2 using data currently reported in the NIR, where possible. (ARR2018 I.21) | The AD in the CRF is modified. | CRF Table2(II).B-Hs2 |
| IPPU/ Foam blowing agents (2.F.2) | Explain in the NIR the reasons behind the increase in the uses of HFC-245fa and HFC-365mfc between 2005 and 2006, when the average annual stock in the operating system increased by 203.6 per cent (ARR2018 I.36 (Encouragement)) | Explanation on reason for increase is provided. | NIR Chapter 4 (4.7.2.1.a) below Table 4-73 |
| Agriculture/ General | The notation key “NE” is used for several parameters in the inventory. The ERT encourages Japan to revise the notation keys used in the CRF tables from “NE” to “NA”. (ARR2018 A.3) | Some notation keys are revised from NE to NA in the CRF table 3.As.2. | CRF Table3.As.2 |
| Agriculture/ Rice cultivation (3.C) | Explain why the new data on the amount of organic matter application is used for recalculation for 2017 submission are more accurate for national circumstances. (ARR2018 A.4) | The explanation is provided in the NIR. | NIR Chapter 5 (5.4.1) |
| Agriculture/ Direct $N_2O$ emissions from managed soils (3.D.a). | Explain the background information for the decrease of N amount for inorganic and organic fertilizer between 1990 to 2016. (ARR2018 A.5) | The background information is provided in the NIR. | NIR Chapter 5 (5.5, 5.5.1.1) |
| Agriculture/ Cultivation of organic soils (i.e. histosols) (3.D.a.6) | Include in the NIR a clear explanation for the difference between areas reported for cultivated histosols under the agriculture sector and cropland and grassland organic soils reported under the LULUCF sector. (ARR2018 A.6) | Explanation for the area reported under Agriculture sector is provided in NIR additionally. | NIR Chapter 5 (5.5.1.6) |
| Agriculture/ Cultivation of organic soils (i.e. histosols) (3.D.a.6) | Justify the use of the country-specific EF for cultivation of histosols on paddy field by including a description. (ARR2018 A.7) | The description for justifying the reason of using the country-specific EF is provided in the NIR. | NIR Chapter 5 (5.5.1.6) |
| LULUCF Cropland remaining cropland (4.B.1) | Include in the NIR a clear explanation for the difference between areas reported for cultivated histosols under the agriculture sector and cropland and grassland organic soils reported under the LULUCF sector (ARR2018 L.4) | Explanation on reason for difference between area reported under LULUCF sector and the agriculture sector was provided in the 2019 NIR | NIR Chapter 6 (6.6.1) |
| LULUCF Cropland remaining cropland (4.B.1) | Explain in the NIR the resulting estimates from the Roth-C model and their trends (ARR 2018 L.6) | The descriptions on outputs from Roth C model and their trends were included in the 2019 NIR. However, more clear explanation in driver for the trends was under investigation. | NIR Chapter 6 (6.6.1.a) |
| LULUCF Grassland remaining grassland (4.C.1) | Explain in the NIR the resulting estimates from the Roth-C model and their trends (ARR 2018 L.8) | The descriptions on outputs from Roth C model and their trends were included in the 2019 NIR. However, more clear explanation in driver for the trends was under investigation. | NIR Chapter 6 (6.7.1.a) |
| LULUCF Direct $N_2O$ emissions from N mineralization/ immobilization – $N_2O$ (4. (III)) | Improve the consistency of the reporting for the sector across categories 4.B, 4.C and 4.(III) (ARR2018 L.11). | The areas reported in the CRF table are modified. | CRF Table4.B, 4.C and 4.(III). |
| LULLUCF HWP – $CO_2$ (4.G) | Improve the documentation in the NIR of what is included in each HWP commodity reported under category 4.G (ARR2018 | The estimation equation and explanation are provided in the NIR. | NIR Chapter 6 (6.11.1) |

| Sector/Category | Recommendations by ERT | Actions taken | NIR/CRF |
|---|---|---|---|
| | L.14). | | |
| LULUCF<br>Forest land remaining forest land – $CO_2$ (4.A.1) | Include in the NIR explanations of the major drivers for the changes in carbon stock, as well as information on the FM practices that have been applied to intensively managed forests and semi-natural forests that caused the increase in carbon stock (ARR2018 L.16). | The explanations are provided in the NIR. | NIR Chapter 6 (6.5.1) |
| LULUCF<br>Land converted to forest land– $CO_2$ (4.A.2) | Provide in the NIR an explanation or justification on why no biomass stock in living biomass is removed when cropland is converted to other land uses, including forest land (ARR2018 L.17). | The estimation is added in 2020 submission and the explanation is provided in the NIR. | NIR Chapter 6 Table 6-8a and Table 6-8b |
| LULUCF<br>Cropland remaining cropland – $CO_2$ (4.B.1) | Provide a clear explanation in the NIR of the reduction of organic soil in rice fields, including information on the conversion rate and land types to which rice fields are converted (ARR2018 L.18). | The explanation is provided in the NIR. | NIR Chapter 6 (6.6.1) |
| Land converted to settlements- $CO_2$ (4.E.2) | Clarify and justify the use of the notation key "NO" for net carbon stock change per area for organic soils under category 4.E.2.2, considering that it is unclear how the organic soils used to conduct embankment activities, remove defective soils, and solidify soils are handled (ARR2018 L.19). | The estimation is added in 2020 submission and the explanation is provided in the NIR. | NIR Chapter 6 (6.9.2, 6.13) |
| Waste<br>Solid waste disposal on land (5.A) | Provide a justification for the use of the country-specific half-life of biodegradation k to calculate $CH_4$ emissions from solid waste disposal. (b)If it is not possible to provide the appropriate justification, calculate $CH_4$ emissions from solid waste disposal assuming the IPCC default half-lives of biodegradation from table 3.4 in the 2006 IPCC Guidelines (volume 3, chapter 3).<br>(ARR 2018 W.5) | A justification for use of the country-specific half-lives of biodegradation was provided in the NIR. | NIR Chapter 7 (7.2.1) |
| Waste<br>Anaerobic digestion at biogas facilities (5.B.2) | Report $CH_4$ emissions from anaerobic digestion of solid waste as "NE" in CRF table 5.B and justify the use of this notation key in annex 5 to the NIR on the basis of the threshold of significance in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.<br>(ARR 2018 W.6) | $CH_4$ emissions from anaerobic digestion of solid waste were reported as "NE" in CRF table 5.B, and a justification for the use of this notation key was provided in annex 5 to the NIR. | CRF Table5D<br>NIR Chapter 7 (7.3.2) |
| Waste<br>Domestic wastewater (5.D.1) | Calculate the $CH_4$ emissions from *Gappei-shori Johkasou* units assuming a more realistic scenario for the impact on the $CH_4$ EF, such as by incorporating in the calculation a more gradual replacement of the older generation (pre-2001) *Johkasou* units with the new anaerobic–aerobic *Johkasou* units, which comply with the new building standards.<br>(ARR 2018 W.7) | By revisioning the estimation methods, the $CH_4$ emissions from current type *Johkasou* were recalculated. | NIR Chapter 7 (7.5.1) |

### 10.4.2. Planned Improvements

The following improvements are continuously performed and reflect in an inventory preparation process accordingly. See relative sections for details.

1. Review of estimation methods, activity data, emission factors and other elements

   Japan holds meetings of a Committee for Greenhouse Gas Emission Estimation Methods and considers improvements of estimation methods, activity data, emission factors and other elements

used in the current inventory. In case of implementation, Japan prioritizes highly important issues such as those relevant to key-categories and those pointed out in the past review reports.

2. Improvement of transparency

   Japan will further improve transparency of the inventory by examining descriptions of methodologies, assumptions, data, and other elements in NIR, and by adding necessary information to NIR.

# Chapter 11. Supplementary Information on LULUCF activities under Article 3, Paragraphs 3 and 4 of the Kyoto Protocol

## 11.1. Summary of removal related trends, and emissions and removals from KP LULUCF activities

In accordance with the decision 2/CMP.8 in paragraph 4 adopted by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP8), Japan reports afforestation/reforestation (AR), deforestation (D), forest management (FM), cropland management (CM), grazing land management (GM) and revegetation (RV) as LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol for the second commitment period. Table 11-1 shows the activity coverage and other information relating to activities under Article 3.3, forest management under Article 3.4 and elected activities under Article 3.4. The net removals in FY2018 by those activities were 43,008 kt-$CO_2$ eq. (Table 11-2). Methodological tiers used are shown in Table 11-3.

Table 11-1 Activity coverage and other information relating to activities under Article 3.3 and elected activities under Article 3.4 (CRF-Table NIR 1)

| Activity | | Change in carbon pool reported | | | | | | | Greenhouse gas sources reported | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Above-ground biomass | Below-ground biomass | Litter | Dead wood | Soil | | HWP | Fertilization | Drained, rewetted and other soils | | Nitrogen mineralization in mineral soils | Indirect $N_2O$ emissions from managed soil | Biomass burning | | |
| | | | | | | Mineral | Organic | | $N_2O$ | $CH_4$ | $N_2O$ | $N_2O$ | N2O | $CO_2$ | $CH_4$ | $N_2O$ |
| Article 3.3 activities | Afforestation and reforestation | R | R | R | R | R | NO | NO | IE | NO | NO | NA | IE | IE | R | R |
| | Deforestation | R | R | R | R | R | R | IO | IE | R | NO | R | R | NO | NO | NO |
| Article 3.4 activities | Forest management | R | R | R | R | R | NO | R | R | NO | NO | R | R | IE | R | R |
| | Cropland management | R | R | NR | NR | R | R | | | R | | R | | IE | R | R |
| | Grazing land management | R | R | NR | NR | R | R | | | R | | R | | NO | NO | NO |
| | Revegetation | R | R | R | IE | R | NO | | IE | NO | NO | NA | IE,NA | NO | NO | NO |
| | Wetland drainage and rewetting | NA | NA | NA | NA | NA | NA | | NA | NA | NA | | NA | NA | NA | NA |

Note:
R: Reported; NR: Not reported; IO: Instantaneous oxidation;
See annex 5 for the definitions of the other notation keys.

Table 11-2 Accounting summary for activities under Articles 3.3 and 3.4 of the Kyoto Protocol

| Greenhouse gas source and sink activities | Net Emissions/removals [kt $CO_2$ eq.] | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1990（Base Year） | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| A. Article 3.3 activities | | | | | | | |
| A.1. Afforestation/reforestation | | -1,558 | -1,563 | -1,562 | -1,562 | -1,536 | -1,442 |
| Excluded emissions from natural disturbances | | NA | NA | NA | NA | NA | NA |
| Excluded subsequent removals from land subject to natural disturbances | | NA | NA | NA | NA | NA | NA |
| A.2. Deforestation | | 2,049 | 2,055 | 2,274 | 2,275 | 1,611 | 1,605 |
| B. Article 3.4 activities | | | | | | | |
| B.1. Forest management | | | | | | | |
| Net emissions/removals | | -51,149 | -51,449 | -49,216 | -46,650 | -46,469 | -45,361 |
| Excluded emissions from natural disturbances | | NA | NA | NA | NA | NA | NA |
| Excluded subsequent removals from land subject to natural disturbances | | NA | NA | NA | NA | NA | NA |
| Any debits from newly established forest (CEF-ne) | | NA | NA | NA | NA | NA | NA |
| Forest management reference level (FMRL) | | 0 | 0 | 0 | 0 | 0 | 0 |
| Technical corrections to FMRL | | 1,069 | 1,252 | 1,404 | 1,544 | 1,687 | 1,821 |
| Forest management cap | | | | | | | |
| B.2. Cropland management | 10,265 | 3,693 | 4,476 | 4,413 | 4,917 | 4,139 | 3,721 |
| B.3. Grazing land management | 840 | -190 | 9 | -70 | -118 | -127 | -209 |
| B.4. Revegetation | -82 | -1,228 | -1,247 | -1,267 | -1,285 | -1,308 | -1,322 |
| B.5. Wetland drainage and rewetting (not elected) | NA | NA | NA | NA | NA | NA | NA |
| Total (excluding Technical corrections to FMRL) | - | -48,382 | -47,718 | -45,427 | -42,423 | -43,689 | -43,008 |

Note:
The total values and results of summing up each figure are not always the same because of the difference in display digit.

Table 11-3 Methodological tiers used under Articles 3.3 and 3.4 of the Kyoto Protocol

| Activity | | $CO_2$ | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|---|
| | | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| Article 3.3 activities | Afforestation and reforestation | T2 | CS | T1 | D | T1 | D |
| | Deforestation | T2 | CS,D | T1 | CS,D | T1 | CS,D |
| Article 3.4 activities | Forest management | T2,T3 | CS,D | T1 | D | T1,T2 | CS,D |
| | Cropland management | T2,T3 | CS,D | T1 | CS,D | T1,CS | CS,D |
| | Grazing land management | T2,T3 | CS,D | T1 | CS,D | CS | CS |
| | Revegetation | T2 | CS,D | | | | |
| | Wetland drainage and rewetting | | | | | | |

D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country-specific method or emissions factor

## 11.2. Information relating to the decision 3/CMP.11 in paragraph 8

Japan describes information about LULUCF activities under Article 3.4 of the Kyoto protocol for the second commitment period in accordance with decision 3/CMP.11 in paragraph 8, as follows:

- Japan reports CM and GM as new activities under Article 3.4 of the Kyoto Protocol, in addition to FM which became mandatory in the second commitment period, and RV which was elected in the first commitment period.
- For the FM and the RV, the methodology on land identification, which was applied to the first commitment period, is also applied to the second commitment period; lands that have been accounted for the first commitment period are also included in the second commitment period. Regarding the CM and the GM added from the second commitment period, the lands are identified based on statistics which are applied for reporting of LULUCF under the Convention. Detailed information is described in relevant sections of each activity.

## 11.3. General information

### 11.3.1. Definition of forest and any other criteria

The definitions of forest in Japan of forest are identified as the following, in accordance with decision 16/CMP.1, paragraph 20 of the annex to decision 2/CMP.7 and the requirement from *the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (hereafter *KP Supplement*).

- Minimum value for forest area: 0.3 [ha]
- Minimum value for tree crown cover: 30 [%]
- Minimum value for tree height: 5 [m]
- Minimum value for forest width: 20 [m]

The minimum tree crown cover and the minimum forest width (mentioned above) are consistent with forests under the existing forest planning system in Japan. Although any minimum values for tree height is not defined under the existing system, forests with usual composition of tree species and under usual climate conditions in Japan usually reach a tree height of 5 m at maturity *in situ*. Each prefecture has surveyed and compiled information on forest resources under the forest planning system into Forest Registers, which are primarily intended to be prepared for establishing forest plans. Therefore, forests under the forest planning system are considered as forests under the Kyoto Protocol, and Forest

Registers are suitable as basic data source for reporting. This is the same concept as the one used for reporting the LULUCF forest sector under the Convention. The definitions of forest used for the second commitment period are the same as the first commitment period.

The definitions of forest mentioned above are consistent with those in the Country Report under Global Forest Resources Assessment (FRA) by the Food and Agriculture Organization of the United Nation (FAO) (Table 11-4).

Table 11-4 Japan's forest categories and definition used in reporting to FAO

| Category | | Definition |
|---|---|---|
| Forest | | Land on which trees and/or bamboo grow collectively, together with those trees and bamboo, or any other lands that are provided for collective growth of trees and/or bamboo covering 0.3 ha or more. Lands that are utilized mainly for agriculture, residential use or other similar purposes, and trees and bamboo on these lands, are not included. |
| | Forest with standing trees | Forest that has a tree crown cover of 30 percent or higher (including young stands with the degree of stocking of 3 or higher). |
| | Forest with less standing trees (Cut-over forest, lesser stocked forest) | Forest that does not fall under "forest with standing trees" or "bamboo forest". |
| | Bamboo forest | Forest that does not fall under "forest with standing trees" and is mainly dominated by bamboo (excluding bamboo grass). |

Note: See section 6.2. for a more detailed definition of each category

Before 1995, Japan classified forests with standing trees into two sub-categories, "intensively managed forests" and "semi-natural forests" in the Forestry Status Survey. Since 2002, Japan has conducted new sub-categories which are "ikusei-rin forest" and "tennensei-rin forest". In these new sub-categories, the degree of human-induced activities and stratification of forest have been taken into account. In ikusei-rin forests, intensively managed forests regenerated mainly by planting after felling and semi-natural forests regenerated by supplementary works such as site preparation are included. The definitions of intensively managed forest, semi-natural forest, ikusei-rin forest and tennensei-rin forest are shown below.

Table 11-5 Definitions of intensively managed forest, semi-natural forest, ikusei-rin forest and tennensei-rin forest[1]

| Sub-categories by regeneration method | | Sub-categories by management types | |
|---|---|---|---|
| Intensively managed forest | Forest regenerated by planting and so on. | Ikusei-rin Forest | Forest where practices for establishment and maintenance of single-storied forests have been carried out after clear-cutting ("ikusei-tansou-rin"), or forest where practices for establishment and maintenance of multi-storied forests have been carried out after selective cutting ("ikusei-fukusou-rin"). |
| Semi-natural forest | Forest which is not classified as intensively managed forest. | Tennensei-rin forest | Forest where practices for establishment and maintenance of forest mainly depending on natural power are carried out. |

### 11.3.2. Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

Japan elected FM, CM, GM and RV defined by decision 2/CMP.7 in paragraph 6 and 7 of the annex, as "additional human-induced activities related to changes in GHG emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories" defined by Article 3,

[1] Explanations for Ikusei-rin forest and Tennensei-rin forest have been changed in accordance with the revision of the "Basic Plan for Forest and Forestry". However, the coverage of those forests remains the same.

paragraph 4 of the Kyoto Protocol.

Japan interprets the definition of elected activities as follows by recalling *the KP Supplement* which the parties shall apply in accordance with decision 6/CMP.9, paragraph 9.

#### 11.3.2.1. Forest Management

FM is defined in paragraph 1 (f) of the annex to decision 16/CMP.1 as "a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner". Japan interprets the definition of FM as the following.

- Activities for FM in ikusei-rin forests are appropriate forest practices including regeneration (land preparation, soil scarification, planting, etc.), tending (weeding, pre-commercial cutting, etc.), thinning and harvesting which have been carried out since 1990.
- Activities for FM in tennensei-rin forests are practices for protection or conservation of forests including controlling logging activities and land-use change which have been carried out by law.

#### 11.3.2.2. Cropland Management

CM is defined in paragraph 1 (g) of the annex to decision 16/CMP.1 as "a system of practices on land on which agricultural crops are grown and on land that is set aside or temporarily not being used for crop production". Japan interprets the definition of CM as follows:

- Practices for cultivating in rice fields, upland fields and orchard[2]

#### 11.3.2.3. Grazing Land Management

GM is defined in paragraph 1 (h) of the annex to decision 16/CMP.1 as "a system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced". Japan interprets the definition of GM as follows:

- Practices for meadow and grazing in pasture land[3]

#### 11.3.2.4. Revegetation

RV is defined in paragraph 1 (e) of the annex to decision 16/CMP.1 as "a direct human-induced activity to increase carbon stocks on sites through the establishment of vegetation that covers a minimum area of 0.05 ha and does not meet the definitions of AR". Japan interprets the definition of RV as follows:

- Practices for the creation of "parks and green space", "public green space", and "private green space guaranteed by administration" which have been carried out in settlements since 1990[4]. Activities which cover less than an area of 0.05 ha or meet the definitions of AR are not included.

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[2] Abandoned cultivated land which is included in cropland for reporting of LULUCF under the Convention, is not included in the CM because appropriate managements have not been carried out there.

[3] As for grazed meadow and wild land that are included in grassland for reporting of LULUCF under the Convention, they are not included in GM because management practices changes have not been occurred in grazed meadow and wild land is not for use of grazing.

[4] In Japan, the urban green facilities subject to RV activities are: "urban parks", "green areas on roads", "green areas at ports", "green areas around sewage treatment facilities", "green areas by greenery promoting systems for private green space", "green areas along rivers and erosion control sites", "green areas around government buildings", and "green areas around public rental housing".

### 11.3.3. Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

The forest definition explained in section 11.3.1 has not changed over time. The same forest definition is used for AR and D under Article 3.3 as well as FM under Article 3.4. The definitions of FM, CM, GM and RV explained in section 11.3.2 above have been implemented and applied consistently over time.

### 11.3.4. Description of precedence conditions and/or hierarchy among elected Article 3.4 activities, and how they have been consistently applied in determining how land was classified

Japan interprets that FM activities occur only in forest land, and CM, GM, and RV activities occur only in non-forest land (cropland, grassland and settlements). Therefore, there is no overlap between FM and non-FM activities (CM, GM, and RV). The areas of CM and GM are not double counted, as they are identified by the different items in the same data source. However, there is a possibility that overlap may occur between CM, GM and RV when new planting is implemented in settlements converted from cropland and pasture land. In order to prevent double counting among activities under Article 3.4 of the Kyoto Protocol, Japan made arrangement that the converted land area and the emissions from carbon stock existed in original activities and lost due to conversion were reported under the original activities, but removals from the increase in carbon stock due to growth after conversion were reported under the current activities.

## 11.4. Land-related information

### 11.4.1. Spatial assessment unit used for determining the area of the units of land under Article 3.3

In accordance with the definition of forest explained in section 11.3.1, Japan determines the spatial assessment unit used for determining the area of the units of land under Article 3.3 as 0.3 ha.

### 11.4.2. Methodology used to develop the land transition matrix

#### 11.4.2.1. Description of land transition matrix (CRF-NIR Table 2)

Table 11-6 shows the land transition matrix related to the activities under Articles 3.3 and 3.4 of the Kyoto Protocol. The FM area in Japan is estimated by using the narrow approach concept described in section 2.7.1 of t*he KP Supplement*. Therefore, new FM areas are identified every year due to the progress of FM practices in managed forests which previously had not been categorized as FM area. These areas are classified as land transition from “other” to FM in table 11-6. Also, areas where RV practices have been newly performed become new RV areas and are classified as land transition from “other” to RV in table 11-6.

Regarding CM and GM, Japan basically estimates emissions/removals for current cropland (except for cultivation abandoned agricultural land) and current grazing land respectively; in accordance with paragraph 24 of the annex to the decision 2/CMP.7, cropland and pasture land converted to other land-use since 2013, were also included in CM and in GM with the following exceptions. The area of cropland or grassland converted to forest land is reported under “Afforestation and Reforestation”, the area of cropland or grassland converted to settlements with new planting is reported under “RV” land and newly created cropland or pasture land derived from the conversion of forests is reported under “Deforestation”. Moreover, the land conversion across CM and GM is reported as “IE”, because the

changed areas between CM and GM from the previous year cannot be clearly separated from each other, although the spatially explicit data used in the tier 3 model itself considers the above-mentioned land use changes in its calculation.

As for the values of 2018 in the land transition matrix, changes from reported figures in 2017, are reported.

Table 11-6 Land transition matrix of Kyoto Protocol activities (CRF-Table NIR 2)

| TO 2018 / FROM 2017 | | Article 3.3 activities | | Article 3.4 activities | | | | | Other | Total area at the end of the previous inventory year |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Afforestation and reforestation | Deforestation | Forest management | Cropland management | Grazing land management | Revegetation | Wetland drainage and rewetting (not elected) | | |
| | | (kha) | | | | | | | | |
| Article 3.3 activities | Afforestation and Reforestation | 105.70 | 0.12 | | | | | | | 105.82 |
| | Deforestation | | 316.78 | | | | | | | 316.78 |
| Article 3.4 activities | Forest management | | 3.97 | 15,824.15 | | | | | | 15,828.12 |
| | Cropland management | NO | | NA | 3,932.77 | IE | NO | NA | | 3,932.77 |
| | Grazing land management | 0.08 | | NA | IE | 607.58 | NO | NA | | 607.66 |
| | Revegetation | NO | | NA | NA | NA | 87.76 | NA | | 87.76 |
| | Wetland drainage and rewetting (not elected) | NA | | NA | NA | NA | NA | NA | | NA |
| Other | | 0.01 | 2.11 | 122.25 | 7.78 | 2.61 | 0.83 | NA | 16,782.91 | 16,918.51 |
| Total area at the end of the current inventory year | | 105.79 | 322.98 | 15,946.40 | 3,940.55 | 610.19 | 88.59 | NA | 16,782.91 | 37,797.42 |

### 11.4.2.2. Overview of the procedures to estimate emissions and removals

This section gives an overview of the procedures to estimate emissions and removals for AR, D and FM activities in Japan. For AR and D activities, emissions and removals are estimated in AR and D areas which are detected for each prefecture based on sample survey data. For FM activity, emissions and removals are estimated by firstly subtracting emissions and removals in AR and D land from those in all managed forests for each prefecture, and then applying the FM ratio determined by the sample survey to the remaining emissions and removals.

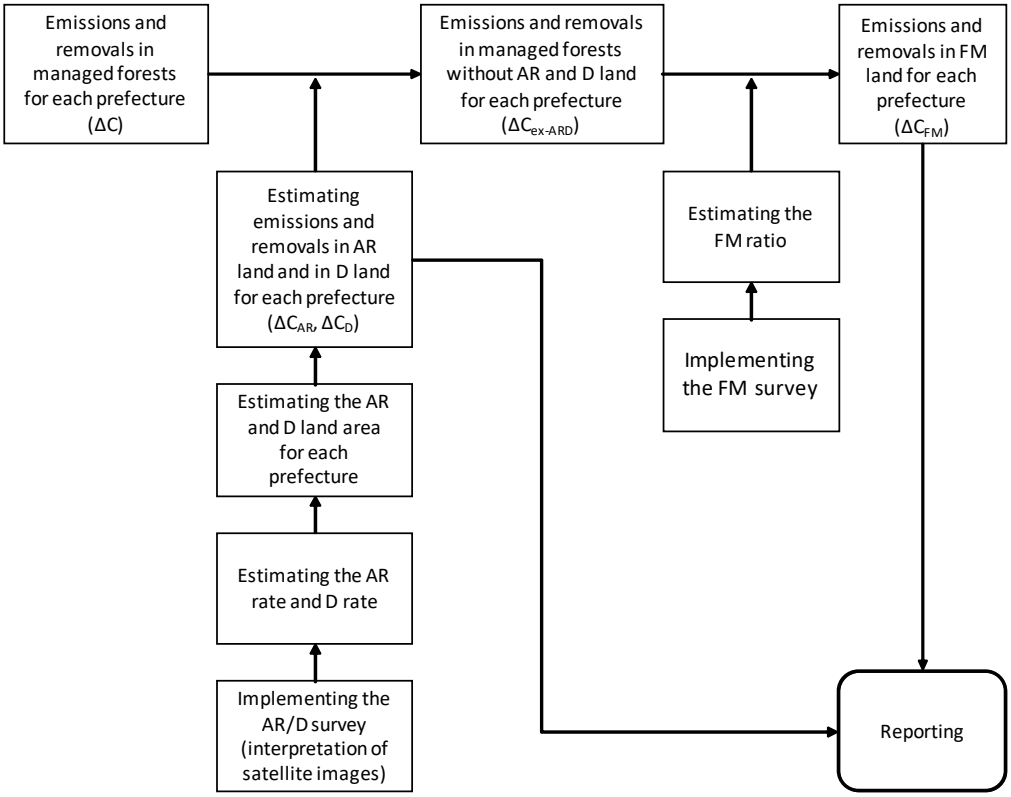


Figure 11-1 Procedures to estimate emissions and removals for AR, D and FM activities

### 11.4.2.3. Afforestation/Reforestation and Deforestation

### 11.4.2.3.a. Methodology and Procedure

#### *a) Plot design*

Japan identifies the change of forest cover in each sample plot by using orthophotos taken at the end of 1989 and recent satellite images, considering the spatial assessment unit (area 0.3 ha and width 20 m). Plots identified as non-forest land converted to forest land due to human-induced forestation practice are categorized as AR plot, and plots identified as forest land converted to non-forest land are categorized as D plot (Hayashi et al., 2008). The plots on the whole country are set in a grid with an interval of 500 m, which are approximately 1,500 thousand plots in total. Satellite images since 2005 are used for the following time series to count the number of AR and/or D plots occurring from the end of 1989 up to recent images by comparing the orthophotos in 1989. Interpretation is annually done for the half of the total number of plots and it takes two years to complete one cycle of interpretation covering whole land area. AR and D land areas are calculated based on the results of the most recent two sets of interpretation work (Ministry of Agriculture, Forestry and Fisheries, 2018 and 2019). Plots which are difficult to interpret are excluded from "available sample plots" which are used for the estimation of AR or D rates. Furthermore, the land-use status before / after conversion from / to forest land is analyzed from satellite images at each plot point and these data are used for the estimation of previous land-use in AR land and/or of new land-use status in D land.

### *b) Estimate land area of AR and D*

Estimate AR rate for FY1990-FY2018:

Plots recognized as AR from FY1990 to FY2018 are counted from the interpretation by comparison between orthophotos taken at the end of 1989 and the latest two satellite images of SPOT/7HRV-P taken in 2017 and 2018. And after that, the year when all AR plots occurred are detected, using the orthophotos taken at the end of 1989 and the images taken every 2 years since 2005 (see table 11-7 for the data used). For the AR plots occurred between FY1990 and FY2005, the total AR rate for FY1990-2005 was derived by dividing the total number of AR occurrence by the "available sample plots" (i). For those AR plots occurred from 2005 onward, the number of AR that occurred between two images photographed in two year intervals is divided by 2 to estimate the occurrence of AR in a single year and then divided by the "available sample plots". This becomes the AR rate for each year (ii). As one interpretation cycle is completed with 2 works, the number of occurrences is summed up for these two. As it is mentioned above, one cycle is completed in two years, if that is the year when the latter half of interpretation work is not available yet, the results of the latter half interpretation of previous cycle is used to cover the entire land area. The AR rate in 2006 is not included in the calculation above, so the amount of the total AR rate for FY 1990-2005 (i) divided into 16, counted the number of years from 1990 to 2005, is considered as the rate of 2006's AR rate (iii). Finally, the rates from (i), (ii) and (iii) are aggregated to become the total AR rate for FY1990 to FY2018.

Estimate D rate for FY1990-FY2018:

The total D rate for FY 1990-FY2018 is estimated based on the same procedure applied for AR explained above. But, the way of allocation for the rate for 2006 is different from the one in AR rate estimation. D rate for 2006 is estimated through dividing the number of D plots during FY1990-FY2005 by land conversion rate in each fiscal year provided by statistics. The rate for 2005 is alternatively used for 2006.

Estimate land area of AR and D for FY1990-FY2018:

The AR land area for each prefecture during FY1990-FY2018 is calculated by multiplying the land area for each prefecture by the total AR rate during FY1990-FY2018, which is obtained by summating the total AR rates as mentioned above. In the same way, the D land area for each prefecture during FY1990-FY2018 is calculated by multiplying the land area for each prefecture by the D rate during FY1990-FY2018, which is obtained by summating the increase of D rate in each year during FY1990-FY2018.

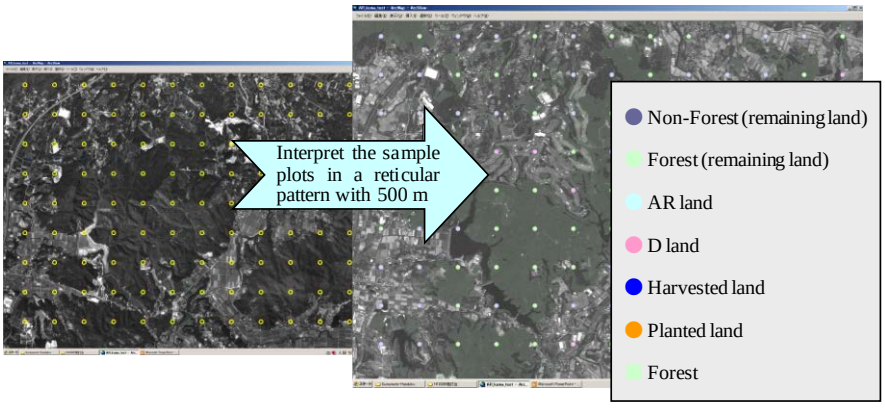


Figure 11-2 ARD land identification by interpreting remote sensing images

Although Forest Registers are used as basic data source for reporting since forests under the forest planning system are considered as forests under the Kyoto Protocol in Japan, orthophotos and satellite images are used for AR and D detection. This is because it is difficult to simulate the forest status during FY1990-FY2005 from the data in the Forest Registers, and to distinguish human-induced AR from forest expansion due to other causes.

With respect to possible over- or under-estimation of D rate based on orthophotos and satellite images, there is a possibility that the D rate may be over-estimated. The reason is that there is a possibility that plots on cut-over forests, which have lost forest cover but not classified as deforested, and those on areas of decreasing tree cover in land other than forest land may be misidentified as D plots. Hence, Japan has implemented field surveys on a part of plots identified as D plots thus far. As a result of the surveys so far, about 90% of plots identified as D plots was actuate, but about 10% was located on cut-over forests or on areas of decreasing tree cover in land other than forest land. In contrast, the result of double-checking a part of plots identified as not changed revealed that there were very few misidentifications; hence, possibility of under-estimation of D rate was extremely low. Therefore, it can be said that possibility of under-estimation of D rate is extremely low, but that the D rate may be over-estimated.

#### 11.4.2.3.b. Data

Japan determines the ARD land area by using the following data.

Table 11-7 Data used in ARD land detection

| | Resolution [m] | Data format |
|---|---|---|
| Ortho air-photo (at the end of 1989) | 1 | Raster |
| SPOT5/HRV-P (2005, 2007 and 2009 - 2014) | 2.5 | Raster |
| SPOT6/7/HRV-P (2015 - 2018) | 1.5 | Raster |

#### 11.4.2.3.c. Land-use change in deforested land

Japan determines the area of D land in accordance with the procedures mentioned in section 11.4.2.3.a. However, these procedures do not cover the continuous tracking of land-use change in D land. Therefore, the land-use change status in the D land has been assessed separately.

Japan has compiled land-use mesh data in the so called “Digital National Land Information” continuously over time. Although this mesh data cannot be used directly to monitor land-use change in the plots identified as D land because this mesh data is not absolutely consistent with the system mentioned in section 11.4.2.3.a (e.g. definition, resolution and land identification method), it can detect the overall tendency of land-use transition in the D plot. The results of the analysis of this mesh data show that D land is seldom converted to other land use again. Therefore, Japan assumes that the status of land use after D will continue to be the same and secondary land-use change will not occur.

### 11.4.2.4. Forest Management

#### 11.4.2.4.a. Procedure

Japan estimates the FM land area for ikusei-rin forests and tennensei-rin forests according to the following procedures. As explained in section 11.3.2.1., forests to which activities for FM have been implemented since 1990 are subject to FM. Hence, if forests do not fulfill this condition, they are not counted as the forests subject to FM even if they are reported as managed forests under the Convention. Therefore, areas of the forests subject to FM are not equivalent to those of the managed forests under the Convention.

Areas subject to forest management are extracted from the areas of remaining managed forests which are determined after the areas of deforestation have been subtracted from the area of the total managed forests of the previous year; hence, the area subject to forest management has reflects the decrease in forest management area resulting from deforestation. This means that the areas subject to forest management are not overestimated.

***a) Ikusei-rin forests***

1. A field survey in private forests and national forests is implemented each year to identify lands which have been subject to FM activities (the number of sample plots are systematically distributed by tree species and regions; then, sample plots are selected randomly from the National Forest Resource Database (NFRDB)).

   Survey items: current status of forests (tree species, stand age, number of trees, etc.), status and contents of practices since 1990, etc.

2. The ratio of these FM land areas (FM ratio) is estimated according to the survey findings.

3. After the AR land area for each prefecture is subtracted from the total forest area, the remaining forest area for each prefecture is multiplied by the FM ratio for each tree species, region and age class.

Table 11-8 FM ratio for ikusei-rin forests (private forests / national forests)

| Sub-category / Tree species | | Region | Private forest | National forest |
|---|---|---|---|---|
| Intensively managed forest | Japanese cedar | Tohoku, Kita-kanto, Hokuriku, Tosan | 0.88 | 0.91 |
| | | Minami-kanto, Tokai | 0.71 | 0.87 |
| | | Kinki, Chugoku, Shikoku, Kyusyu | 0.78 | 0.90 |
| | Hinoki cypress | Tohoku, Kanto, Chubu | 0.83 | 0.92 |
| | | Kinki, Chugoku, Shikoku, Kyusyu | 0.87 | 0.93 |
| | Japanese larch | All | 0.88 | 0.84 |
| | Other | All | 0.70 | 0.83 |
| Semi-natural forest / All | | All | 0.43 | 0.67 |

Note:
1) Data at the end of FY2018. About 22,400 sample plots are located all across the country.
2) These regions generally used broad boundaries which aggregated several prefectures.
3) FM ratios shown in this table are area-weighted average values of FM ratio for each age class.
4) Uncertainty for FM ratios is 5% for entire Japan.

***b) Tennensei-rin forests***

For tennensei-rin forests, forest lands subject to practices for protection or conservation such as controlling logging activities and land-use change which have been carried out under law are identified by the NFRDB. Tennennsei-rin forests under Article3.4 of KP consist of Protection Forests, Special Zones and Special Protection Zones of National Parks and other protected forests/zones as shown in Table 11-9 below. The Protection Forests are designated under article 25 of the Forest Law (legislation No. 249 of 26$^{th}$ June 1951) for the purpose of fulfilling forest multiple functions (such as headwater conservation and disaster prevention). In the Protection Forests, implementing cutting stands, changing land characteristics and related activities without pre-permission are prohibited. In addition, placing signs which show the Protection Forest area, conducting field inspection and monitoring by utilizing satellite images are implemented. With respect to the National Parks, the parks are protected by restriction of development and changing land characteristics, prohibition of hunting animals and

harvesting plants, limitation of people's and vehicles' accesses, based on the Natural Parks Law (legislation No.161 of 1st June, 1957). These measures have been applied to the Tennensei-rin forests under Article 3.4 of KP continuously after FY1990.

Table 11-9 Area of protected/conserved tennensei-rin forests

[Unit: kha]

| Protected / Conserved forest type | Private forest | National forest | Total |
|---|---|---|---|
| Protection Forest | 2,849 | 4,553 | 7,402 |
| Area for Conservation facility installation project | 1 | 0 | 1 |
| Protected Forest | 0 | 603 | 603 |
| Special Protected Zones in National Parks | 44 | 113 | 157 |
| Class I Special Zones in National Parks | 43 | 164 | 207 |
| Class II Special Zones in National Parks | 142 | 201 | 343 |
| Special Protected Zones in Quasi-National Parks | 9 | 37 | 46 |
| Class I Special Zones in Quasi-National Parks | 31 | 104 | 135 |
| Class II Special Zones in Quasi-National Parks | 94 | 84 | 178 |
| Special Zone in National Environment Conservation Area | 1 | 9 | 10 |
| Special Seed Forest | 1 | 1 | 1 |
| Total | 3,214 | 5,869 | 9,083 |
| (excluding duplicate designations) | (2,735) | (4,311) | (7,046) |

Reference: Data source: NFRDB (1st April 2019)

Note: This table includes forests with less standing trees.

### 11.4.2.4.b. Data

#### *a) Basic data for estimation*

The basic data sources for FM estimation are Forest Registers and yield tables developed by prefectures or regional forest offices. Some of the yield tables are developed by the Forestry and Forest Products Research Institute. These Forest Registers and yield tables are also used for reporting under the Convention. Detailed information on Forest Registers and yield tables is provided in section 6.5.1.b) 1), Chapter 6 of this report.

#### *b) Development of the National Forest Resources Database*

To estimate emissions from or removals by forests, the Forestry Agency has developed the NFRDB. In the NFRDB, Forest Registers which are the basic data source for estimation and report, administrative information including forest planning maps and geographical location data such as orthophotos and satellite images like Landsat-TM and SPOT are archived.

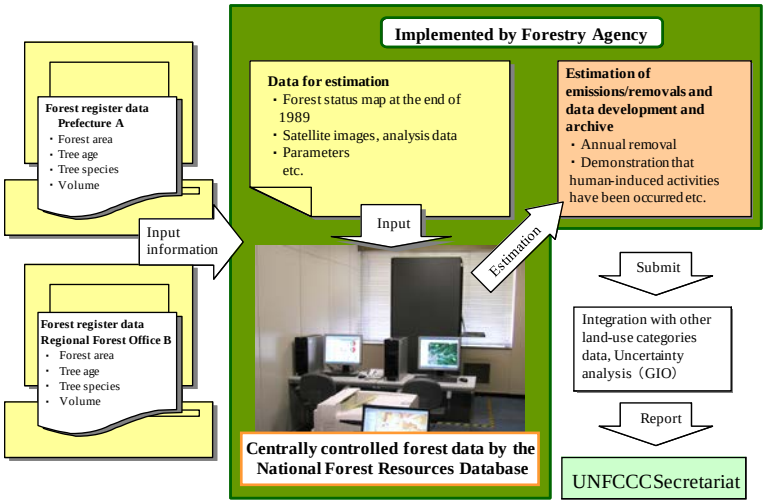


Figure 11-3 Summary of the National Forest Resources Database

### 11.4.2.5. Cropland Management

Basically, current cropland is subject to CM, area of CM was obtained from *Statistics of Cultivated and Planted Are*a by the MAFF in each prefecture for each land-use category (rice fields, upland fields and orchards). The data source and definition of land use are the same as reporting of LULUCF under the Convention (see section 6.6 in Chapter 6 in this NIR).

Since, land which was converted from forest land to cropland is classified as D activity, area of CM were calculated by subtracting the area of cropland converted from forest land since 1990 obtained from the D survey, from the current area of rice fields, upland fields and orchards in each prefecture.

The land converted from cropland between 1991 and 2012 was not been included in the estimation because the land is not subject to CM activity in accordance with *the KP Supplement.*

In accordance with paragraph 24 of the annex to the decision 2/CMP.7, the land converted from cropland in the second commitment period since 2013 is included in area of CM activity; hence, the annul decrease area of cropland for each land-use category (rice fields, upland fields and orchard) in each prefecture obtained from *Statistics of Cultivated and Planted Are*a by the MAFF, etc. was included in area as "current non-cropland subject to CM activity". However, as planting on cropland is classified as AR activity, the decrease of cropland area is calculated by subtracting annual area of afforestation (AR) in cropland since 2013, from the area subject to CM activity.

### 11.4.2.6. Grazing Land Management

Method of determining and procedure for GM area are the same as the CM. Using the cultivation area of pasture in each prefecture obtained from *Statistics of Cultivated and Planted Area* by the MAFF as base data, GM area was calculated by identifying area of current pasture, current non-pasture converted from pasture since 2013, past-pasture area subject to D activity and subject to AR activity by using the same method as CM.

### 11.4.2.7. Revegetation

#### 11.4.2.7.a. Procedure

Japan estimates the RV land area by types of urban green facilities according to the following procedures.

***a) Urban parks***

1. The information on the notification date and the establishment areas are sorted out as of the end of each corresponding fiscal year during the commitment period for all urban parks which are installed in our country.

2. The urban parks which have been notified since 1 January 1990 and whose establishment area is 500 $m^2$ or more are extracted.

3. The urban parks extracted in step 2 are sorted out by geographical boundaries (prefectures) are counted.

4. The area of land which was classified as forest land on 31 December 1989 is calculated by multiplying the establishment area estimated in step 3 by the sum of the area ratios of "Land that has been converted from forest land to settlements per annum" since 1990 until each corresponding fiscal year during the commitment period. This area is excluded from the establishment areas because it is classified as D. The remaining area is considered as RV land area.

5. The areas of "Remaining land (settlements remaining settlements)" and "Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)" are calculated by multiplying the land area estimated in step 4 by the area ratio of "Land converted to settlements" in the single year[5].

***b) Green areas on roads***

1. The number of tall trees at the end of each corresponding fiscal year during the commitment period is calculated by geographical boundaries (prefectures) based on the results of "Road Tree Planting Status Survey".

2. The number of tall trees on 31 March 1990 is calculated by using linear regression of two surveyed data sets (1986 and 1991) from the "Road Tree Planting Status Survey". Next, the number of tall trees for each prefecture on 31 March 1990 is calculated by multiplying these values by the ratio of the number of tall trees for each prefecture on 31 March 2007. The ratio of the number of tall trees on 31 March 1990 is fixed to the value on 31 March 2007.

3. The number of tall trees which have been planted since 1 April 1990 is calculated by subtracting the value estimated in step 1 from the value in step 2 (RV is considered to be an activity which takes place after 1 January 1990. However, Japan considers RV as an activity after 1 April 1990 because the "Road Tree Planting Status Survey" has been implemented on a fiscal year basis).

4. The ratio of the number of tall trees planted on roads with a planted area less than 500 $m^2$ is estimated by using data from the sampling survey implemented in 2006 (general road: 1.00%, expressway: 0.00%, significance level: 95%).

5. The land area per tall tree is estimated by using modeled data from the sampling survey implemented in 2006 (general road: 0.0062 ha/tree, expressway: 0.0008 ha/tree, significance level: 95%). (These modeled data are calculated by dividing randomly sampled RV land areas by the number of tall trees planted on the land).

6. The area of land planted with tall trees, which is 500 $m^2$ or more, is calculated by multiplying the values estimated in steps 4 and 5 by the number of tall trees for each geographical boundary (prefecture) estimated in step 3.

Area of land where tall trees have been planted since 1 April 1990 and whose size is 500 $m^2$ or more[ha]
= Number of tall trees planted since 1 April 1990 [tree]
× Ratio of the number of tall trees planted on land which is 500 $m^2$ or more [%]
× Land area per tall tree [ha/tree]

7. The area of land which was classified as forest land on 31 December 1989 is calculated by multiplying the area estimated in step 6 by the sum of the area ratios of "Land that has been converted from Forest land to settlements per annum" since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.

8. The areas of "Remaining land (settlements remaining settlements)" and "Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)"

[5] Land-use change from the previous year to each corresponding year is applied when the area ratio of "single year" is used.

are calculated by multiplying the land area estimated in step 7 by the area ratio of "Land converted to settlements" in the single year.

***c) Green areas at ports***

1. The green areas at ports which have been established since 1 January 1990 and which have a service area of 500 $m^2$ or more are extracted. Then, their areas are sorted out by geographical boundaries (All green areas at ports can be reported because they are considered not to be classified as forest land on 31 December 1989).

2. The areas of "Remaining land (settlements remaining settlements)" and "Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)" are calculated by multiplying the land area estimated in step 1 by the area ratio of "Land converted to settlements" in the single year.

***d) Green areas around sewage treatment facilities***

1. The green areas around sewage treatment facilities which have been established since 1 January 1990 and which have a greening area of 500 $m^2$ or more are extracted. Then, their areas are sorted out by geographical boundaries.

2. The area of land which was classified as forest land on 31 December 1989 is calculated by multiplying the greening areas estimated in step 1 by the sum of the area ratios of "Land that has been converted from Forest land to settlements per annum" since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.

3. The areas of "Remaining land (settlements remaining settlements)" and "Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)" are calculated by multiplying the land area estimated in step 2 by the area ratio of "Land converted to settlements" in the single year.

***e) Green areas by greenery promoting systems for private green space***

1. The green areas by greenery promoting systems for private green space which have a greening area (excluding wall green areas) of 500 $m^2$ or more are extracted and their areas are sorted out by geographical boundaries. All of them are activities which took place after 1 January 1990 because greenery promoting systems have been implemented since May 2001.

2. All green areas by greenery promoting systems for private green space to be reported are "Remaining land (settlements remaining settlements)" because they were not classified as Forest land on 31 December 1989, and land-use conversion, if any in recent years, occurred only within settlements.

***f) Green areas along rivers and erosion control sites***

1. The works of greening and erosion and sediment control including hillside works in river zones which have been established since 1 January 1990 and which have a greening area of 500 $m^2$ or more are extracted (greening works: (1) – (8), erosion and sediment control works: (9) – (11) in the following table).

Table 11-10 RV projects in green areas along rivers and erosion control sites and definition of planted land area

| RV works in green areas along rivers and erosion control sites | Definition of planted land area |
|---|---|
| (1) Planting in inspection passage of excavated channel | Area of land from levee wall shoulder to private land |
| (2) Planting in face of river bank of excavated channel | Area of land from levee wall shoulder to private land |
| (3) Planting in backslope banquette | Area of embanked land |
| (4) Planting in levee marginal strip (second-class and third-class) | Area of marginal strip which is subject to greening works |
| (5) Planting in high water channel | Area of land from low-flow channel shoulder to foot of levee slope |
| (6) Planting in retarding basin | Area of retarding basin |
| (7) Planting in lake foreshore | Area of land from low-flow channel shoulder to foot of levee slope |
| (8) Planting in super levee | (Same as planting in excavated channel) |
| (9) Greening under erosion and sediment control works | Area of land which is subject to hillside works |
| (10) Greening under landslide control works | Area of land which is subject to hillside works |
| (11) Greening under steep slope failure prevention works | Area of land which is subject to hillside works |

2. The planted land area in green areas along rivers and erosion control sites for each geographical boundary (prefecture) extracted in step 1 is calculated. Double-counting between RV land and D land is prevented because forested land (on 1 January 1990) is not included in step 1.

3. The land areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 2 by the area ratio of” Land converted to settlements (excluding forest land converted to settlements)” in the single year.

***g) Green areas around government buildings***

1. The green areas around government buildings which have been established since 1 January 1990 and whose RV land area (= total land area - building area) is 500 $m^2$ or more are extracted.

2. The RV land area for each geographical boundary (prefecture) extracted in step 1 is calculated.

3. The area of land which was classified as Forest land on 31 December 1989 is calculated by multiplying the land area estimated in step 2 by the sum of the area ratios of “Land that has been converted from Forest land to settlements per annum” since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.

4. The areas of “remaining land (settlements remaining settlements)” and “land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 3 by the area ratio of “land converted to settlements” in the single year.

***h) Green areas around public rental housing***

1. The green areas around public rental housing which have been established since 1 January 1990 and which have a RV land area (= total land area - building area) of 500 $m^2$ or more are extracted.

2. The RV land area for each geographical boundary (prefecture) extracted in step 1 are calculated.

3. The area of land which was classified as Forest land on 31 December 1989 is calculated by

multiplying the land area estimated in step 2 by the sum of the area ratios of "Land that has been converted from Forest land to settlements per annum" since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.

4. The areas of "Remaining land (settlements remaining settlements)" and "Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)" are calculated by multiplying the land area estimated in step 3 by the area ratio of "Land converted to settlements" in the single year.

#### 11.4.2.7.b. Data

The data applied in estimating RV land area are shown below.

Table 11-11 Data applied in estimating RV land area

| Sub-division | Data type | Method for data collection |
|---|---|---|
| Urban parks | Area for each urban park | Urban Parks Status Survey (conducted every year since FY2008) |
| Green area on roads | Number of tall trees | Road Tree Planting Status Survey (conducted every year since FY2007) |
| | Land area per tall tree | Basic Data Collection Survey on Tall Tree Planting on Roads (February 2007) |
| Green areas at ports | Service area | Complete census (conducted every year since FY2008) |
| Green areas around sewage treatment facilities | Green area | Sewage Treatment Facility Status Survey (conducted every year since FY2008) |
| Green areas by greenery promoting systems for private green space | Greening area<br>Wall greening area<br>Number of tall trees | Application form for greenery promoting systems for private green space<br>Urban Greening Status Survey (conducted every year since FY2008) |
| Green areas along river and erosion control sites | Planted land area | Survey on carbon dioxide absorption at source in river works (conducted every year since FY2008) |
| Green areas around government buildings | Total land area and building area | Complete census (conducted every year since FY2008) |
| Green areas around public rental housing | Total land area and building area | Progress survey on tree planting for public rental housing (conducted every year since FY2008) |

### 11.4.3. Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

Section 2.2.2 of *the KP Supplement* shows two methods for identifying and reporting the units of land subject to Article 3.3 activities and lands subject to Article 3.4 activities. Reporting Method 1 entails delineating areas that include multiple land units subject to Article 3.3 and 3.4 activities by using legal, administrative, or ecosystem boundaries. Reporting Method 2 is based on the spatially explicit and complete geographical identification of all units of land subject to Article 3.3 activities and all lands subject to Article 3.4 activities.

Japan elects Reporting Method 1 in accordance with the decision tree indicated in Figure 2.2.2 in Chapter 4 of *the KP Supplement*, which means that the entire national land is stratified by using the geographic boundary of prefectures, and the total area of each "unit of land" subject to each Article 3.3 activity and each "land" subject to each Article 3.4 activity is reported within each boundary. The identification code is determined for each prefecture as shown in the following map (see Table 11-12). Each activity under Articles 3.3 and 3.4 is detected as described in sections 11.4.2.3-11.4.2.7 and the units of land or lands subject to it are identified within prefectural boundaries in accordance with

Reporting Method 1.

This geographical boundary is applied for all units of land: units of land subject to activities under Article 3.3, units of land subject to activities under 3.3 which would otherwise be included in land subject to forest management or elected activities under Article 3.4, under the provisions of paragraph 9 of the annex to the decision 2/CMP.7, and lands subject to forest management and to nay elected activities under Article 3.4.


Figure 11-4 Japan's determination of identification codes

Table 11-12 Identification codes and prefectures

| ID | Prefecture | ID | Prefecture | ID | Prefecture | ID | Prefecture | ID | Prefecture |
|---|---|---|---|---|---|---|---|---|---|
| 01 | Hokkaido | 11 | Saitama | 21 | Gifu | 31 | Tottori | 41 | Saga |
| 02 | Aomori | 12 | Chiba | 22 | Shizuoka | 32 | Shimane | 42 | Nagasaki |
| 03 | Iwate | 13 | Tokyo | 23 | Aichi | 33 | Okayama | 43 | Kumamoto |
| 04 | Miyagi | 14 | Kanagawa | 24 | Mie | 34 | Hiroshima | 44 | Oita |
| 05 | Akita | 15 | Niigata | 25 | Shiga | 35 | Yamaguchi | 45 | Miyazaki |
| 06 | Yamagata | 16 | Toyama | 26 | Kyoto | 36 | Tokushima | 46 | Kagoshima |
| 07 | Fukushima | 17 | Ishikawa | 27 | Osaka | 37 | Kagawa | 47 | Okinawa |
| 08 | Ibaraki | 18 | Fukui | 28 | Hyogo | 38 | Ehime | | |
| 09 | Tochigi | 19 | Yamanashi | 29 | Nara | 39 | Kochi | | |
| 10 | Gunma | 20 | Nagano | 30 | Wakayama | 40 | Fukuoka | | |

## 11.5. Activity-specific information

### 11.5.1. Methods for carbon stock change and GHG emission and removal estimates

#### 11.5.1.1. Description of the methodologies and the underlying assumptions used

#### 11.5.1.1.a. Afforestation/Reforestation

***a) Above-ground biomass, Below-ground biomass***

- ***Methodology***

The carbon stock change in living biomass in AR land ($\Delta C_{AR\_LB}$) was calculated by summing the loss of carbon stock due to conversion ($\Delta C_{LB\_conversion\_to\_AR}$) and the carbon stock change occurred after conversion ($\Delta C_{AR\_LB\_SC}$).

$$\Delta C_{AR\_LB} = \Delta C_{LB\_conversion\_to\_AR} + \Delta C_{AR\_LB\_SC}$$

| | |
|---|---|
| $\Delta C_{AR\text{-}LB}$ | : Annual carbon stock change in living biomass in AR [t-C/yr] |
| $\Delta C_{LB\_conversion\_to\_AR}$ | : Annual carbon stock change due to land conversion to Forest land (loss) [t-C/yr] |
| $\Delta C_{AR\text{-}LB\_SC}$ | : Annual carbon stock change due to biomass growth, felling, fuelwood gathering, disturbance in living biomass in AR [t-C/yr] |

The loss of carbon stock due to conversion ($\Delta C_{LB\_conversion\_to\_AR}$) was calculated using the same method as "Land converted to Forest land (4.A.2)".

$$\Delta C_{LB\_conversion\_to\_AR} = \sum_i \left\{ \Delta A_{i-AR} \times \left( B_{after} - B_{before_i} \right) \times CF_i \right\}$$

| | |
|---|---|
| $\Delta A_{i\text{-}AR}$ | : Annual increase of land area that has been converted from land-use type *i* to forest [ha/yr] |
| $B_{after}$ | : Dry matter weight per unit area immediately after conversion to forest [t-d.m./ha] (assumed to be zero) |
| $B_{before\ i}$ | : Dry matter weight per unit area before conversion from land-use type *I* to forest [t-d.m./ha] |
| $CF_i$ | : Carbon fraction of dry matter in land-use type *i* [t-C/t-d.m.] |
| *i* | : Type of land use (rice field and upland field, orchard, grassland, wetlands, settlements and other land) |

Regarding the carbon stock change occurred after conversion ($\Delta C_{AR\_LB\_SC}$), the same method of the Tier 2 stock difference method as "Forest land remaining Forest land (4.A.1)" was used. See section 6.5.1.b)1) for estimation equations and their parameters.

- ***Parameters***

The biomass stock data for each land use category to estimate carbon stock change due to land conversion are provided in Table 6-8a, Chapter 6 of this report.

- ***Activity data***

The activity data is AR land area which was calculated by using the procedure described in section 11.4.2.3 of this report.

### *b) Dead wood, Litter and Soils*

- ***Methodology***

The carbon stock changes in dead wood, litter and soils in AR land were calculated using the same method as "Land converted to Forest land (4.A.2)" with the assumption that it takes 20 years to reach the average carbon stocks in forest land with linearly increase from carbon stock in land before conversion. See section 6.5.2.b)2) for estimation equations.

As mentioned in section 6.5.1.b).2), soil drainage activities for organic soil in forest land are not implemented in general in Japan, and it is considered as same for forests subject to AR activity. Therefore, the emissions from organic soils are reported as "NO".

- ***Parameters***

The parameters are determined based on the CENTURY-jfos model and relevant literature.

- ***Activity data***

The AR land area is calculated by using the procedure described in section 11.4.2.3 of this report.

### *c) Harvested Wood Products (HWP)*

HWP from forest land subject to AR activity was reported as "NO" because wood supply for HWP from AR land do not occur in Japan.

### *d) Other gases*

#### *1) Direct and inderect $N_2O$ emissions from N fertilization*

The amount of nitrogen-based fertilizer applied in Forest land cannot be separated to those in AR and in FM. Hence, $N_2O$ emissions from N fertilization are reported in FM in a lump. Therefore, this category in AR has been reported as "IE".

#### *2) $N_2O$ and $CH_4$ emissions from drainage of soils*

Soil drainage in forest land with organic soils is not implemented in Japan. $N_2O$ and $CH_4$ emissions from organic soils in forest land do not occur and were reported as "NO".

#### *3) $N_2O$ emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils*

Since soil carbon stock changes in AR are reported to be on the increases, according to method under Tier 2 described in *the 2006 IPCC Guidelines*, $N_2O$ emissions from N immobilization associated with gain of soil organic matter were not estimated. Therefore, $N_2O$ emissions from this subcategory in AR land were reported as "NA". Since "NA" could not be entered in the CRF Reporter for this category, they were reported as "NO" in the CRF-Table NIR 1.

#### *4) Biomass burning*

GHG emissions from wild fire exist in Japan as explained in section 6.16.b) 1), Chapter 6 of this report. Since there is no data which directly express biomass burning status in AR land, GHG emissions in AR land are estimated by multiplying GHG emissions due to fire for all forest land by the ratio of AR land area to all forest land area. Carbon released due to fire for all forest land (national forests and private forests) is estimated by multiplying the damaged timber volume due to fire by wood density, biomass expansion factor and carbon fraction of dry matter. Calculations only for non-CO2 emissions are

performed since $CO_2$ emissions are already included in the calculation of carbon stock change. Moreover, controlled burning activities in forests and land converted from land-use categories other than forest land to forest land are not implemented in Japan because of severe restrictions imposed by the "Waste Management and Public Cleansing Law" and the "Fire Defense Law".

***e) Results***

Table 11-13 Net emissions and removals from AR activity

| | | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|
| | | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] |
| AR | | -1,558.42 | -1,562.77 | -1,562.41 | -1,561.77 | -1,535.62 | -1,441.91 |
| | Above-ground biomass | -892.21 | -891.03 | -891.25 | -887.57 | -864.55 | -848.64 |
| | Below-ground biomass | -227.58 | -227.17 | -223.08 | -222.22 | -221.94 | -217.61 |
| | Dead wood | -309.25 | -319.54 | -327.24 | -334.57 | -336.16 | -274.62 |
| | Litter | -97.82 | -94.18 | -89.79 | -85.42 | -79.79 | -66.64 |
| | Soils | -31.58 | -30.95 | -31.07 | -32.00 | -33.29 | -34.42 |
| | Harvested wood products (HWP) | NO | NO | NO | NO | NO | NO |
| | Other gases | 0.02 | 0.11 | 0.03 | 0.01 | 0.11 | 0.01 |

### 11.5.1.1.b. Deforestation

***a) Above-ground biomass, Below-ground biomass***

- ***Methodology***

The carbon stock change in living biomass in D land ($\Delta C_{D\_LB}$) was estimated by adding the living biomass loss in forests due to land conversion ($\Delta C_{LB\_conversion\_to\_others}$) and carbon stock change due to growth of living biomass in D land after land conversion ($\Delta C_{D\_LB\_SC}$).

The loss of living biomass of forest due to land conversion ($\Delta C_{LB\_conversion\_to\_others}$) was estimated from data in the NFRDB taking into account the status of D land such as tree species and stand ages, and all carbon losses were allocated as emissions in the year of land conversion.

The carbon stock change due to growth of living biomass ($\Delta C_{D\_LB\_SC}$) was estimated depending on land uses after conversion in D land. The land-use categories, where living biomass growth after conversion is calculated, were "land converted to cropland", "land converted to grassland" and "land converted to settlements" as with reporting of LULUCF under the Convention. The growth of living biomass which was increased after D practices, i.e. the carbon gain which was occurred under the land subject to both Article 3.3 and 3.4 activities, was reported under D activity. The calculation was performed according to land-use status immediately after conversion in D land with the assumption that D land was seldom converted to other land uses again as explained in section 11.4.2.3.c.

$$\Delta C_{D\_LB\_SC} = \Delta C_{D-CL\_LB\_SC} + \Delta C_{D-GL\_LB\_SC} + \Delta C_{D-SL\_LB\_SC}$$

$$\Delta C_{D-CL\_LB\_SC} = \Delta A_{D-annualcrop} \times C_{annualcrop\_LB}$$

$$\Delta C_{D-GL\_LB\_SC} = \Delta A_{D-GL,5} \times b_{GL}$$

$$\Delta C_{D-SL\_LB\_SC} = \Delta C_{RV\_LB\_SC} \times RA_{D-RV}$$

$\Delta C_{D\_LB\_SC}$ : Annual carbon stock change due to living biomass growth after D activity [t-C/yr]

$\Delta C_{D\text{-}CL\_LB\_SC}$ : Carbon stock change due to living biomass growth in cropland subject to D activity [t-C/yr] (Estimated for annual crop only. All carbon stock change in Orchard is included in CM because of the applied method)

$\Delta C_{D\text{-}GL\_LB\_SC}$ : Carbon stock change due to living biomass growth in grassland subject to D activity [t-C/yr]

$\Delta C_{D\text{-}SL\_LB\_SC}$ : Carbon stock change due to living biomass growth in settlements subject to D activity [t-C/yr]

$\Delta A_{D\text{-}annualcrop}$ : Area of rice field and upland field in cropland subject to D activity within a year [ha/yr]

$C_{annualcrop\_LB}$ : Carbon accumulation in living biomass per area for annual crop in rice field or upland field in cropland [t-C/ha/yr]

$\Delta A_{D\text{-}GL,5}$ : Area of grassland subject to D activity within the past 5 years [ha]

$b_{GL}$ : Annual carbon stock change in living biomass per area in grassland [t-C/ha/yr]

$\Delta C_{RV\_LB\_SC}$ : Carbon stock change in living biomass due to all RV practices [t-C/yr] (see section 11.5.1.1.f)

$RA_{D\text{-}RV}$ : Ratio of the area subject to both D and RV activities within all areas subject to RV activities

- ***Parameters***

Information relating to loss of forest biomass is obtained from the NFRDB. Table 6-8b in Chapter 6 of this report were used to calculate the carbon stock changes due to living biomass growth after D activity. The parameters for estimating carbon stock change due to RV practices are the same as those used for RV activity.

- ***Activity data***

The D land area is calculated by the method described in section 11.4.2.3. The D land area where RV practices have been taken place is calculated by the method described in section 11.5.1.1.f.

### *b) Dead wood, Litter and Soils*

The carbon stock change in dead wood, litter and soils associated with D is calculated in accordance with the Tier 2 method in the *2006 IPCC Guidelines*. Japan assumes that all carbon stocks in dead wood and litter are emitted at the time when D activities occur. The carbon stock change in mineral soils is calculated under the assumption that it takes 20 years to reach the soil carbon stocks in non-forest land with linearly increase from carbon stocks in forest land. Carbon stocks before conversion were set by the data obtained from the CENTURY-jfos model and carbon stocks after conversion were established based on the data in Tables 6-9 to 6-11 in Chapter 6 of this report.

Land-use changes from forest land with organic soils hardly occur in Japan, however, the emissions from organic soils were reported in the case of forest conversion to settlements from this submission, as it was assumed that the emissions from organic soils would occur under the sites with constructions. As for estimation method, the same estimation equations as section 6.6.1.b)2) in Chapter 6 in this NIR was used to estimate on-site $CO_2$ emissions from organic soils and off-site $CO_2$ emissions via waterborne carbon losses from drained inland organic soils.

### *c) Harvested Wood Products (HWP)*

Carbon stock change of HWP in D land was reported as “IO” because HWP from D land was accounted for on the basis of instantaneous oxidation in accordance with the decision 2/CMP.7.

### *d) Other gases*

#### *1) Direct and indirect $N_2O$ emissions from N fertilization*

The fertilization in deforestation process has not been implemented in Japan. $N_2O$ emissions from N fertilization in land after conversion are included in the estimation of the agriculture sector. Therefore, the emissions in this category were reported as “IE”.

#### *2) $N_2O$ and $CH_4$ emissions from drainage of soils*

As in the case b) above, estimation was made only when land-use changes from forest land to

settlements with organic soils occurred.$CH_4$ emissions from drainage of organic soils were estimated by applying Tier 1 method described in section 2.2.2.1 in the *Wetland Guidelines*, as in Chapter 6, section 6.13.b) The estimation of $N_2O$ emissions from drainage of organic soils were not covered as the method in the *Wetland Guidelines* were not applied.

***3) $N_2O$ emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils***

$N_2O$ emissions from nitrogen mineralization associated with loss of soil organic matter were calculated by using Tier 1 estimation method described in the *2006 IPCC Guidelines*. The estimation equation and parameters used are the same as section 6.14 in Chapter 6 in this NIR. All carbon losses due to deforestation are regarded as annual loss of soil carbon of N mineralized in mineral soils.

***4) Biomass burning***

In Japan, controlled burning activities are not carried out in deforestation activities and on the lands after conversion because of severe restrictions imposed by the "Waste Management and Public Cleansing Law" and the "Fire Defense Law". In addition, wild fires do not occur on all land after conversion. Therefore, $CH_4$, CO, $N_2O$, and $NO_x$ emissions from biomass burning in D land are reported as "NO".

***e) Results***

Table 11-14 Net emissions and removals from D activity

| | | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|
| | | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] |
| D | | 2,049.45 | 2,055.14 | 2,274.41 | 2,274.72 | 1,611.15 | 1,605.29 |
| | Above-ground biomass | 1,082.34 | 1,089.37 | 1,203.73 | 1,207.06 | 850.98 | 850.49 |
| | Below-ground biomass | 263.07 | 265.78 | 297.32 | 298.15 | 206.72 | 208.91 |
| | Dead wood | 512.80 | 511.92 | 560.86 | 558.58 | 396.39 | 395.10 |
| | Litter | 206.59 | 206.56 | 227.31 | 227.54 | 161.96 | 161.98 |
| | Soils (mineral) | -17.94 | -21.13 | -17.57 | -19.45 | -8.79 | -14.46 |
| | Soils (organic) | 2.09 | 2.16 | 2.23 | 2.31 | 2.37 | 2.43 |
| | Harvested wood products (HWP) | IO | IO | IO | IO | IO | IO |
| | Other gases | 0.50 | 0.48 | 0.53 | 0.53 | 1.53 | 0.85 |

## 11.5.1.1.c. Forest Management

***a) Above-ground biomass, Below-ground biomass***

- ***Methodology***

1. Emissions/removals in all forest lands are estimated from biomass stock data in the NFRDB (based on the stock difference method).

2. Emissions/removals relating to AR and D activities are subtracted from emissions/removals in all forest land. For ikusei-rin forest, emissions/removals in FM land are estimated by applying the FM ratio for each tree species, region and age class[6,7]. For tennensei-rin forest, the areas of forest land

[6] Only a part of stock losses may be accounted for as FM removals/emissions, when carbon stock changes obtained through the stock change method are multiplied by the FM ratios. In order to avoid this, all stock losses resulted from harvesting are included in the estimation of FM removals/emissions.

[7] When prefectures and Regional Forest Offices update the Forest Registers, the Registers' data like tree species or areas may be revised in order to reflect the current status of forests. In this case, FM removals/emissions are modified to obtain values based on appropriate carbon stock changes. Without modification, the difference between carbon stock without revision at a time point and carbon stock with revision at another time point would be regarded as the carbon stock change between the two points of time under the stock change method, and it would not reflect the correct removals or emissions.

with standing trees subject to practices for protection or conservation activities such as controlling logging activities and land-use change which have been implemented under laws are identified by using the NFRDB, and emissions/removals are estimated.

- ***Parameters***

The parameters are the same as those used for AR.

***b) Dead wood, Litter and Soils***

- ***Methodology***

The carbon stock changes in dead wood, litter and mineral soil pools were estimated by using the same method of the Tier 3 method as "Forest land remaining Forest land (4.A.1)". It was estimated by multiplying carbon emissions/removals per area in each pool, which were calculated by the CENTURY-jfos model for each type of forest management, by the land area of each type of forest management and then summating them. See section 6.5.1.b)2) for estimation equations of this report.

$CO_2$ emissions from organic soil do not occur because soil drainage activities for organic soil in forest land were not implemented in Japan. Therefore, this category is reported as "NO".

- ***Parameters***

Detailed explanation of the CENTURY-jfos model and its parameters are provided in section 6.5.1.b) 2), Chapter 6 of this report.

***c) Harvested Wood Products (HWP)***

HWP under FM is the same of the HWP reporting of LULUCF under the Convention; carbon stock change in sawnwood, wooden board, and plywood used in buildings were estimated by using Tier 3 country-specific method. As for wood used for other than buildings (sawnwood, wooden board, plywood) and paper and paperboard (including waste paper), Tier 2 method described in *the KP Supplement* were used for calculation. The estimation equation, parameters used and activity data are the same as section 6.11 in Chapter 6 in this NIR.

***d) Other gases***

***1) Direct and indirect $N_2O$ emissions from N fertilization***

The amount of nitrogen-based fertilizer applied in Forest land cannot be separated to those in AR and in FM. Hence, $N_2O$ emissions from N fertilization are reported in FM in a lump. With respect to the methodology and parameters applied to this category, see section 6.12, Chapter 6, of this report.

***2) $N_2O$ and $CH_4$ emissions from drainage of soils***

Soil drainage activity for organic soils in forest land does not occur in Japan, this category is reported as "NO".

***3) $N_2O$ emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils***

$N_2O$ emissions from N mineralization associated with loss of soil organic matter is estimated by using Tier 1 method described in the *2006 IPCC Guidelines*. The estimation method and parameters are the same as section 6.14 and section 6.15 in Chapter 6 in this NIR. The activity data is gross loss of soil carbon which was extracted from land that soil carbon has reduced by each tree age and tree species in

each prefecture.

***4) Biomass burning***

Emissions due to biomass burning are estimated in the same way as in the case of AR by multiplying GHG emissions due to fire for all forest land by the ratio of FM land area to all forest land area. Calculations are performed only for non-$CO_2$ emissions since $CO_2$ emissions are already included in the calculation of carbon stock change. Moreover, controlled burning activities in forests are not implemented in Japan because of severe restrictions imposed by the "Waste Management and Public Cleansing Law" and the "Fire Defense Law".

***e) Results***

Table 11-15 Net emissions and removals from FM activity

| | | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|
| | | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] |
| FM | | -51,149.26 | -51,449.41 | -49,215.52 | -46,649.87 | -46,469.11 | -45,360.92 |
| | Above-ground biomass | -41,420.51 | -40,832.63 | -38,858.34 | -36,821.49 | -36,224.38 | -35,184.14 |
| | Below-ground biomass | -10,471.12 | -10,344.76 | -9,817.10 | -9,426.52 | -9,263.86 | -8,931.71 |
| | Dead wood | 2,019.47 | 2,090.48 | 2,143.54 | 2,178.69 | 2,147.73 | 2,074.22 |
| | Litter | -199.72 | -195.36 | -184.00 | -163.95 | -160.65 | -151.00 |
| | Soils | -1,516.68 | -1,454.63 | -1,392.36 | -1,329.38 | -1,275.96 | -1,210.13 |
| | Harvested wood products (HWP) | 344.25 | -822.94 | -1,207.75 | -1,186.73 | -1,809.03 | -2,062.00 |
| | Other gases | 95.04 | 110.43 | 100.48 | 99.51 | 117.04 | 103.84 |

### 11.5.1.1.d. Cropland Management

***a) Above-ground biomass, Below-ground biomass***

- ***Methodology***

The carbon stock change in living biomass under CM ($\Delta C_{CM\_LB}$) was calculated for the changes of carbon stock in perennial crop (orchard) and annual crop ($\Delta C_{orchard\_LB\_SC}$ and $\Delta C_{annualcrop\_LB\_SC}$) as well as the loss of carbon stock in living biomass due to conversion from cropland ($\Delta C_{orchard\_LB\_SC}$ and $\Delta C_{LB\_conversion\_to\_others}$). Carbon stock changes in living biomass in orchard were estimated by using the same method of Tier 2 stock-difference method as "Cropland remaining Cropland (4.B.1)". The carbon stock change in annual crop is estimated only when land conversion from and to cropland. No carbon stock change was assumed when annual cropland remaining annual cropland. Thus, when land conversion to rice fields or upland fields occurred (except for deforestation), the increase to the average in carbon stock associated with the growth of annual crops due to those conversions ($\Delta C_{annualcrop\_LB\_SC}$) was estimated. When rice fields or upland fields are converted to other land-use categories (except for afforestation or reforestation), the loss in carbon stock associated with loss of annual crops due to those land conversion were included under CM calculation as it was described in section 11.3.4.

The estimation equations were described below and see Table 6-8 and section 6.6.1.b)1) of the report for the parameters and activity data used.

$$\Delta C_{CM\_LB} = \Delta C_{orchard\_LB\_SC} + \Delta C_{annualcrop\_LB\_SC} - \Delta C_{LB\_conversion\_to\_others}$$

$$\Delta C_{annualcrop\_LB\_SC} = \Delta A_{others-annualcrop} \times C_{annualcrop\_LB}$$

$$\Delta C_{LB\_conversion\_to\_others} = \Delta A_{annualcrop-others} \times C_{annualcrop\_LB}$$

$\Delta C_{CM-LB}$ : Carbon stock change in living biomass in CM [t-C/yr]

$\Delta C_{orchard\_LB\_SC}$ : Carbon stock change in living biomass in orchard [t-C/yr] (see 6.6.1.b)1))

$\Delta C_{annualcrop\_LB\_SC}$ : Carbon stock change (gain) in living biomass of annual crops in rice fields and upland field [t-C/yr]

$\Delta C_{LB\_conversion\_to\_others}$ : Carbon stock change (loss) due to land conversion from cropland [t-C/yr]

$\Delta A_{others-annualcrop}$ : Annual area converted from other non-forest land-use category to cropland (rice fields or upland fields) [ha/yr]

$C_{annualcrop\_LB}$ : Carbon stocks in living biomass of annual crops per unit area in rice fields and upland fields [t-C/ha]

$\Delta A_{annualcrop-others}$ : Area converted from rice fields and upland field to other non-forest land-use categories[ha/yr]

### *b) Dead Wood, Litter*

Dead wood and litter in rice fields and in upland fields do not occur. In orchards, the practices that accumulate dead organic matter on the soil are not implemented. Therefore, carbon stocks are not changed over time and are not net sources. Hence, the carbon stock changes are treated as “NA” and reported as “NR” in the CRF-NIR table 1.

### *c) Soils*

- ***Methodology***

#### *1) Mineral soil*

Carbon stock changes in mineral soils in CM were estimated by applying the tier 3 model (Roth C) estimation method. As described in section 6.6.1.b) 2) in Chapter 6 in this NIR, mesh data have been used as input data of Roth C model and carbon stock changes were calculated by Roth C model in each grid (100 x 100 meter mesh). From the result of grid level calculation, the average carbon stock changes per unit area were estimated by prefecture and by land use subcategory (rice field, upland fields and orchards). This output (carbon stock change per unit area) was multiplied by the area in each prefecture and land use subcategory from statistics, and then the final results of carbon stock change were obtained. For the input parameters and data for Roth C model and annual fluctuation and main drivers of soil carbon stock change in mineral soil in CM, see section 6.6 in Chapter 6 in this NIR.

#### *2) Organic soil*

On-site $CO_2$ emissions from organic soils in rice fields and in upland fields were estimated by applying Tier 1, 2 described in the *2006 IPCC Guidelines*. Off-site $CO_2$ emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields were estimated by applying Tier 1 described in section 2.2.1.2 in the *Wetlands Guidelines.* In Orchard, it was reported as "NO" because tillage and drainage were not implemented. When those area is converted to settlements, emissions from drainage of organic soils converted from cropland to settlements during the second commitment periods were also reported under CM. For detailed information on the method, see section 11.5.1.1.b.b) and 6.6.1.b) 2) in Chapter 6 in this NIR.

- ***Parameters***

Parameters used are the same as section 6.6.1.b) 2) in Chapter 6 in this NIR.

- ***Activity data***

Regarding area subject to CM activity in current cropland obtained by using method described in section 11.4.2.6, areas of mineral soil and organic soil were estimated by the ratio of organic soil in each

prefecture, and were regarded as activity data, respectively. The emissions from drainage of organic soils under land converted to settlements reported under CM activity were estimated at the cumulative areas of conversion during the second commitment period in each sub-category level that "the area converted from pasture land, upland and orchard to settlements" multiplied by the ratio of organic soils in each sub-category. For calculation of ratio of organic soil in cropland, see section 6.6.1.b)2) in Chapter 6 in this NIR.

***d) Other gases***

***1) $CH_4$ emissions from drainage of soils***

$CH_4$ emissions from drainage of organic soils in upland fields were estimated by applying Tier 1 method described in section 2.2.2.1 in the *Wetlands Guidelines*. The estimation equation and parameters used are the same as section 6.13 in Chapter 6 in this NIR. The activity data is the same as section 6.6.1.b) 2) in Chapter 6 in this NIR.

***2) $N_2O$ emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils***

Since the emissions from cropland converted from other-land use is subject to CM, the emissions calculated for reporting of LULUCF under the Convention are reported. The estimation equation and parameters used and activity data are the same as section 6.14 in Chapter 6 in this NIR.

***3) Biomass burning***

Since $CO_2$ emissions are already included in the calculation of carbon stock change, non-$CO_2$ emissions from burning of pruned branches from orchard trees were reported as part of the GHG emissions in CM land. In addition, emissions from wild fires are not reported, as it is considered almost impossible that wild fires occur under our farmland management system. The estimation method, parameters and activity data are the same as section 6.16.b) 2) in Chapter 6 in this NIR.

***e) Results***

Table 11-16 Net emissions from CM activity

| | | 1990 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|
| | | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] |
| CM | | 10,265.40 | 3,693.26 | 4,475.96 | 4,413.01 | 4,916.91 | 4,139.15 | 3,720.57 |
| | Above-ground biomass | 157.89 | 157.22 | 190.57 | 234.15 | 261.18 | 240.74 | 255.82 |
| | Below-ground biomass | 118.80 | 54.45 | 51.86 | 66.36 | 65.42 | 62.41 | 76.69 |
| | Dead wood | NA | NA | NA | NA | NA | NA | NA |
| | Litter | NA | NA | NA | NA | NA | NA | NA |
| | Soils (mineral) | 8,235.39 | 1,807.13 | 2,557.89 | 2,436.91 | 2,915.61 | 2,156.06 | 1,700.60 |
| | Soils (organic) | 1,652.36 | 1,613.70 | 1,615.07 | 1,615.51 | 1,615.39 | 1,619.22 | 1,625.92 |
| | Non-$CO_2$ (organic soil) | 35.96 | 34.81 | 34.86 | 34.91 | 34.96 | 35.15 | 35.53 |
| | Non-$CO_2$ (N mineralization) | 32.86 | 3.62 | 3.66 | 3.50 | 3.04 | 4.60 | 5.46 |
| | Non-$CO_2$ (biomass burning) | 32.13 | 22.33 | 22.04 | 21.67 | 21.31 | 20.97 | 20.57 |

## 11.5.1.1.e. Grazing Land Management

***a) Above-ground biomass, Below-ground biomass***

- ***Methodology***

The carbon stock change in living biomass under GM ($\Delta C_{GM\_LB}$) was calculated from the carbon stock change occurred after conversion ($\Delta C_{GM\_LB\_SC}$) and the loss of carbon stock in living biomass due to conversion from pasture land ($\Delta C_{LB\_conversion\_to\_others}$). No carbon stock change is assumed when Grazing land is remaining Grazing land. The estimation equation, parameters and activity data used were the

same as Table 6-8, sections 6.7.2.b) 1) in Chapter 6 and 11.4.2.6 in Chapter 11 in this NIR.

***b) Dead Wood, Litter***

It is assumed that carbon stocks in dead wood and litter in grassland do not change in Japan, according to the *2006 IPCC Guidelines*. Therefore, the carbon stock changes are treated as "NA" and are reported as "NR" in the CRF-Table NIR 1 because these carbon pools are not net sources of GHGs.

***c) Soils***

- ***Methodology***

***1) Mineral soil***

Carbon stock changes in mineral soils in GM were estimated by applying the tier 3 model (Roth C) estimation method. For detailed information on the method, see section 6.6.1 b 2) in Chapter 6 in this NIR. For the annual fluctuation and main drivers of soil carbon stock change in mineral soil in GM, see section 6.7 in Chapter 6 in this NIR.

***2) Organic soil***

On-site $CO_2$ emissions from organic soils in pasture land were estimated by applying the Tier 1 estimation method described in section 6.2.3.1 in the *2006 IPCC Guidelines*. The estimation method is the same as cropland remaining cropland. Off-site $CO_2$ emissions via waterborne carbon losses from drained inland organic soils were estimated by applying Tier 1 estimation method described in the *Wetlands Guidelines*. Emissions from drainage of organic soils, whose areas were converted from GM during the second commitment periods and currently used as non-pasture land, were also reported under GM. For detailed information on the method, see section 11.5.1.1.b.b) and section 6.7.1.b) 2) in Chapter 6 in this NIR, as described in CM section.

- ***Parameters***

Parameters used are the same as section 6.7.1.b) 2) in Chapter 6 in this NIR.

- ***Activity data***

Regarding area subject to GM activity in current pasture land obtained by using method described in section 11.4.2.6, areas of mineral soil and organic soil were estimated by using the ratio of organic soil by prefecture, and were used for estimating as activity data, respectively. As explanation described in Box1.1 in *the KP Supplement*, since emissions and removals are treated as zero, the area subject to GM activity in current non-pasture land is not included in activity data to be used for the estimation. For calculation of ratio of organic soil in pasture land, see section 6.7.1.b) 1) in Chapter 6 in this NIR.

***d) Other gases***

***1) $CH_4$ emissions from drainage of soils***

$CH_4$ emissions from drainage of organic soils in pasture land were estimated by applying Tier 1 method described in section 2.2.2.1 in the *Wetlands Guidelines*. The estimation equation and parameters used are the same as section 6.13 in Chapter 6 in this NIR. The activity data is the same as section 6.7.1.b) 1) in Chapter 6 in this NIR.

***2) $N_2O$ emissions from N mineralization/immobilization due to carbon loss/gain associated with***

***land-use conversions and management change in mineral soils***

Estimation equation, parameters used and activity data are the same as section 6.14 in Chapter 6 in this NIR.

***3) Biomass burning***

Emissions from biomass burning in GM were reported as "NO" because open burning in pasture land do not occur in Japan.

***e) Results***

Table 11-17 Emissions and removals from GM activity

| | | 1990 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|
| | | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] | [kt-$CO_2$ eq.] |
| GM | | 840.17 | -189.55 | 9.46 | -69.51 | -117.74 | -127.20 | -209.20 |
| | Above-ground biomass | -10.76 | 13.65 | 17.88 | 15.04 | 16.72 | 21.20 | 20.67 |
| | Below-ground biomass | -43.03 | 54.60 | 71.50 | 60.16 | 66.90 | 84.78 | 82.67 |
| | Dead wood | NA | NA | NA | NA | NA | NA | NA |
| | Litter | NA | NA | NA | NA | NA | NA | NA |
| | Soils (mineral) | 860.47 | -297.34 | -126.34 | -194.22 | -239.61 | -272.54 | -353.41 |
| | Soils (organic) | 28.88 | 33.21 | 39.68 | 42.50 | 32.90 | 33.81 | 35.06 |
| | Non-$CO_2$ (organic soil) | 2.26 | 2.73 | 3.39 | 3.77 | 3.17 | 3.37 | 3.64 |
| | Non-$CO_2$ (N mineralization) | 2.36 | 3.61 | 3.36 | 3.24 | 2.18 | 2.18 | 2.17 |

## 11.5.1.1.f. Revegetation

Methodologies for estimating GHG emissions and removals from RV activity are described in two cases: when RV activity is performed on the land where no land conversion has occurred (remaining land) and on the land where land conversion has occurred (Conversion Land).

***a) Remaining land: Above-ground biomass, Below-ground biomass***

Japan estimates the carbon stock change in above-ground biomass and below-ground biomass of tall trees planted in RV lands. Tall trees are consistent with the definition in "Standards for the quality and size of planted trees for the public (draft)[8]".

- ***Methodology***

The carbon stock change in living biomass under "remaining land" was estimated by using the same equation of the Tier 2b as described in "Settlements remaining Settlements (4.E.1.)" See section 6.9.1.b)1) of this NIR.

- ***Parameters[9]***

The parameters at each type of urban green facility were described below.

➢ ***Urban parks***

Carbon stock changes due to the loss of living biomass in urban parks are assumed to be zero based on Tier 2b method in the *2006 IPCC Guidelines* (p. 8.9), because the average age of trees is found to be

[8] "Standards for the quality and size of planted trees for the public (draft)" was decided by the Ministry of Land, Infrastructure, Transport and Tourism in order to promote proper enforcement of projects such as greening in public spaces. Tall tree is defined in the standards as tree which reaches 3 ~ 5 m in height.

[9] The Tier 1b method described in the *2006 IPCC Guidelines* and the Tier 2b method with country-specific annual biomass growth rates are applied for the estimation of the annual growth rate of living biomass per tree. Japan will further improve the accuracy of this estimation.

less than or equal to 30 years in the tree survey for sample urban parks[10] (*Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism (MLIT)*, 2014).

The annual living biomass growth of trees in urban parks is calculated by using the country-specific value for annual growth rate of living biomass per tree, which was developed by combining the default values (0.0033-0.0142 t-C/tree/yr) provided in the *2006 IPCC Guidelines* (p. 8.10, Table 8.2) and the country specific annual growth rates of living biomass for the trees in Japan (0.0204 for Japanese zelkova, 0.0103 for ginkgo, 0.0095 for bamboo-leaf oak and 0.0122 t-C/tree/yr for camphor tree) by taking into account the distribution ratio of tree species in sample urban parks[11]. The annual growth rates of living biomass for Japanese zelkova, ginkgo, bamboo-leaf oak and camphor tree are calculated by using the growth curve for each tree species (Matsue et al., 2009), which were developed based on the results of surveys conducted by the National Institute for Land and Infrastructure Management (NILIM) of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the average trunk diameter at breast height for each tree species (Parks and Green Spaces Division of the MLIT, 2005), which were determined from the results of surveys in urban parks.

For the ratio of above-ground biomass/below-ground biomass, the default value (root-to-shoot ratio: 0.26) provided in the *2006 IPCC Guidelines* (p. 8.9) is applied.

- ***Green areas on roads***

Carbon stock changes due to the loss of living biomass in green areas on roads are assumed to be zero, because the average age of trees is found to be less than or equal to 30 years for those trees planted in randomly extracted green areas on roads.

The annual living biomass growth in green areas on roads is calculated by using the country-specific value for annual growth rate of living biomass per tree, which was developed by combining the default values and the annual growth rates of living biomass for the trees in Japan (4 species), which were also used for the urban parks, taking into account the distribution ratio of tree species indicated by the surveys in green areas on roads[12].

For the ratio of above-ground biomass/below-ground biomass, the same value used for urban parks is applied.

- ***Urban green areas other than Urban parks, Green areas on roads and Green areas by greenery promoting systems for private green space***

Carbon stock changes due to the loss of living biomass in these green areas are assumed to be zero, because the standard of planted trees, tree types and their distribution are applied in the same manner as in urban parks.

The annual living biomass growth and the ratio of above-ground biomass/below-ground biomass are the same parameters as for urban parks.

[10] 129 samples were randomly extracted from the urban parks notified after 1 January 1990 and located in Kanagawa prefecture, which is located in Japan's typical climate zone and has various types of urban parks. In addition, the same survey was implemented in 3 urban parks in Chiba prefecture, which is located next to Kanagawa prefecture, in order to cover the park types that did not exist in Kanagawa prefecture.

[11] The distribution ratio of tree types was calculated by using tree registers and plantation maps for all urban parks in Kushiro city and Yubari city in Hokkaido and for 321 randomly extracted urban parks in the other prefectures.

[12] The distribution ratio of tree types is taken from the *Road Tree Planting Status Survey (The Street tree of Japan VI)*, which covered green areas on roads throughout Japan.

➢ ***Green areas by greenery promoting systems for private green space***

Carbon stock changes due to the loss of living biomass in these green areas are assumed to be zero, because the standard of planted trees is selected in the same manner as in urban parks and all facilities have been certified since 2002.

The annual living biomass growth and the ratio of above-ground biomass/below-ground biomass are the same parameters as for urban parks.

- ***Activity data***

➢ ***Urban parks***

The area of land remaining urban parks is calculated by multiplying the area of urban parks by the area ratio of land conversion for the whole country. The activity data for carbon stock changes in living biomass in urban parks is the number of tall trees planted in urban parks which is calculated by multiplying the area of urban parks obtained from the "Urban Parks Status Survey" by the number of tall trees per area (Hokkaido: 329.5 tree/ha, the other prefectures: 222.3 tree/ha). The number of tall trees per area is calculated based on the number of tall trees and the land areas of sample urban parks. Sample number was intended to satisfy the significance level of 95%.[13]

Table 11-18 Area of urban parks which were not classified as forest land on 31 December 1989

At the end of FY2018

| | Land-use category | Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2018 | Area [ha] | Classified as RV land |
|---|---|---|---|---|
| Urban parks which have been notified since 1st January 1990 and whose establishment area is 500 $m^2$ or more | Forest | 5.49% | 3,482.45 | No |
| | Non-forest | 94.51% | 59,982.14 | Yes |
| | Total | 100.00% | 63,464.59 | - |

Table 11-19 Area of urban parks which have been classified as RV and activity data (remaining land / converted land)

At the end of FY2018

| | Land-use category | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|---|
| Urban parks which have been notified since 1st January 1990 and whose establishment area is 500 $m^2$ or more (classified as RV land) | Converted (except land converted from forest land) | 0.37% | 220.98 | 51,682 |
| | Remaining | 99.63% | 59,761.15 | 13,976,561 |
| | Total | 100.00% | 59,982.14 | 14,028,243 |

➢ ***Green areas on roads***

The activity data (the number of tall trees) in "Remaining green areas on roads" is calculated by the following procedures.

1. The number of tall trees in all green areas on roads on 31 March 1990 and in the end of each corresponding fiscal year during the commitment period is estimated by using data from the "Road Tree Planting Status Survey" which have been implemented in FY1987, FY1992 and each

[13] The number of tall trees per area in urban parks was calculated by using data from tree registers and planting maps for randomly extracted 176 sample urban parks in Hokkaido and 321 sample urban parks in the other prefectures.

corresponding fiscal year.

2. The number of tall trees planted after 1 April 1990 was calculated by subtracting the number at 31 March 1990 from the number for the end of each corresponding fiscal year (RV is an activity which takes place after 1 January 1990. However, Japan considers it an activity after 1 April 1990 because it is impossible to estimate the number of tall trees which have been planted between 1 April 1990 and 31 March 1990).

3. The number of tall trees calculated in step 2 is multiplied by the ratio of the number of tall trees planted on roads whose planted area is more than 500 $m^2$.

4. The number of tall trees calculated in step 3 is multiplied by the area ratio of green areas on roads, which were classified as "Forest land" on 31 December 1989.

5. The number of tall trees calculated in step 4 is multiplied by the area ratio of "Land remaining settlements".

Table 11-20 Area of green areas on roads which have been classified as RV

At the end of FY2018

| | Area of green areas on roads per tall tree [ha/tree] | Number of planted tall trees [tree] | | | Area ratio of planted lands which are 500 $m^2$ or more [%] | Area ratio of land which was classified as forest land on 31st December 1989 [%] | Area of green areas on roads which was classified as RV land [ha] | Activity data [Number of tall trees] |
|---|---|---|---|---|---|---|---|---|
| | | 31st March 1990 | 31st March 2019 | FY1990 - FY2018 | | | | |
| | a | b | c | c-b | d | e | a*(c-b)*d/100*(100-e)/100 | (c-b)*d/100*(100-e)/100 |
| General roads (managed by the MLIT, Prefectures, local authorities, public corporations) | 0.006237 | 4,342,070 | 6,898,885 | 2,556,815 | 99.00% | 5.49% | 14,921 | 2,392,270 |
| Expressway (managed by now-defunct public corporation) | 0.000830 | 1,096,380 | 8,896,993 | 7,800,613 | 100.00% | 5.49% | 6,119 | 7,372,575 |
| Total | - | 5,438,450 | 15,795,878 | 10,357,428 | - | - | 21,039 | 9,764,845 |

Note: MLIT: Ministry of Land, Infrastructure, Transport and Tourism

Table 11-21 Area of green areas on roads which have been classified as RV and activity data [number of tall trees] (remaining land / converted land)

At the end of FY2018

| | | Land-use category | Area ratio of land which has been converted in the current year | Activity data [Number of tall trees] | Area [ha] |
|---|---|---|---|---|---|
| Green areas on roads which have been notified since 1st January 1990 and whose establishment area is 500 $m^2$ or more (classified as RV land) | | Converted | 0.37% | 35,975 | 77.51 |
| | | Remaining | 99.63% | 9,728,870 | 20,961.60 |
| | | Total | 100.00% | 9,764,845 | 21,039.11 |
| | General roads | Converted | 0.37% | 8,813 | 54.97 |
| | | Remaining | 99.63% | 2,383,457 | 14,865.62 |
| | | Total | 100.00% | 2,392,270 | 14,920.59 |
| | Expressway | Converted | 0.37% | 27,161 | 22.54 |
| | | Remaining | 99.63% | 7,345,413 | 6,095.98 |
| | | Total | 100.00% | 7,372,575 | 6,118.52 |

Note: "Converted": except land converted from forest land.

### ➢ *Green areas at ports*

The activity data for carbon stock changes in living biomass in green areas at ports is the number of tall trees planted in green areas at ports. The activity data is calculated by multiplying the service area obtained from complete census by the number of tall trees per unit area of urban parks (329.5 trees/ha for Hokkaido and 222.3 trees/ha for the other prefectures). These values were adopted by taking into account the similarities between the urban parks and the green areas at ports as mentioned above. All green areas at ports are located in "settlements" and judged not being classified as "Forest land" on 31 December 1989.

Table 11-22 Area of green areas at ports and activity data (remaining land / converted land)

At the end of FY2018

| Land-use category | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|
| Converted | 0.37% | 6.88 | 1,562 |
| Remaining | 99.63% | 1,859.72 | 422,445 |
| Total | 100.00% | 1,866.60 | 424,007 |

### ➢ *Green areas around sewage treatment facilities*

The area of land remaining green areas around sewage treatment facilities is calculated in the same manner as for urban parks. The activity data for carbon stock change in living biomass in green areas around sewage treatment facilities are obtained from the "Sewage Treatment Facility Status Survey" for each fiscal year during the commitment period. The number of tall trees planted in green areas around sewage treatment facilities is calculated by multiplying the greening areas by the number of tall trees per greening area (129.8 tree/ha for Hokkaido and 429.2 tree/ha for the other prefectures).[14] All green areas around sewage treatment facilities are located in "settlements".

Table 11-23 Area of green areas around sewage treatment facilities which were not classified as "Forest land" on 31 December 1989

At the end of FY2018

| Land-use category | Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2018 | Area [ha] (Green areas) | Classified as RV land |
|---|---|---|---|
| Forest | 5.49% | 38.67 | No |
| Non-forest | 94.51% | 666.04 | Yes |
| Total | 100.00% | 704.71 | - |

Table 11-24 Area and activity data of "Green areas around sewage treatment facilities" [number of tall trees] (remaining land / converted land)

At the end of FY2018

| Land-use category | Area ratio of land has been converted for the current year | Area [ha] (Green areas) | Activity data [Number of tall trees] |
|---|---|---|---|
| Converted (except land converted from forest land) | 0.37% | 2.45 | 997 |
| Remaining | 99.63% | 663.59 | 269,514 |
| Total | 100.00% | 666.04 | 270,511 |

[14] The number of tall trees per area for green areas around sewage treatment facilities was established by using data on the number of tall trees and greening areas measured in 59 green areas.

### ➢ *Green areas by greenery promoting systems for private green space*

Activity data (the number of tall trees) is available for each facility. Therefore, the total number of tall trees is used as activity data.

Table 11-25 Activity data and area of "Green areas by greenery promoting systems for private green space"

| Certification year | Location | Area [$m^2$] | Breakdown of area [$m^2$] | | | Area | Activity data |
|---|---|---|---|---|---|---|---|
| | | | Ground | Roof | Wall | Wall green area by greenery promoting system for private green space [$m^2$] | Number of tall trees [tree] |
| 2002 | Minato-ku, Tokyo | 17,244 | 1,314 | 2,042 | 106 | 3,356 | 335 |
| 2002 | Minato-ku, Tokyo | 19,708 | 3,285 | 736 | 0 | 4,021 | 147 |
| 2002 | Minato-ku, Tokyo | 52,766 | 10,679 | 0 | 0 | 10,679 | 672 |
| 2002 | Minato-ku, Tokyo | 84,780 | 8,846 | 9,386 | 0 | 18,232 | 813 |
| 2003 | Minato-ku, Tokyo | 5,519 | 1,374 | 280 | 0 | 1,654 | 167 |
| 2003 | Osaka City | 22,282 | 1,527 | 3,164 | 110 | 4,691 | 500 |
| 2005 | Kawaguchi City | 1,995 | 586 | 164 | 18 | 750 | 153 |
| 2006 | Kyoto City | 3,857 | 1,271 | 0 | 0 | 1,271 | 90 |
| 2006 | Hiroshima City | 4,453 | 130 | 783 | 0 | 913 | 1 |
| 2007 | Hiroshima City | 14,353 | 4,058 | 0 | 0 | 4,058 | 261 |
| 2007 | Fukuoka City | 5,689 | 773 | 799 | 0 | 1,572 | 19 |
| 2008 | Ishikawa Prefecture | 7,281 | 682 | 1,411 | 0 | 2,093 | 19 |
| 2009 | Setagaya-ku, Tokyo | 5,526 | 1,116 | 0 | 0 | 1,116 | 51 |
| 2009 | Setagaya-ku, Tokyo | 6,459 | 1,370 | 0 | 0 | 1,370 | 15 |
| Total | | 251,912 | 37,011 | 18,765 | 234 | 55,776 | 3,243 |

Note: There were no areas certified from FY2010 to FY2018.

### ➢ *Green areas along rivers and erosion control sites*

The area of land remaining green areas along rivers and erosion control sites is calculated by multiplying the area of this green area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is calculated by multiplying this area by the number of tall trees per area (Hokkaido: 1470.8 tree/ha, the other prefectures: 339.0 tree/ha).[15]

The green areas along rivers and erosion control sites exclude lands, which were classified as Forest land at the time of survey. Therefore, land conversion from Forest land is not taken into account for the estimation of activity data.

Table 11-26 Activity data and area of "Green areas along rivers and erosion control sites" (remaining land / converted land)

At the end of FY2018

| | Land-use category | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|---|
| Green areas along rivers and erosion control sites which have been established since 1st January 1990 and whose establishment area is 500 $m^2$ or more (classified as RV land) | Converted (except land converted from forest land) | 0.37% | 6.44 | 3,556 |
| | Remaining | 99.63% | 1,740.71 | 961,555 |
| | Total | 100.00% | 1,747.15 | 965,111 |

### ➢ *Green areas around government buildings*

The area of land remaining green area around government buildings is calculated by multiplying the

[15] For green areas along rivers and erosion control sites, the number of tall trees was measured in approximately 95% of this green area. Based on these data, the number of planted trees per area was estimated in order to simplify the estimation of the number of tall trees in all green areas.

area of this green area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is calculated by multiplying this area by the number of tall trees per area (all prefecture: 108.8 tree/ha).[16]

Table 11-27 Area of "Green areas around government buildings" which were not classified as "Forest land" on 31 December 1989

At the end of FY2018

| | Land-use category | Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2018 | Area [ha] (Green areas) | Classified as RV land |
|---|---|---|---|---|
| Green areas around government buildings which have been established since 1st January 1990 and whose establishment area is 500 $m^2$ or more | Forest | 5.49% | 18.60 | No |
| | Non-forest | 94.51% | 320.29 | Yes |
| | Total | 100.00% | 338.89 | - |

Table 11-28 Area and activity data of "Green areas around government buildings" (remaining land / converted land)

At the end of FY2018

| | Land-use category | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|---|
| Green areas around government buildings which have been established since 1st January 1990 and whose establishment area is 500 $m^2$ or more (classified as RV land) | Converted (except land converted from forest land) | 0.37% | 1.18 | 128 |
| | Remaining | 99.63% | 319.11 | 34,720 |
| | Total | 100.00% | 320.29 | 34,848 |

- ***Green areas around public rental housing***

The area of land remaining green areas around public rental housing is calculated by multiplying the area of this green area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is calculated by multiplying this area by the number of tall trees per area (all prefecture: 219.9 tree/ha).[17]

Table 11-29 Area of "Green areas around public rental housing" which were not classified as "Forest land" on 31 December 1989

At the end of FY2018

| | Land-use category | Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2018 | Area [ha] (Green areas) | Classified as RV land |
|---|---|---|---|---|
| Green areas around public rental housing which have been established since 1st January 1990 and whose establishment area is 500 $m^2$ or more | Forest | 5.49% | 172.08 | No |
| | Non-forest | 94.51% | 2,963.88 | Yes |
| | Total | 100.00% | 3,135.96 | - |

[16] For green areas around government buildings, the number of tall trees per area was estimated by dividing the number of tall trees by the "total land area – building area" (these data were based on 30 facilities where planting maps were available). The common value is used for all prefectures, since the sample data were not sufficient enough to set values for Hokkaido and the other prefectures, respectively.

[17] For green areas around public rental housing, the number of tall trees per area was estimated for 33 facilities, where planting maps were available, by dividing the number of tall trees by the area "total land area – building area". The common value is used for all prefectures, since the sample data were not sufficient enough to set values for Hokkaido and the other prefectures, respectively.

Table 11-30 Area and activity data of "Green areas around public rental housing" (remaining land / converted land)

At the end of FY2018

| | Land-use category | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|---|
| Green areas around public rental housing which have been established since 1st January 1990 and whose establishment area is 500 $m^2$ or more (classified as RV land) | Converted (except land converted from forest land) | 0.37% | 10.92 | 2,401 |
| | Remaining | 99.63% | 2,952.96 | 649,357 |
| | Total | 100.00% | 2,963.88 | 651,758 |

### *b) Remaining land: Dead wood*

- ***Urban parks***

The number of tall trees per land area used in the estimation of activity data for living biomass includes trees which have died and have been complementary planted since the establishment of the park. Thus, the carbon stock changes in dead wood are thought to be included in the carbon stock changes in living biomass. Therefore, this category is reported as "IE".

- ***Green areas on roads***

The number of tall trees used in the estimation of activity data for living biomass is obtained in the survey every 5 years (implemented every year since 2007). These data include the effects of dead wood and complementary planting, thus the carbon stock change in dead wood is included in the carbon stock changes in living biomass. Therefore, this category is reported as "IE".

- ***Urban green facilities other than Urban parks and Green areas on roads***

These categories are reported as "IE" based on the same assumption as urban parks.

### *c) Remaining land: Litter*

Carbon stock changes in litter are estimated for urban parks and green areas at ports.

The carbon stock change in litter under "remaining land" was estimated by using the same equation as described in "Settlements remaining Settlements (4.E.1.)". See section 6.9.1.b)2) of this NIR.

- ***Parameters***

The parameters at each type of urban green facility were described below.

- ***Urban parks and Green areas at ports***

Carbon stock changes in litter were estimated only in branches and leaves dropped naturally from tall trees. The carbon stock changes in litter per urban park area are calculated by using the annual accumulation of litter per tall tree (all prefectures: 0.0006 t-C/tree/yr) based on the results of a field survey in urban parks[18], the number of tall trees per area and the ratio of litter moved to off-site due to management including cleaning (54.4%). As a result, carbon stock change in litter per urban park area is calculated to be 0.0882 t-C/ha/yr for Hokkaido and 0.0594 t-C/ha/yr for other prefectures. In addition,

[18] The annual accumulation of litter dropped naturally was measured for some tree types by using litter traps installed in Takino Suzuran Kyuryo National Government Park (Hokkaido) and Showa Kinen National Government Park (Tokyo). Litter is defined as branches and leaves dropped on the surface. In the selection of parks for the survey, large-sized and intensively managed national government parks in which continuous monitoring is available and different types of trees have been planted are considered to meet the measurement requirements. In addition, it is also considered that the distribution of tree types differs between Hokkaido and other prefectures. Therefore, Japan selected two parks for the survey, one in Hokkaido and the other in a typical climate zone excluding Hokkaido.

the carbon fraction in litter is assumed to be 0.4 t-C/t-d.m., which is a default value provided in the *2006 IPCC Guidelines* (p.8.21).

➢ ***Urban green facilities other than urban parks and green areas at ports***

Litter in these urban green facilities includes branches and leaves dropped naturally and dead roots. A part of the litter remains on-site and leads to an increase in carbon stocks, although other litter is moved to off-site due to management such as cleaning (such litter is dropped from trees planted after the establishment of green areas). Dead roots also lead to an increase in carbon stocks because they are not moved to off-site.

It is clear that the litter in the urban green facilities other than urban parks and green areas at ports because the input of fallen branches and leaves and dead roots into these facilities increases carbon stocks as mentioned above. However, it is difficult to accurately estimate the carbon stock changes in litter in these urban green facilities because of limited information on various managements (such as cleaning). Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

- ***Activity data***

The activity data is the same as for living biomass.

***d) Remaining land: Soils***

Urban parks, for which the carbon stock changes in soils per area were determined, and green areas at ports, whose management practices are similar to those for urban parks, are the subject of estimation. In general, soils in RV land are not organic soils (peat soils and muck soils). Therefore, organic soils are reported as "NO", and only mineral soils are estimated.

- ***Methodology***

The carbon stock change in soils under "remaining land" was estimated by using the same equation as described in "Settlements remaining Settlements (4.E.1.)". See section 6.9.1.b)3) of this NIR.

- ***Parameters***

The parameters at each type of urban green facility were described below.

➢ ***Urban parks and Green areas at ports***

Carbon stock changes in soils per area of RV land are estimated based on the results of surveys[19] conducted in urban parks which have been established within 30 years (1.28t-C/ha/yr for 0~20 years and 1.38t-C/ha/yr for 21~30 years) (Tonosaki et al., 2013; Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 2015)[20].

[19] Soil carbon stocks (at 30 cm depth) were measured for areas with different types of vegetation cover in urban parks (planted: 31 areas, lawn: 29 areas, bare: 21 areas), which are located in Tokyo and were established in different years.

[20] Since urban parks are generally established by turning entire sites into urban parks, soil carbon stocks within the site immediately after establishment are assumed to be uniform irrespective of previous types of vegetation cover. The soil carbon stocks of the area, where basically carbon is not supplied by plants (bare area), are assumed to be the same as soil carbon stocks of sites immediately after conversion. Based on the soil carbon stocks in the areas with different types of vegetation cover (planted, lawn and bare) in urban parks, which were established in different years, "carbon accumulation rates in planted areas" and "carbon accumulation rates in lawn areas" are calculated:

- Carbon accumulation rates in planted areas = "Difference in soil carbon stocks between planted and bare areas" / "Average years after establishment of surveyed planted areas"
- Carbon accumulation rates in lawn areas = "Difference in soil carbon stocks between lawn and bare areas" / "Average years after establishment of surveyed lawn areas"

This value is applicable to land, which is the subject of revegetation activity and was established within 30 years, because the value is based on the results of surveys conducted in urban parks which have been established within 30 years.

➢ ***Urban green facilities other than Urban parks and Green areas at ports***

It is assumed that the patterns of carbon stock changes in soils in these urban green facilities are similar to those in urban parks, because planting, establishment and management practices are implemented in a similar way. The slopes on the expressway, where different plantation practices are applied, are assumed to be a sink, because field surveys have revealed that the carbon stocks keep increasing for at least 20 years after establishment.

However, it is difficult to accurately estimate the carbon stock changes in soils in these urban green facilities because of limited available data. Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs. The estimation for urban green facilities other than urban parks and green areas at ports will be further considered in the future.

- ***Activity data***

The area is as obtained for estimating the activity data for living biomass.

***e) Remaining land: Other gases***

***1) Direct and indirect $N_2O$ emissions from N fertilization***

It is assumed that the volume of nitrogen-based fertilizer applied to urban parks is included in the demand for nitrogen-based fertilizers in the Agriculture sector, although fertilization in urban parks has been conducted in Japan. Therefore, these sources have been reported as “IE”.

***2) $N_2O$ and $CH_4$ emissions from drainage of soils***

Because soil drainage activity for organic soils in RV does not occur in Japan, this category is reported as “NO”.

***3) $N_2O$ emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils***

Since soil carbon stock changes in RV are reported to be on the increases, according to method under Tier 2 described in *the 2006 IPCC Guidelines*, $N_2O$ emissions from immobilization associated with gain of soil organic matter were not estimated. Therefore, $N_2O$ emissions in this subcategory is reported as “NA”.

***4) Biomass burning***

In settlements subjected to RV activities, burning of residues is restricted by the “Waste Management and Public Cleansing Law” and the “Fire Defense Law”. In addition, wild fires do not usually occur in lands subjected to RV activities because these lands are managed. Therefore, biomass burning activities which lead to carbon emissions do not occur and Japan reports this category as “NO”.

Furthermore, changes in soil carbon stocks per area are determined by taking the weighted average based on the typical area ratio among planted, lawn and bare sites in urban parks. The soil carbon stocks of bare area are about 38 t-C/ha when converted from the sample data.

### *f) Land converted from other land-use categories: Above-ground biomass, Below-ground biomass*

- ***Methodology***

For RV activities, land conversion occurs due to the establishment or building of "facilities" and all living biomass is basically replaced in one year. In Japan's basic estimation principles for land converted to RV land, the facilities newly established by land conversion in the reporting year are defined as "Land converted to RV land". The estimation was made by summing the loss of carbon stock due to conversion ($\Delta C_{LB\_conversion\_to\_RV}$) and the carbon stock change occurred after conversion ($\Delta C_{RV\_LB\_SC}$). However, in the case of land conversion that crosses the activities under Article 3.4, the loss of carbon stock due to the conversion was reported under the original activities, as described in section 11.3.4. So, the loss of carbon stock due to conversion from cropland and pasture land was estimated under CM and GM and not reported under RV. Those were estimated by using the same equation as described in "Land converted to Settlements (4.E.2.)". See section 6.9.2.b)1) of this NIR. Moreover, there is no land conversion from RV to other land-use.

- ***Parameters***

➢ ***Urban parks***

The loss of the carbon stocks in living biomass immediately before conversion were estimated under the original activities under Kyoto protocol, as mentioned above. And those in the land conversion from non-Kyoto protocol activities was not estimated due to the parameters set. The carbon stocks in living biomass immediately after conversion are assumed to be zero (When urban parks classified as RV land are established, planting activities occur and living biomass is stocked. It is assumed that these biomass stocks are zero because they are carried from other fields and they are grown by the RV activities). In addition, it is assumed that all living biomass before conversion is lost due to the establishment of RV land. The other parameters are assumed to be the same as the ones for "Remaining urban parks".

➢ ***Urban green facilities other than Urban parks***

The carbon stocks in living biomass immediately before and after conversion [t-C/ha] are the same as those for urban parks converted from other land uses.

The other parameters are assumed to be the same as the ones for "Remaining green area on roads", "Remaining green area at ports", "Remaining green area around sewage treatment facilities", "Remaining green area along rivers and erosion control sites", "Remaining green area around public rental housing" and "remaining green area around government buildings".

- ***Activity data***

➢ ***Urban parks***

The area of land converted to urban parks is calculated by multiplying the area of urban parks by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for "remaining urban parks".

Table 11-31 Area of "Urban parks" and activity data (remaining land /converted land)

At the end of FY2018

| | Land-use category before conversion | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|---|
| Urban parks which have been notified since 1st January 1990 and whose establishment area is 500 $m^2$ or more | Remaining land | 99.63% | 59,761.15 | 13,976,561 |
| | Cropland | 0.32% | 190.94 | 44,655 |
| | Grassland | 0.05% | 30.05 | 7,027 |
| | Wetlands | IE | IE | IE |
| | Other land | IE | IE | IE |
| | Total | 100.00% | 59,982.14 | 14,028,243 |

- ***Green areas on roads***

The area of land converted to green area on roads is calculated by multiplying the area of green areas on roads by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for "remaining green area on roads".

Table 11-32 Area of "Green areas on roads" and activity data for each land-use category

At the end of FY2018

| | Land-use category before conversion | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|---|
| Green areas on roads which have been notified since 1st January 1990 and whose establishment area is 500 $m^2$ or more | Remaining | 99.63% | 20,961.60 | 9,728,870 |
| | Cropland | 0.32% | 66.97 | 31,084 |
| | Grassland | 0.05% | 10.54 | 4,891 |
| | Wetlands | IE | IE | IE |
| | Other land | IE | IE | IE |
| | Total | 100.00% | 21,039.11 | 9,764,845 |

- ***Green areas at ports***

The area of land converted to green areas at ports is calculated by multiplying the service area of green areas at ports by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for "remaining green areas at ports".

Table 11-33 Area of "Green areas at ports" and activity data for each land-use category

At the end of FY2018

| Land-use category before conversion | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|
| Remaining land | 99.63% | 1,859.72 | 422,445 |
| Cropland | 0.32% | 5.94 | 1,350 |
| Grassland | 0.05% | 0.93 | 212 |
| Wetlands | IE | IE | IE |
| Other land | IE | IE | IE |
| Total | 100.00% | 1,866.60 | 424,007 |

- ***Green areas around sewage treatment facilities***

The area of land converted to green areas around sewage treatment facilities is calculated by multiplying the green areas around sewage treatment facilities by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner

as for “remaining green area around sewage treatment facilities”.

Table 11-34 Area of “green areas around sewage treatment facilities” and activity data for each land-use category

At the end of FY2018

| Land-use category before conversion | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|
| Remaining land | 99.63% | 663.59 | 269,514 |
| Cropland | 0.32% | 2.12 | 861 |
| Grassland | 0.05% | 0.33 | 136 |
| Wetlands | IE | IE | IE |
| Other land | IE | IE | IE |
| Total | 100.00% | 666.04 | 270,511 |

- ***Green areas along rivers and erosion control sites***

The area of land converted to green areas along rivers and erosion control sites is calculated by multiplying the planted land area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area along rivers and erosion control sites”.

Table 11-35 Area of “green areas along rivers and erosion control sites” and activity data for each land-use category

At the end of FY2018

| Land-use category before conversion | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|
| Remaining land | 99.63% | 1,740.71 | 961,555 |
| Cropland | 0.32% | 5.56 | 3,072 |
| Grassland | 0.05% | 0.88 | 483 |
| Wetlands | IE | IE | IE |
| Other land | IE | IE | IE |
| Total | 100.00% | 1,747.15 | 965,110 |

- ***Green areas around government buildings***

The area of land converted to green areas around government buildings is calculated by multiplying the “total land area – building area” by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area around government buildings”.

Table 11-36 Area of “green areas around government buildings” and activity data for each land-use category

At the end of FY2018

| Land-use category before conversion | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|
| Remaining land | 99.63% | 319.11 | 34,720 |
| Cropland | 0.32% | 1.02 | 111 |
| Grassland | 0.05% | 0.16 | 17 |
| Wetlands | IE | IE | IE |
| Other land | IE | IE | IE |
| Total | 100.00% | 320.29 | 34,848 |

➢ ***Green areas around public rental housing***

The area of land converted to green areas around public rental housing is calculated by multiplying the "total land area – building area" by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for "remaining green area around public rental housing".

Table 11-37 Area of "green areas around public rental housing" and activity data for each land-use category

At the end of FY2018

| Land-use category before conversion | Area ratio of land which has been converted in the current year | Area [ha] | Activity data [Number of tall trees] |
|---|---|---|---|
| Remaining land | 99.63% | 2,952.96 | 649,357 |
| Cropland | 0.32% | 9.43 | 2,075 |
| Grassland | 0.05% | 1.48 | 326 |
| Wetlands | IE | IE | IE |
| Other land | IE | IE | IE |
| Total | 100.00% | 2,963.88 | 651,758 |

### *g) Land converted from other land use categories: Dead wood*

When a RV activity following land-use conversion is implemented, dead wood is removed off-site and supplemental planting is implemented before conversion because almost all of such lands are managed and trees are assumed to be "property". Therefore, dead wood is not left on the ground immediately before land-use conversion. The carbon stocks in dead wood immediately after conversion are assumed to be zero, the same as living biomass. Therefore, the carbon stocks in dead wood before and after conversion are assumed to be zero.

The carbon stocks in dead wood accumulated for a year after conversion are reported as "IE", the same as for "Remaining land".

### *h) Land converted from other land-use categories: Litter*

Likewise the "remaining land", Japan estimates carbon stock changes in litter in urban parks and green areas at ports only. The other urban green facilities (green areas on roads, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around public rental housing and green areas around government buildings) are not the subject of estimation and are not reported (NR) , since these facilities are not net sources.

- ***Methodology***

➢ ***Urban parks and Green areas at ports***

When urban parks are converted from cropland, grassland or wetlands, soils before conversion are not moved to off-site and in general, these soils are used continuously after conversion or covered by additional soils. Therefore, litters and dead roots accumulated before conversion do not decrease due to the land-use conversion.

In addition, litter in urban parks immediately following conversion is very little, because the parks are newly planted. Therefore, carbon stock changes in litter due to land conversion are assumed to be zero.

The amount of carbon in litter accumulated for a year after conversion is estimated in the same manner as for "Remaining urban parks". See section 11.5.1.1.f.b) for estimation methods.

➢ ***Urban green facilities other than Urban parks and Green areas at ports***

The carbon stock changes in litter due to land-use conversion are assumed to be zero for the same reasons as for urban parks. With respect to after conversion, it is clear that the litter in the urban green facilities other than urban parks and green areas at ports because the input of fallen branches and leaves and dead roots into these facilities increases carbon stocks likewise the "remaining green area on roads", "remaining green area around sewage treatment facilities", "remaining green area along rivers and erosion control sites", "remaining green area around public rental housings" and "remaining green area around government buildings" mentioned above. However, it is difficult to accurately estimate the carbon stock changes in litter in these urban green facilities because of limited information on various managements (such as cleaning). Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

- ***Activity data***

The activity data is the same as for living biomass.

***i) Land converted from other land-use categories: Soils***

Likewise the "remaining land", urban parks and green areas at ports, whose management practices are similar to those in urban parks, are the only subject of estimation.

- ***Methodology***

➢ ***Urban parks and Green areas at ports***

As mentioned in the section for litter, when urban parks are converted from cropland, grassland or wetlands, soils before conversion are almost never moved to off-site (even if moved to off-site, carbon in these soils are not emitted due to combustion). In general, these soils are used after conversion continuously or covered by additional soils.

Therefore, soil carbon stocks do not change due to land-use conversion (the carbon stocks may increase due to additional soils. However, Japan assumes that soil carbon stocks do not change because additional soils do not lead to carbon sequestration from the atmosphere).

Carbon stock changes in soils within a year after conversion is estimated in the same manner as for the remaining urban parks and green areas at ports. See section 11.5.1.1.f.c) for estimation methods.

➢ ***Urban green areas other than Urban parks and Green areas at ports***

The urban green facilities other than urban parks and green areas at ports are not sources of GHGs because of the same reasons as for the "Land converted to urban parks". Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

- ***Activity data***

The area is as used for living biomass.

***j) Land converted from other land-use categories: Other gases***

For reporting each GHG emission, the same way as the RV remaining RV is used.

### *k) Results*

Table 11-38 Emissions and removals from RV activity

| | | 1990 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|
| | | [kt-$CO_2$] | [kt-$CO_2$] | [kt-$CO_2$] | [kt-$CO_2$] | [kt-$CO_2$] | [kt-$CO_2$] | [kt-$CO_2$] |
| RV | | -81.97 | -1,227.59 | -1,246.64 | -1,267.46 | -1,284.96 | -1,307.71 | -1,322.21 |
| | Above-ground biomass | -49.64 | -750.71 | -760.21 | -770.52 | -779.41 | -793.66 | -800.34 |
| | Below-ground biomass | -12.91 | -195.19 | -197.65 | -200.33 | -202.65 | -206.35 | -208.09 |
| | Dead wood | IE | IE | IE | IE | IE | IE | IE |
| | Litter | -0.92 | -12.94 | -13.22 | -13.54 | -13.77 | -13.94 | -14.17 |
| | Soils | -18.49 | -268.75 | -275.56 | -283.07 | -289.14 | -293.76 | -299.62 |
| | Other gases | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO | IE,NA,NO |

For RV activities, various parameters (annual living biomass growth of trees, number of tall trees per area, etc.) which corresponding to specific characteristic of types of urban green facilities (sub-categories) and climatic division (Hokkaido, areas other than Hokkaido), have been applied.

Hence, the total removals per unit of revegetation area in each year are not the same because of composition of the sub-categories are different in each year.

## 11.5.1.2. Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3, forest management and elected activities under Article 3.4

Some carbon pools under RV activities (litter and soils: green areas on roads, green areas around sewage treatment facilities, green areas by greenery promoting systems for private green space, green areas along river and erosion control sites, green areas around public rental housing and green areas around government buildings) are not included in the reporting. Some intermediate results of the ongoing research project relating to RV land by the MLIT show a clear tendency that those carbon pools have been increasing although more research and analysis are necessary to quantify carbon stock changes in these carbon pools (Handa et al., 2008). This does not lead to over-estimation of removals because these carbon pools are not sources of GHGs, although further information and data are needed for estimating carbon stock changes in these carbon pools.

Carbon pools of dead wood and litter in CM and in GM are not included in the reporting. As described in the relevant sections, carbon stock changes in dead wood and litter in CM and in GM were estimated as zero. This does not lead to over-estimation of removals because theses carbon pools are not sources of GHGs.

## 11.5.1.3. Information relating to exclusions of emission from natural disturbances

Japan does not apply to exclusion of emissions from natural disturbances.

## 11.5.1.4. Information relating to Harvest Wood Product (HWP)

- ***Overview and methodologies used***

As described in 11.5.1.1.c), for HWP of the reporting of LULUCF under the Convention, carbon stock change in sawnwood, wooden board, and plywood used in buildings were estimated by using Tier 3 country-specific method. As for wood use other than buildings and paper and paperboard (including waste paper), were calculated by using Tier 2 method described in *the KP Supplement*. The estimation equation and used parameters and activity data are the same as section 6.11 in Chapter 6 in this NIR.

In the reporting under the Kyoto Protocol, the values were estimated by deducting the HWP resulting from deforestation as instantaneous oxidation.

- ***Information on reporting HWP before the second commitment period of the Kyoto Protocol***

As shown in the CRF table 4(KP-I) B.1.1, forest management reference level (FMRL) is not based on a projection in Japan. Therefore, carbon stock changes in the HWP pool before the second commitment period of the Kyoto Protocol were included in the estimation in Japan. The FMRL for reporting five carbon pools (not including HWP) was set as zero in Japan. For the reporting HWP, HWP reference level was set newly based on a projection and reported as technical corrections. For detailed information on setting of HWP reference level, see section 11.7.5.

- ***Information on emissions from HWP calculated already during the first commitment period***

In Japan, emissions from the HWP pool that have been already accounted during the first commitment period of the Kyoto Protocol on the basis of instantaneous oxidation have not been excluded from the accounting for the second commitment period of the Kyoto Protocol, as well as from the HWP reference level. This is because the HWP reference level was set based on a projection. As a result, emissions from the HWP pool that have been accounted for during the first commitment period of the Kyoto Protocol on the basis of instantaneous oxidation has been canceled out and it to be zero.

- ***Information on HWP resulting from D land***

HWP resulting from D have been accounted on the basis of instantaneous oxidation (see section 11.5.1.1.b). For detailed information on methodology, see section 11.5.1.7.

- ***Information on $CO_2$ emissions from HWP in SWDS and logged wood for energy purpose***

The methodologies used for calculating carbon stock change in HWP are explained in section 6.11 in chapter 6 and the same methodologies are applied for reporting of LULUCF under the Kyoto Protocol. Since $CO_2$ emissions from HWP in solid waste disposal site (SWDS) are considered to be similar to incineration and not included in the HWP pool. Also, logged wood for energy purpose is not included in the HWP pool subject to accounting; those emissions from HWP have been accounted on the basis of instantaneous oxidation.

- ***Information on imported HWP***

As Production Approach for calculating carbon stock change in HWP was applied, emissions and removals resulting from changes in the HWP pool accounted for do not include imported HWP (see section 6.11 Chapter 6 in this NIR).

### 11.5.1.5. Information on whether or not indirect and natural GHG emissions and removals have been factored out

Japan does not factor out indirect, natural and pre-1990 effects specified in paragraph 3 in the annex II to decision 2/CMP.8 in estimating emissions/removals from activities under Articles 3.3 and 3.4.

### 11.5.1.6. QA/QC and verification

- ***General inventory QA/QC procedure***

As for reporting of LULUCF under the Kyoto Protocol, general inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines* as with reporting of LULUCF under the Convention. The focus of general inventory QC is on the checking of the parameters for activity data and emissions factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

- ***Verification of Tier 3 estimation method***

For the calculation using Tier 3 method, the following verification activities have been carried out when applying the Roth C model in Japan.

➢ ***Information on activities of calibration and validation***

Although calibration for Roth C estimation method has not been carried out, it was confirmed that the simulation results of Roth C matched well the measured data with selectively using the three modified versions of the Roth C model adopting to different land uses and soil types (Paddy soils, Andosols and non-Andosols). Regarding the suitability of Roth C model for estimating carbon stock changes in mineral soils in CM and GM, the modification and the verification of plot scale using the measured data in long-term field experiments have been carried out.

➢ ***Demonstration that sites of calibration and validation have covered all of soil species and activities***

First of all, it is necessary to divide soils broadly into paddy soils and non-paddy soils depending on whether or not the soils are waterlogged due to the characteristics of soil carbon dynamics. Furthermore, for non-paddy soils, it is appropriate to divide them into Andosols and non-Andosols from the characteristics of soil carbon dynamics. As a result, it is considered appropriate that all agricultural soils to be divided into these three types above.

➢ ***More detailed information on input data***

More detailed information on input data of Roth C model for estimating was described in a research paper listed below.

For detailed information on calibration and validation and input data of Roth C model, see references; Shirato Y, 2006, Shirato.Y & Taniyama.I, 2003, Shirato. Y et al., 2004, Shirato.Y & Yokozawa.M., 2005, Takata.Y et al., 2011, Shirato. Y et al., 2011, Yagasaki. Y et al., 2014 listed in this chapter.

### 11.5.1.7. Changes in data and methods since the previous submission (recalculations)

For reporting of LULUCF under the Kyoto Protocol, recalculation described below was carried out. For the impact of the recalculation, refer to Chapter 10.

- ***Revision of AR and D areas***

In this submission, Japan revised the ARD ratio. As a result, the AR and D areas were recalculated. Due to this revision, carbon stock changes in above-ground biomass, below-ground biomass, litter, dead wood and mineral soils in AR, D and FM from FY2013 to FY2017 were also recalculated.

Due to this revision, the areas of CM, GM and RV were recalculated, so, carbon stock changes in all carbon pools in CM, GM and RV were also recalculated.

Moreover, $CH_4$ and $N_2O$ emissions from biomass burning in AR and FM was recalculated because of this revision in AR area.

- ***Recalculation due to adding a new estimation category under organic soils in the case that the land conversion to Settlements occurred***

It had not been reported emissions from drainage of organic soils from settlements after conversion to settlements, however, based on the figures from survey conducted after receiving the identification in the review 2018 (ARR L.19), it could not be denied that oxidation of organic soils occurred under

construction work, for example, on road in soft ground being conducted on the premise of land subsidence. Thus, we reported the emissions from this submission. With this revision, $CO_2$ and $CH_4$ emissions (on-site and off-site) due to drainage of organic soil and off-site $CO_2$ emission due to water-soluble carbon in organic soil are added under each category of activity.

- ***Recalculation due to adding a new estimation of carbon stock changes in living biomass associated with conversion at cropland for annual crops***

We added a new estimation of carbon stock gain in living biomass associated with conversion to cropland for annual crops and that of carbon stock loss associated with conversion from cropland for annual crops. With this revision, carbon stock changes in living biomass were recalculated in rice fields and upland fields under AR, D and CM activities.

- ***Recalculation due to adding a new estimation of carbon loss in living biomass associated with conversion from pasture land.***

We added a new estimation of carbon stock loss in living biomass associated with conversion from pasture land from this submission. With this revision, carbon stock changes in living biomass were recalculated under AR, D and GM activities.

- ***Recalculation due to revision of allocation of biomass loss associated with conversion.***

Biomass loss due to conversion previously reported under RV was allocated under the original activities where it occurred from CM or GM. With this revision, carbon stock changes in living biomass were recalculated under RV, CM and GM activities.

- ***Revisions of activity data, parameters and equations used for calculating carbon stock change in HWP***

With update of wood supply and demand statistics for FY2017, carbon stock changes for FY2017 were recalculated.

In addition, the outflow values were recalculated for all years due to the correction of the equation for calculating the domestic wood rate in demolition materials and input amount of demolition material per unit area. According to the change of domestic wood rate in demolition materials, the inflow values of wood boards were also recalculated for all years.

With this revision, the carbon stock changes in HWP pools were recalculated.

- ***Revisions of HWP reference level***

HWP reference level was projected by using average value of D area from 2008 to 2012 and also has deducted the inflow resulting from D. Due to the revision of D area as well as some revisions related to AD and EF above mentioned, HWP reference level for FY2013 - FY2017 were recalculated.

### 11.5.1.8. Uncertainty estimates

The uncertainty of the total emissions/removals from activities under Articles 3.3 and 3.4 in FY2018 has been assessed to be -15% to +15%.

See relevant sections of chapters 6 and 11 for uncertainties of respective parameters of the LULUCF sector. Specifically, see Table 11-39 to 11-43 below for detailed information on disaggregated uncertainties on emission factors and activity data used for estimating GHG emissions from and removals by each KP-LULUCF activity.

Table 11-39 Uncertainty of emissions/removals from activities under Articles 3.3 and 3.4 of KP

| Greenhouse gas source and sink activities | GHGs | Emissions/Removals [kt $CO_2$eq.] | | Emissions/Removals Uncertainty [%] | | Emissions/Removals Uncertainty as % of net removals [%] | |
|---|---|---|---|---|---|---|---|
| | | | % | (-)[%] | (+)[%] | (-)[%] | (+)[%] |
| Article 3.3 activities Afforestation and Reforestation | $CO_2$, $N_2O$, $CH_4$ | -1,442 | -3% | -35% | 35% | -1% | 1% |
| Article 3.3 activities Deforestation | $CO_2$, $N_2O$, $CH_4$ | 1,605 | 4% | -23% | 23% | 1% | -1% |
| Article 3.4 activities Forest management | $CO_2$, $N_2O$, $CH_4$ | -45,361 | -105% | -14% | 14% | -15% | 15% |
| Article 3.4 activities Cropland management | $CO_2$, $N_2O$, $CH_4$ | 3,721 | 9% | -40% | 40% | 3% | -3% |
| Article 3.4 activities Grazing land management | $CO_2$, $N_2O$, $CH_4$ | -209 | 0% | -22% | 22% | 0% | 0% |
| Article 3.4 activities Revegetation | $CO_2$, $N_2O$, $CH_4$ | -1,322 | -3% | -33% | 33% | -1% | 1% |
| Total | | -43,008 | -100% | -15% | 15% | | |

### 11.5.1.8.a. Uncertainties of emissions/removals of afforestation/reforestation activities

Uncertainties of emissions/removals in living biomass resulting from AR activities were estimated by applying Tier 1 – error propagation equation – based on uncertainties in accuracy of AR area identification (activity data), in estimation of carbon stock changes in living biomass in forest land, and in carbon stocks before land conversion. Uncertainties of emissions/removals in litter, dead woods and soils were estimated by applying Monte Carlo Analysis in the CENTURY-jfos Model. As a result, the uncertainty of emissions/removals from AR activities in FY2018 has been assessed to be -35% to +35%.

Table 11-40 Uncertainty of emissions and removals from afforestation and reforestation activities

| Greenhouse gas source and sink activities | | | GHGs | Emissions/ Removals [kt $CO_2$ eq.] | AD Uncertainty [%] | | EF/RF Uncertainty [%] | | Combined Uncertainty [%] | | Combined Uncertainty as % of emissions/ removals [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (-)[%] | (+)[%] | (-)[%] | (+)[%] | (-)[%] | (+)[%] | (-)[%] | (+)[%] |
| Article 3.3 activities Afforestation and Reforestation | Change in carbon pool reported | | | | | | | | | | | |
| | | Above-ground biomass | $CO_2$ | -848.64 | -12% | 12% | -43% | 43% | -45% | 45% | -33% | 33% |
| | | Below-ground biomass | $CO_2$ | -217.61 | IE | IE | IE | IE | IE | IE | IE | IE |
| | | Litter | $CO_2$ | -274.62 | - | - | - | - | -51% | 51% | -10% | 10% |
| | | Dead wood | $CO_2$ | -66.64 | - | - | - | - | -22% | 22% | -1% | 1% |
| | | Soil | $CO_2$ | -34.42 | - | - | - | - | -20% | 20% | 0% | 0% |
| | | Harvested wood products (HWP) | $CO_2$ | NO | - | - | - | - | - | - | - | - |
| | Greenhouse gas sources reported | | | | | | | | | | | |
| | | Fertilization | $N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | $N_2O$ emissions from drainage of soils | $N_2O$ | NO | - | - | - | - | - | - | - | - |
| | | $N_2O$ emissions from N mineralization associated with loss of soil organic matter | $N_2O$ | NA | - | - | - | - | - | - | - | - |
| | | Biomass burning | $CO_2$ | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | | $CH_4$ | 0.01 | - | - | - | - | -51% | 51% | 0% | 0% |
| | | | $N_2O$ | 0.001 | - | - | - | - | -53% | 53% | 0% | 0% |
| | Total | | | -1,441.91 | | | | | -35% | 35% | | |

### 11.5.1.8.b. Uncertainties of emissions/removals of deforestation activities

Uncertainties of emissions/removals in living biomass resulting from D activities were estimated, as same as AR activities, by applying Tier 1 – error propagation equation – based on uncertainties in accuracy of D area identification (activity data), in estimation of carbon stock changes in living biomass in forest land, and in growth of living biomass after land conversion. Uncertainties of emissions/removals in litter, dead woods and soils were estimated by applying Monte Carlo Analysis in the CENTURY-jfos Model. As a result, the uncertainty of emissions/removals from D activities in

FY2018 has been assessed to be -23% to +23%.

Table 11-41 Uncertainty of emissions and removals from deforestation activities

| Greenhouse gas source and sink activities | | | GHGs | Emissions/ Removals [kt $CO_2$ eq.] | AD Uncertainty [%] | | EF/RF Uncertainty [%] | | Combined Uncertainty [%] | | Combined Uncertainty as % of emissions/ removals [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (-)[%] | (+)[%] | (-)[%] | (+)[%] | (-)[%] | (+)[%] | (-)[%] | (+)[%] |
| Article 3.3 activities<br>Deforestation | Change in carbon pool reported | | | | | | | | | | | |
| | | Above-ground biomass | $CO_2$ | 850.49 | -12% | 12% | -26% | 26% | -28% | 28% | -19% | 19% |
| | | Below-ground biomass | $CO_2$ | 208.91 | IE | IE | IE | IE | IE | IE | IE | IE |
| | | Litter | $CO_2$ | 395.10 | - | - | - | - | -51% | 51% | -13% | 13% |
| | | Dead wood | $CO_2$ | 161.98 | - | - | - | - | -22% | 22% | -2% | 2% |
| | | Mineral soil | $CO_2$ | -14.46 | - | - | - | - | -20% | 20% | 0% | 0% |
| | | Organic soil | $CO_3$ | 2.43 | -1% | 1% | -90% | 90% | -90% | 90% | 0% | 0% |
| | | Harvested wood products (HWP) | $CO_2$ | IO | - | - | - | - | - | - | - | - |
| | Greenhouse gas sources reported | | | | | | | | | | | |
| | | Fertilization | $N_2O$ | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | Drainage of soils under forest management | $CH_4$ | 0.52 | - | - | - | - | -71% | 71% | 0% | 0% |
| | | $N_2O$ emissions from N mineralization associated with loss of soil organic matter | $N_2O$ | 0.27 | - | - | - | - | -75% | 202% | 0% | 0% |
| | | Indirect $N_2O$ emissions (from N mineralization) | $N_2O$ | 0.06 | - | - | - | - | -119% | 288% | 0% | 0% |
| | | Biomass burning | $CO_2$ | NO | - | - | - | - | - | - | - | - |
| | | | $CH_4$ | NO | - | - | - | - | - | - | - | - |
| | | | $N_2O$ | NO | - | - | - | - | - | - | - | - |
| | Total | | | 1,605.29 | | | | | -23% | 23% | | |

### 11.5.1.8.c. Uncertainties of emissions/removals of forest management activities

Uncertainties of emissions/removals in living biomass resulting from FM activities were estimated by applying Tier 1 – error propagation equation – based on uncertainties in data on forest areas and FM ratio and in estimation of carbon stock changes in living biomass in forest land. Uncertainties of emissions/removals in litter, dead woods and soils were estimated by applying Monte Carlo Analysis in the CENTURY-jfos Model. As a result, the uncertainty of emissions/removals from FM activities in FY2018 has been assessed to be -14% to +14%.

Table 11-42 Uncertainty of emissions/removals from forest management activities

| Greenhouse gas source and sink activities | | | GHGs | Emissions/ Removals [kt $CO_2$ eq.] | AD Uncertainty [%] | | EF/RF Uncertainty [%] | | Combined Uncertainty [%] | | Combined Uncertainty as % of emissions/ removals [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (-)[%] | (+)[%] | (-)[%] | (+)[%] | (-)[%] | (+)[%] | (-)[%] | (+)[%] |
| Article 3.4 activities<br>Forest management | Change in carbon pool reported | | | | | | | | | | | |
| | | Above-ground biomass | $CO_2$ | -35,184.14 | -12% | 12% | -8% | 8% | -14% | 14% | -14% | 14% |
| | | Below-ground biomass | $CO_2$ | -8,931.71 | IE | IE | IE | IE | IE | IE | IE | IE |
| | | Litter | $CO_2$ | 2,074.22 | - | - | - | - | -51% | 51% | 2% | -2% |
| | | Dead wood | $CO_2$ | -151.00 | - | - | - | - | -22% | 22% | 0% | 0% |
| | | Soil | $CO_2$ | -1,210.13 | - | - | - | - | -20% | 20% | -1% | 1% |
| | | Harvested wood products (HWP) | $CO_2$ | -2,062.00 | - | - | - | - | -30% | 30% | -1% | 1% |
| | Greenhouse gas sources reported | | | | | | | | | | | |
| | | Fertilization | $N_2O$ | 0.51 | - | - | - | - | -31% | 31% | 0% | 0% |
| | | Drainage of soils under forest management | $N_2O$ | NO | - | - | - | - | 0% | 0% | - | - |
| | | $N_2O$ emissions from N mineralization associated with loss of soil organic matter | $N_2O$ | 82.67 | - | - | - | - | -75% | 202% | 0% | 0% |
| | | Biomass burning | $CO_2$ | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | | $CH_4$ | 1.65 | - | - | - | - | -29% | 29% | 0% | 0% |
| | | | $N_2O$ | 0.14 | - | - | - | - | -32% | 32% | 0% | 0% |
| | Total | | | -45,360.92 | | | | | -14% | 14% | | |

### 11.5.1.8.d. Uncertainties of emissions/removals of cropland management

For the uncertainties of activity data for living biomass in orchards, the uncertainties of statistics and the default values given in the *2006 IPCC Guidelines* are applied. For the uncertainties of mineral soil, the comparison of simulation results and actual measurement, when both data are available, revealed

that the uncertainty due to model structure was estimated about 10%. The uncertainties caused by input values have not been quantified yet and remain as an issue to be solved. For the uncertainties of organic soil, the uncertainties of statistical data and default values given in the *Wetlands Guidelines* are used. As a result, the uncertainty of emissions and removals accompanied by cropland management was evaluated to be -40% to +40%.

#### 11.5.1.8.e. Uncertainties of emissions/removals of grazing land management

The description of method used in GM is omitted as uncertainties of carbon stock change in mineral soil are the same as that in CM. Uncertainties of existing statistics and the default values described in the *Wetlands Guidelines* were applied to the estimation of emissions from organic soil. As a result, the uncertainty of emissions and removals accompanied by grazing land management was evaluated to be -22% to +22%.

#### 11.5.1.8.f. Uncertainties of emissions/removals of revegetation activities

Uncertainties of emissions/removals resulting from RV activities were estimated by following processes of estimating carbon stock changes in 8 sub-categories. First, uncertainties of each carbon pool (living biomass, litter and soils) in the 8 sub-categories were estimated by combining uncertainties of parameters and activity data (areas and the number of tall trees) used for estimating carbon stock changes. Next, an uncertainty of emissions/removals resulting from RV activities as a whole was estimated by applying Tier 1 – error propagation equation – based on the carbon stock changes in the 8 sub-categories. As a result, the uncertainty of emissions/removals from RV activities in FY2018 has been assessed at -33% to +33%.

Table 11-43 Uncertainty of emissions/removals from revegetation activities

| Greenhouse gas source and sink activities | | | GHGs | Emissions/ Removals [kt $CO_2$ eq.] | AD Uncertainty [%] | | EF/RF Uncertainty [%] | | Combined Uncertainty [%] | | Combined Uncertainty as % of emissions/ removals [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (-)[%] | (+)[%] | (-)[%] | (+)[%] | (-)[%] | (+)[%] | (-)[%] | (+)[%] |
| Article 3.4 activities | Change in carbon pool reported | | | | | | | | | | | |
| Revegetation | | Above-ground biomass | $CO_2$ | -800.34 | - | - | - | - | -42% | 42% | -32% | 32% |
| | | Below-ground biomass | $CO_2$ | -208.09 | IE | IE | IE | IE | IE | IE | IE | IE |
| | | Litter | $CO_2$ | -14.17 | - | - | - | - | -61% | 61% | -1% | 1% |
| | | Dead wood | $CO_2$ | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| | | Soil | $CO_2$ | -299.62 | - | - | - | - | -38% | 38% | -9% | 9% |
| | Total | | | -1,322.21 | | | | | -33% | 33% | | |

### 11.5.1.9. Information on other methodological issues (methods dealing with the effects of natural disturbances[21])

#### 11.5.1.9.a. Afforestation/Reforestation and Deforestation

The effects of natural disturbances have been reflected in forest resources data when Forest Registers are updated every 5 years in each planning area.

#### 11.5.1.9.b. Forest Management

The effects of natural disturbances have been reflected in forest resources data when Forest Registers are updated every 5 years in each planning area.

[21] Including fires, windstorms, insects, droughts, flooding and ice storms, etc.

### 11.5.1.9.c. Revegetation

It is considered that windstorms, floods and insects are natural disturbances which have a considerable impact on carbon stock changes in RV land. However, all land classified as RV is under human-induced management by administration etc. In addition, when tall trees disappear and outflow of soils occur in RV land located in settlements, the business budget is often appropriated and urgent restoration measures are administered from the viewpoint of safety and view.

Consequently, the effects of natural disturbances are not considered in the estimation because it looks that carbon stocks do not change. Furthermore, carbon stock change due to post-disaster restoration practices which are not implemented in the year when the disaster occurred does not lead to double-counting because it is not considered in this reporting.

### 11.5.1.10. The year of the onset of an activity

In this submission, all units of land and lands which start to be subject to activities under Article 3.3, Article 3.4 and any elected activities under Article 3.4 until 2018 are reported. The emissions and removals from the units of land and the lands which activities started in FY2018 for the first time are not included in the calculated emissions and removals in FY2017. The areas of such lands are shown below.

Table 11-44 Areas of afforestation/reforestation, deforestation and forest management

| Area of activities | Afforestation/ Reforestation [kha] | Deforestation [kha] | Forest Management [kha] | | |
|---|---|---|---|---|---|
| | | | Ikusei-rin forest | Tennensei-rin forest | Total |
| FY1990-2018 | 105.8 | 323.0 | 8,898.8 | 7,047.6 | 15,946.4 |
| (FY2018) | – | 6.2 | – | – | – |

Table 11-45 Areas of revegetation

| Categories | Urban parks [ha] | Green areas on roads [ha] | Green areas at ports [ha] | Green areas around sewage treatment facilities [ha] | Green areas by greenery promoting systems for private green space [ha] |
|---|---|---|---|---|---|
| FY1990 | 3,743 | 1,623 | 198 | 44 | 0 |
| FY1990-FY2018 | 59,982 | 21,039 | 1,867 | 666 | 6 |
| (FY2018) | 1,032 | -269 | 17 | 12 | 0 |

| Categories | Green areas along rivers and erosion control sites [ha] | Green areas around government buildings [ha] | Green areas around public rental housing [ha] | Total [ha] |
|---|---|---|---|---|
| FY1990 | 58 | 13 | 248 | 5,926 |
| FY1990-FY2018 | 1,747 | 320 | 2,964 | 88,591 |
| (FY2018) | 11 | 2 | 22 | 828 |

## 11.6. Article 3.3

### 11.6.1. Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are direct human-induced

Japan identifies AR and D by detecting changes of the forest cover which has occurred since 1 January 1990 using orthophotos taken at the end of 1989 and recent satellite images. At that time, AR and forest restoration through natural succession are distinguished by judging through imagery interpretation whether each forest cover change is human-induced or not. This judgement is based on whether any signs of human activities such as uniform tree species and uniform tree height, artificial forestation blocks, or work roads for forestation are observed or not.

### 11.6.2. Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

In Japan, land conversion from forest land to other land use means exclusion of the land from forest plans. Therefore, as far as the area of harvested forest would remain included in forest plans, the area would be considered to be subject not to D but to temporary loss of biomass stock, and in Forest Registers would be distinguished from D which means conversion to other land use.

Japan identifies forest cover change as D only in the case when land form transformation or artificial construction are observed or obvious conversion to non-forest land such as cropland are detected through imagery interpretation using aerial photos and satellite images. By this methodology, D is distinguished from temporary loss of biomass stock in forest land such as clear-cut under ongoing forestry activities.

Sample field surveys are conducted at plots which are interpreted as D areas in several prefectures every year, and accuracy of D interpretation is approximately 90% on average.

The total area of forest land that has temporarily lost forest cover due to harvesting or disturbance and which are not classified as deforested but as “cut-over forests” in Forest Registers was about 95 thousand ha in 2018.

The period for tree planting after a harvest event is determined as being within two years at the latest under the standard based on the Forest Law. In the case of natural regeneration, it is expected that trees are established within five years following a harvest event.

## 11.7. Article 3.4

### 11.7.1. Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

#### 11.7.1.1. Forest Management

The status of FM activities since 1 January 1990 has been investigated since FY2007 by sample surveys including field surveys, interviews with forest owners’ associations and detection of administrative information on subsidies for forest practices, of ikusei-rin forests throughout the country. The results of the survey have been used to estimate the FM ratio.

With respect to Tennensei-rin forests, the measures described in detail in section 11.4.2.4.a.b) have been applied to the Tennensei-rin forests continuously after January 1, 1990.

### 11.7.1.2. Cropland Management

Cropland is land which anthropogenic management practices such fertilization management is implemented and CM land is subject to direct human induced activities from January 1, 1990 onward.

### 11.7.1.3. Grazing Land Management

Pasture land is land which anthropogenic management practices such fertilization management is implemented and GM land is subject to direct human induced activities from January 1, 1990 onward.

### 11.7.1.4. Revegetation

Japan demonstrates that RV activities have occurred since 1990 and are human induced based on the following reasons.

Table 11-46 Information that demonstrates that revegetation activities have occurred since 1 January 1990 and are human induced

| Urban green facilities | Information that demonstrates that Revegetation activities have occurred since 1 January 1990 and are human induced |
|---|---|
| Urban parks | Extraction of activities which have occurred since 1 January 1990<br>MLIT has implemented the "Urban Parks Status Survey" and has collected data on the notification year of urban parks. In the reporting, only urban parks which have been notified since 1 January 1990 are included. Although some urban parks were established before the notification year, Japan considers that RV activities have occurred since the notification year under the "Urban Park Act".<br>Demonstration that activities are human induced<br>Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities. |
| Green areas on roads | Extraction of activities which have occurred since 1 January 1990<br>MLIT has implemented the "Road Tree Planting Status Survey" every 5 years (implemented every year since 2007) and has collected data on the number of planted tall trees. Activity data after 1990 is calculated by extrapolating or interpolating these data.<br>Demonstration that activities are human induced<br>In the "Road Tree Planting Status Survey", only planted tall trees have been measured. Their measurement procedure ensures that Japan extracts human induced activities. |
| Green areas at ports | Extraction of activities which have occurred since 1 January 1990<br>MLIT has implemented complete census since 2006 and has collected relevant data (year of establishment and service area) for green areas at ports which had been established since 1990.<br>Demonstration that activities are human induced<br>Activity data (the number of tall trees) is calculated by using parameters of urban parks which are based on human-induced activities data. |
| Green areas around sewage treatment facilities | Extraction of activities which have occurred since 1 January 1990<br>MLIT has implemented the "Sewage treatment Facility Status Survey" since 2006 and has collected relevant data (year of establishment and greening area) for green areas around sewage treatment facilities which had been established since 1990.<br>Demonstration that activities are human induced<br>Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities. |
| Green areas by greenery promoting systems for private green space | Extraction of activities which have occurred since 1 January 1990<br>It is clear that all green areas by greenery promoting systems for private green space have been established since 1 January 1990 because greenery promoting systems have been implemented since 2001. Existing tall trees before 1990 in some green areas are reported when it have been notified by the local authority mayor. They are excluded from RV land area.<br>Demonstration that activities are human induced<br>All green areas by greenery promoting systems for private green space have been established by human-induced activities. |

| | |
|---|---|
| (continued)<br><br>Green areas along rivers and erosion control sites | Extraction of activities which have occurred since 1 January 1990<br>MLIT has implemented the "Survey on carbon dioxide absorption at source in river works" since 2007 and has collected relevant data (name, location, year of establishment, planted land area [projected area] and the number of tall trees) for river works and erosion and sediment control works which had been implemented since 1990.<br>Demonstration that activities are human induced<br>Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities |
| Green areas around government buildings | Extraction of activities which have occurred since 1 January 1990<br>MLIT has implemented complete census since 2007 and has collected relevant data (name, location, year of establishment, total land area and building area) for government buildings which had been established since 1990.<br>Demonstration that activities are human induced<br>Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities. |
| Green areas around public rental housing | Extraction of activities which have occurred since 1 January 1990<br>MLIT has implemented the "Progress survey on tree planting for public rental housing" since 2007 and has collected relevant data (name, location, year of establishment, total land area and building area) for public rental housing which had been established since 1990.<br>Demonstration that activities are human induced<br>Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities. |

### 11.7.2. Information relating to cropland management, grazing land management and revegetation for the base year and the commitment period

The anthropogenic greenhouse gas emissions/removals in "Cropland management", "Grazing land management" and "Revegetation" for the base year are those from CM, GM and RV area in 1990. The anthropogenic greenhouse gas emissions/removals in "Cropland management", "Grazing land management" and "Revegetation" for the commitment period are those from CM, GM and RV area in each year. Those emissions/removals are reported within the relevant geographical location. The data and the methodologies used are provided in sections 11.4.2.5 through 11.4.2.7 and 11.5.1.1.d through 11.5.1.1.f.

### 11.7.3. Information that demonstrates the emissions and removals resulting from elected Article 3.4 activities are not accounted for under activities under Article 3.3 activities

#### 11.7.3.1. Information on emissions and removals by FM activities are not accounted for under Article 3.3 activities

AR and D are of higher hierarchy than FM in the land classification system of Articles 3.3 and 3.4 in Japan. Emissions and removals by AR and D are estimated in the first step, then emissions and removals by FM are estimated by subtracting emissions and removals by AR and D from emissions and removals in managed forests as explained in section 11.4.2.2 (see Figure 11-1). Therefore, emissions and removals by FM could not be included in those by AR nor D.

#### 11.7.3.2. Information on emissions and removals from CM activities are not accounted under Article 3.3 activities

As described in definition of CM in section 11.3.2.2 and identifying method of CM area in section 11.4.2.5, the land that does not fall under AR can be classified as CM. In addition, in the cropland, the land that fall under D was excluded from land subject to CM.

#### 11.7.3.3. Information on emissions and removals from GM activities are not accounted under Article 3.3 activities

As described in definition of GM in section 11.3.2.3 and identifying method of GM area in section 11.4.2.6, land that does not fall under AR can be classified as GM. In addition, in the pasture land, the land that fall under D was excluded from land subject to GM.

#### 11.7.3.4. Information on emissions and removals from RV activities are not accounted under Article 3.3 activities

RV land is defined as the land which is not included in AR land as described in the definition section 11.3.2.4. Therefore, emissions and removals from RV could not be included in those from AR theoretically.

The area of D land which would otherwise be included in RV lands is reported in the CRF Table 4(KP-I) A.2.1. Since this land is classified as D land and is not included in RV land, all emissions and removals from this land are reported under D activity as described in the explanation of methodologies of D in section 11.5.1.1.b and those of RV in section 11.5.1.1.f. Therefore, there is no double count between D and RV and emissions and removals from RV could not be included in those from D.

### 11.7.4. Information relating to the conversion of natural forests to planted forests

Since the conversion of natural forests to planted forests are accounted as practices subject FM activity if such activities occur, emissions arising from the conversion of natural forests to planted forests are all included in FM estimation.

### 11.7.5. Information on forest reference level (Consistency)

As for reporting FM, forest management reference level (FMRL) was set as zero in Japan. For estimating five carbon pools and GHG emissions and treatment of natural disturbances, methodological consistency between the FMRL and actual calculation is ensured. Regarding the reporting HWP, reference level was set newly by following methodology, and is reported by carrying out technical corrections.

- ***Setting of HWP reference level***

As for setting HWP reference level, prediction values by sub-categories based on the historical trend until 2012 were applied. As for the prediction, floor area of construction, production of wooden board from 2013 to 2020 were estimated by extrapolation their trend from 1993 to 2012; floor area of destroyed building, production of lumber and production of paper and paper board from 2013 to 2020 were estimated by extrapolation their trend from 2003 to 2012. As for rate of domestic logs, average values from 2003 to 2012 were applied. The HWP inflow resulting from D from 2013 to 2020, which were estimated from the average value of deforestation area from 2008 to 2012, were deducted from HWP reference level.

### 11.7.6. Information relating forest management reference (technical correction)

In reporting carbon stock changes of HWP pool in FM, technical correction was submitted. .

### 11.7.7. Information on newly established forest will reach at least the equivalent carbon stock

Japan does not apply the provision of Carbon Equivalent Forests (in paragraphs 37-39 of Annex to Decision/CMP.7).

## 11.8. Other information

### 11.8.1. Key category analysis for Article 3.3 activities and any elected activities under Article3.4

In accordance with section 2.3.6 of *the KP Supplement* as well as section 4.3.3 in Volume 1 of the *2006 IPCC Guidelines*, the activity which meets the following requirements is considered as a key category.

-The activities that associated categories identified as key under the UNFCCC inventory.

- The activities that of emissions/removals are greater than the smallest category identified as key in the tier 1 level assessment under the UNFCCC inventory.

- ***Corresponding key categories under the UNFCCC***

Japan's LULUCF key categories under the UNFCCC for FY2018 (Annex 1 of this report) are as follows;

- 4.A.1. Forest land remaining forest land ($CO_2$)
- 4.A.2. Land converted to Forest land ($CO_2$)
- 4.B.1. Cropland remaining cropland ($CO_2$)
- 4.E.2. Land converted to settlements ($CO_2$)
- 4.G. Harvest Wood Products ($CO_2$)

In accordance with the *KP Supplement*, AR, D, FM, CM and RV may be identified as key categories under the Kyoto Protocol.

Table 11-47 Relationship between UNFCCC categories and Kyoto Protocol activities

| UNFCCC category under the Convention | Kyoto Protocol category |
|---|---|
| 4.A.1. Forest land remaining forest land | FM |
| 4.A.2. Land converted to forest land | AR |
| 4.B.1. Cropland remaining cropland | CM |
| 4.B.2. Land converted to cropland | D |
| 4.C.1. Grassland remaining grassland | GM |
| 4.C.2. Land converted to grassland | D |
| 4.D.1. Wetlands remaining wetlands | - |
| 4.D.2. Land converted to wetlands | D |
| 4.E.1. Settlements remaining settlements | RV |
| 4.E.2. Land converted to settlements | D, RV |
| 4.F.1. Other land remaining other land | - |
| 4.F.2. Land converted to other land | D |
| 4.G. Harvest Wood Products | FM |

Note: The relationship between the Convention categories and the Kyoto categories in this table is based on the Table 2.1.1 of the *KP Supplement*, and the definitions of Articles 3.3 and 3.4 activities in Japan. Shade indicates the key categories under the UNFCCC.

- ***Comparison with the smallest key category under the UNFCCC***

The smallest category for the UNFCCC (Approach 1 level assessment) for FY2018 was 2.C.1. Iron and Steel Production ($CO_2$). As a result of the comparison, only FM activity was greater than this category.

Therefore, AR, D, FM, CM and RV activities ($CO_2$) are identified as key activities for FY2018.

### 11.8.2. Further improvements

Methodological issues relating to Articles 3.3 and 3.4 are identified under the committee for greenhouse gas emissions estimation methods- breakout group on LULUCF. They are updated every year along

with the progress of the inventory-related work and issues identified by the expert review team. Many of the improvement plans on LULUCF reporting under the Convention described in Chapter 6 of this report are closely linked to activities under Articles 3.3 and 3.4 of the Kyoto Protocol. Therefore, both the reporting under the Convention and the reporting under the Kyoto Protocol are discussed together. Major issues to be improved are as follows:

- Improvement of methodology and data to estimate carbon stock change in soil due to land-use conversion which reflects changes in management practices more properly is under discussion in Japan.
- With regard to the annual growth rate of living biomass per tree in RV land, Japan plans to improve the accuracy when new country-specific data by tree species become available.
- Except for urban parks and green areas at ports, carbon stock change in soils is not included in the reporting because soils are not sources of GHGs under RV activities. Collecting fundamental information on soil carbon and development estimation methods will be continued.
- With respect to uncertainties on KP-LULUCF activities, disaggregated uncertainties area shown in section 11.5.1.8 in chapter 11, and additional information in description on each category in Chapter 6 are provided. The method to show more detailed information on uncertainties systematically than in current NIR is regarded as a long-term issue.

## 11.9. Information relating to Article 6

Japan has not carried out any projects under Article 6 of the Kyoto Protocol. Therefore, a special indication of whether the boundary of the geographical location encompasses land subject to the Article 6 project is not prepared.

## 11.10. Information on the reporting status of the Annex II to decision 2/CMP.8

The requirements for reporting about Articles 3.3 and 3.4 which are set out in the annex II to decision 2/CMP.8 are provided in sections shown in Table 11-48.

Table 11-48 List of reference sections for the requirements set in the annex II to decision2/CMP.8

| Checklist for KP reporting (paragraphs 1-5 in the annex to decision 2/CMP.8) | | Paragraph | Main sections of Chapter 11 providing relevant information |
|---|---|---|---|
| Information on how inventory methodologies have been applied taking into account *the KP Supplement* and decision 16/CMP.1 | | 2 (a) | Detailed information is provided in each section |
| Information on the geographical location of the boundaries of areas that encompass: | | 2 (b) | 11.4.2, 11.4.3 |
| | Units of land subject to activities under Article 3.3 | 2 (b) (i) | 11.4.2, 11.4.3 |
| | Units of land subject to activities under Article 3.3, which would otherwise be included in land subject to elected activities under Article 3.4 | 2 (b) (ii) | 11.4.2, 11.4.3 and CRF table 4(KP-I)A.2.1 |
| | Land subject to elected activities under Article 3.4 | 2 (b) (iii) | 11.4.2, 11.4.3 |
| Information on the spatial assessment unit for determining the area of accounting for ARD | | 2 (c) | 11.4.1 |
| GHG emissions by sources and removals by sinks from LULUCF activities under Articles 3.3 and 3.4: | | | |
| | Emissions by sources and removals by sinks are clearly distinguished from emissions from Annex A sources | 1 | 11.5.1: Methodology |
| | Emissions by sources and removals by sinks are reported for all geographical locations reported in current and previous years | 2 (d) | 11.4.2.3, 11.4.2.4, 11.4.2.5, 11.4.2.6, 11.4.2.7 |

| Checklist for KP reporting (paragraphs 1-5 in the annex to decision 2/CMP.8) | Paragraph | Main sections of Chapter 11 providing relevant information |
|---|---|---|
| Emissions/removals from Articles 3.3 or (elected) 3.4 activities are reported since the beginning of the commitment period or the onset of the activity | 2 (d) | 11.5.1.10 |
| Information on which pools (above-ground / below-ground biomass, litter, dead wood and soil organic carbon) were not accounted for | 2 (e) | 11.5.1.2 |
| Information on how emissions from natural disturbance are considered | 2 (f) | 11.5.1.3 |
| Information on GHG emissions /removals from the harvested wood products pool | 2 (g) | 11.5.1.4 |
| Activity data for the HWP categories used for estimating the pool removed from domestic forests, for domestic consumption and for export | 2(g)(i) | 11.5.1.4 |
| Half-lives used in estimating emissions/removals for the HWP categories when the first-order decay method was used | 2(g)(ii) | 11.5.1.4 |
| Whether emissions from HWP originating from forests prior to the start of the second commitment period have been included in the accounting, if the forest management reference level is based on a projection | 2(g)(iii) | 11.5.1.4 |
| How emissions from the HWP pool accounted for in the first commitment period on the basis of instantaneous oxidation have been excluded from the accounting for the second commitment period | 2(g)(iv) | 11.5.1.4 |
| How the HWP resulting from deforestation have been accounted on the basis of instantaneous oxidation | 2(g)(v) | 11.5.1.4 |
| How $CO_2$ emissions from HWP in SWDS and from wood harvested for energy purposes have been accounted on the basis of instantaneous oxidation | 2(g)(vi) | 11.5.1.4 |
| How emissions/removals from changes in the HWP pool accounted for do not include imported harvested wood products | 2(g)(vii) | 11.5.1.4 |
| Information on whether Articles 3.3 and (elected) 3.4 emissions/removals factor out removals from (i) elevated $CO_2$ concentrations above pre-industrial levels; (ii) indirect N deposition; and (iii) dynamic effects of age structure resulting from pre-1 January 1990 activities | 3 | 11.5.1.5 |
| Specific information to be reported for Article 3.3 activities | | |
| Information that activities under Article 3.3 began on or after 1 January 1990 and before 31 December of the last year of the commitment period | 4 (a) | 11.6.1 |
| Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation | 4 (b) | 11.6.2 |
| Specific information to be reported for Article 3.4 activities | | |
| Information that activities under Article 3.4 occurred since 1 January 1990 and are human induced. | 5 (a) | 11.7.1 |
| CM, GM, RV: emissions/removals reported for each year of the commitment period and for the base year for each of the elected activities on the geographical locations reported | 5 (b) | 11.4.2.5, 11.4.2.6, 11.4.2.7, 11.5.1.1.d, 11.5.1.1.e, 11.5.11.f, 11.7.2 |
| Information that emissions/removals from Article 3.4 activities are not accounted for under activities under Article 3.3 | 5 (c) | 11.7.3 |
| Information how all emissions arising from the conversion of natural forests to planted forests are accounted for | 5 (d) | 11.7.4 |
| Information that demonstrates methodological consistency between the reference level and reporting for FM during the second commitment period | 5 (e) | 11.7.5 |
| Information on technical corrections between the reference level and reporting for FM during the second commitment period | 5 (f) | 11.7.6 |
| Information on newly established forest will reach at least the equivalent carbon stock | 5 (g) | 11.7.7 |

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# Chapter 12. Information on accounting of Kyoto units

In line with paragraph 10 of the annex to decision 15/CMP.1 and paragraph 14 of decision 3/CMP.11, Japan reports the information on holdings and transactions of Kyoto units (ERUs, CERs, lCERs, tCERs, AAUs and RMUs)[1]. For the reporting, in accordance with paragraph 11 of annex of decision 15/CMP.1, Japan uses Standard electronic format (SEF) defined in the annex of decision 14/CMP.1. Apart from this NIR, SEF is submitted to the UNFCCC Secretariat with the file name "RREG1_JP_2019_1_1.xlsx".

## 12.1. Summary of information reported in the SEF tables

For information on Kyoto units in Japan's National Registry, see the annex of the NIR "Standard Electric Format for Reporting of Information on Kyoto Protocol Units" (RREG1_JP_2019_1_1.xlsx) submitted on the basis of Decision 14/CMP. 1.

Japan also submits "RREG1_JP_2019_2_1.xlsx".

## 12.2. Discrepancies and notifications

Regarding Japan's national registry, discrepancies and notifications to be reported in accordance with paragraphs 12-17 of annex to decision 15/CMP.1 are as follows.

Table 12-1 Discrepancies and notifications

| Reporting item | Description |
|---|---|
| Para. 12 of the annex to decision 15/CMP.1 Discrepancies | There was no discrepancy to be reported. |
| Para. 13 of the annex to decision 15/CMP.1 Notification from Executive Board of CDM | There was no notification regarding lCERs to be replaced due to a reversal of storage. |
| Para. 14 of the annex to decision 15/CMP.1 Failure of certification | There was no notification regarding lCERs to be replaced due to non-submission of certification report. |
| Para. 15 of the annex to decision 15/CMP.1 List of non-replacements | There was no record of non-replacement identified by the transaction log. |
| Para. 16 of the annex to decision 15/CMP.1 Invalid Kyoto units | There were no units that are invalid for use towards compliance with commitments. |
| Para. 17 of the annex to decision 15/CMP.1 Discrepant transaction that needs actions to correct problem | There was no discrepant transaction that needs actions to correct problem. |

## 12.3. Publicly accessible information

As presented in the section IV of Part 2 of "Report on Japan's Assigned Amount", a list of the information publicly accessible by means of the user interface to the national registry is as below:

- Account information as required by paragraph 45, annex, Decision 13/CMP.1

[1] Kyoto units are: emission reduction units (ERU) from joint implementation (JI) projects, certified emission reductions (CERs) from clean development mechanism (CDM) projects, temporary certified emission reductions (tCERs) and long-term certified emission reductions (lCERs) from afforestation/reforestation CDM projects, assigned amount units (AAUs) and removal units (RMUs) from KP-LULUCF activities within Annex I Parties.

- Article 6 project information as required by paragraph 46, annex, Decision 13/CMP.1
- Kyoto units information as required by paragraph 47, annex, Decision 13/CMP.1
- Legal entities as required by paragraph 48, annex, Decision 13/CMP.1
- The serial numbers of the units in the retirement account at the end of the true-up period as required by paragraph 49(b), annex, Decision 13/CMP.1
- The serial numbers of the units requested to be carried over as required by paragraph 49(c), annex, Decision 13/CMP.1

The information is provided in “Publicly Accessible Information” of Japan’s national registry website.

- URL of the Japan’s national registry system: http://www.registry.go.jp/index_e.html
- Publicly Accessible Information: http://www.registry.go.jp/public_info_en.html

The following information is not published due to confidentiality concerns:

- Unit holdings at an individual account level
- Identity of accounts to which Japan’s national registry transferred units and those from which it acquired units.

In addition, for better readability, information on units is not associated with their respective serial numbers.

## 12.4. Calculation of the commitment period reserve (CPR)

Since Japan does not have a quantified emission limitation or reduction commitment for the second commitment period, it does not have a commitment period reserve.

# Chapter 13. Information on changes in national system

In line with paragraph 50 (J) of the UNFCCC Inventory Reporting Guidelines, and paragraph 21 of the annex to decision 15/CMP.1, Japan reports the changes in its national system from the previous inventory submission.

- The name of the national single entity for GHG inventory preparation was changed from "Low-carbon Society Promotion Office" to "Decarbonized Society Promotion Office".

# Chapter 14. Information on changes in national registry

In line with paragraph 22 of the Annex to decision 15/CMP.1 and paragraph 14 of decision 3/CMP.11, Japan reports changes in the national registry of Japan from the previous inventory submission.

## 14.1. Summary of changes made on national registry of Japan in 2019

Table 14-1 Summary of changes made on national registry of Japan in 2019

| Reporting Items | Descriptions of Changes |
|---|---|
| 15/CMP.1, annex II, para 32. (a) Change of name or contact | No change |
| 15/CMP.1, annex II, para 32. (b) Change of cooperation arrangement | No change |
| 15/CMP.1, annex II, para 32. (c) Change to database or the capacity of national registry | No change |
| 15/CMP.1, annex II, para 32. (d) Change of conformance to technical standards | No change |
| 15/CMP.1, annex II, para 32. (e) Change of procedures to minimize discrepancies | No change |
| 15/CMP.1, annex II, para 32. (f) Change of security measures | No change |
| 15/CMP.1, annex II, para 32. (g) Change of a list of publicly accessible information | Information on unit holdings and transactions is made publicly available on the basis of Standard Electronic Format (SEF) to meet the requirement specified in decision 14/CMP.1. In April 2019, the information for 2018 was published.<br>The following information was not published due to confidentiality concerns:<br>- Unit holdings at an individual account level<br>- Identity of accounts to which national registry of Japan transferred units and those from which it acquired units.<br>In addition, for better readability, information on units was not associated with their respective serial numbers. |
| 15/CMP.1, annex II, para 32. (h) Change of the internet address | No change |
| 15/CMP.1, annex II, para 32. (i) Change of measures for ensuring data integrity | No change |
| 15/CMP.1, annex II, para 32. (j) Change of test results | No change |

## 14.2. Information relevant to the changes made on national registry of Japan

Following changes were made to national registry of Japan. There was no impact on the functions of the ITL and other national registries.

- In February 2019, the firewall and the network device settings were changed because of ITL Data Center Migration.
- In March 2019, the web server was updated with security patches.
- In March 2019, the DNS server was updated with security patches.
- In March 2019, the network device was updated with security patches.
- In March 2019, the firewall was changed.

- In April 2019, the mail server was updated with security patches.
- In April 2019, the DNS server was updated with security patches.
- In April 2019, the firewall was updated with security patches.
- In April 2019, public information on the unit holdings and transactions conducted was updated on the basis of the SEF for 2018, for the purpose of meeting the requirement specified in decision 13/CMP.1. The following information, which is requested to be made publicly available in decision 13/CMP.1, has not been made so due mostly to confidentiality concerns (relevant paragraph numbers of the annex to decision 13/CMP.1 are indicated in parentheses):
  - The full name of the representative of the account holder (paragraph 45(e))
  - Serial numbers of ERUs, CERs, AAUs and RMUs those are subject of this public information (paragraph 47)
  - The total quantity of ERUs, CERs, AAUs and RMUs in each account at the beginning of the year (the total quantity is only available by account type) (paragraph 47(a))
  - The identity of the transferring accounts from which ERUs, CERs, AAUs and RMUs were acquired by national registry of Japan during the year (the identity of the transferring registries is available) (paragraph 47(d))
  - The identity of the acquiring accounts to which ERUs, CERs, AAUs and RMUs were transferred from national registry of Japan during the year (the identity of the acquiring registries is available) (paragraph 47(g))
  - Current holdings of ERUs, CERs, AAUs and RMUs in each account (the current holdings are only available by account type) (paragraph 47(l))
- In June 2019, the mail server was updated with security patches.
- In June 2019, the DNS server was updated with security patches.
- In June 2019, the web server was updated with security patches.
- In June 2019, the password requirements were strengthened.
- In September 2019, the application form for reissuing login password was added.
- In October 2019, the DNS server was updated with security patches.
- In October 2019, the web server was updated with security patches.
- In October 2019, the network device was updated with security patches.

# Chapter 15. Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

In line with paragraphs 23-25 of the Annex to decision 15/CMP.1 and paragraph 4 of Annex III to decision 1/CMP.11, Japan reports the following information on minimization of adverse impacts in accordance with Article 3, paragraph 14. Changes made since the last submission are indicated with underlines.

## 15.1. Overview

Japan takes actions while taking into account the importance of making efforts to minimize adverse impacts in accordance with Article 3, Paragraph 14 of the Kyoto Protocol. On the other hand, it should be noted that we have difficulty in accurately assessing specific adverse impacts due to the implementation of response measures to address climate change issues. For example, the fluctuations in crude oil prices are caused by the balance between supply and demand, as well as various other factors (e.g., trends in crude oil futures market or economic fluctuations), and direct causality and its extent between climate change measures and adverse impacts thereof remain uncertain.

Furthermore, for the genuine resolution of climate change problems, it is essential to change the perception related to response measures, and in such a light sustainable growth may become a key. For instance, it should be underlined that the introduction of renewable energy has aspects not only to contribute to GHG emission reductions but also to improve energy access, disaster preparedness, benefit the job creation through the development of new industries. At the G20 Osaka Summit in 2019, Leaders agreed on the importance of utilizing innovation to address urgent global environmental issues such as climate change, energy, and measures against marine plastic litter, under the concept of "a virtuous cycle of environment and growth". Therefore, efforts as mentioned above toward the establishment of a low-carbon society should be accelerated throughout the world. From that perspective, in 2015, in order to support an agreement at COP21, Japan announced "Actions for Cool Earth 2.0 (ACE 2.0)", which consists of two pillars: (1) the implantation of support to developing countries worth of 1.3 trillion yen in 2020 and (2) innovation. Japan continues to proactively contribute to the international community in these fields.

In accordance with the above-mentioned international commitments, in June 2019, the government of Japan made a Cabinet decision on its long-term low greenhouse gas emission development strategy as requested in the Paris Agreement, which was submitted to the UNFCCC secretariat. The strategy includes (1) aiming at the realization of a decarbonized society as the ultimate goal to be accomplished ambitiously as early as possible in the second half of this century to boldly implement measures towards a reduction in GHGs emissions by 80% by 2050 and (2) realization of a virtuous cycle of environment and growth through business-led disruptive innovation.

## 15.2. Actions to minimize adverse impacts in accordance with Article 3, paragraph 14

Japan has as a priority taken the following measures, taking into consideration of the importance to minimize adverse social, environmental, and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention in implementing the

commitments under Article 3, paragraph 1, of the Kyoto Protocol.

At the same time, it should be added that since there is no internationally established methodology for evaluating efforts related to the minimization of above-mentioned adverse impacts, it is impossible to carry out such evaluations.

- ***Technical assistance in the energy and environmental sectors***

Japan has continued to contribute to the sustainable economic growth of developing countries, based on their needs, through the provision of technical assistance in the field of energy and the environment throughout the world. For example, Japan has provided assistance for the development and operation of institutions related to energy savings and renewable energy, through cooperation in human resource development, such as inviting trainees from and sending experts to developing countries, including in the Middle East region. Moreover, from the viewpoint of the utilization of renewable energy in small island nations particularly vulnerable to climate change, Japan, in collaboration with the International Renewable Energy Agency (IRENA), held an international workshops targeting island nations in the Asia-Pacific region and others including in Maldives, in January 2019, in Tokyo and Miyako-Jima, respectively in November 2019, with a view to supporting human resource development and project formulations.

- ***Development of carbon capture and storage (CCS) technologies***

Japan will work on CCS which is an important technology for addressing global warmings based on decisions that include the Summary of the Director-Level Meeting on the Bid for Thermal Power Supply by the Tokyo Electric Power Company, the Strategic Energy Plan and The Long-term Greenhouse Gas Emission Strategy as requested in the Paris Agreement. In particular, Japan has been implementing large-scale demonstration projects in the pursuit of aiming for its practical use by around 2020 while implementing research and development for cost reductions and safety improvements, evaluations of environmental impacts due to the $CO_2$ capture process, and geological surveys to identify potential $CO_2$ offshore storage sites in Japan. Furthermore, Japan has actively carried out information exchanges with stakeholders of European countries and the United States regarding technologies pertaining to CCS.

# Annex 1. Key Categories

## A1.1. Outline of Key Category Analysis

The *UNFCCC Inventory Reporting Guidelines*[1] require the application of the *2006 IPCC Guidelines*, and the key category analysis given in the Guidelines. The key category analyses were done for both data of FY2018 (the latest reported year) and of FY1990 (the base year for the UNFCCC). Their results are presented here.

## A1.2. Results of Key Category Analysis

### A1.2.2 Key Categories

Key categories were assessed in accordance with the *2006 IPCC Guidelines* assessment methods (Approach 1 level assessment, Approach 1 trend assessment, Approach 2 level assessment, and Approach 2 trend assessment).

The key categories for the LULUCF sector were identified by first conducting key category analysis excluding LULUCF, and then conducting the key category analysis for the whole inventory including the LULUCF sector.

As a result, 46 and 40 sources and sinks were detected as the key categories for FY2018 and FY1990, respectively (Table A1-1 and A1-2).

[1] Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention (Decision 24/CP.19)

Table A1-1 Japan's key categories (FY2018)

| | A<br>IPCC Code | B<br>IPCC Category | | C<br>GHGs | Ap1-L | Ap1-T | Ap2-L | Ap2-T |
|---|---|---|---|---|---|---|---|---|
| #1 | 1.A.1. | Energy Industries | Solid Fuels | CO2 | #1 | #1 | #1 | #1 |
| #2 | 1.A.3. | Transport | b. Road Transportation | CO2 | #2 | #18 | #3 | |
| #3 | 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | #3 | #7 | #2 | #14 |
| #4 | 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | #4 | #4 | #6 | #10 |
| #5 | 1.A.4. | Other Sectors | Liquid Fuels | CO2 | #5 | #5 | #5 | #8 |
| #6 | 1.A.1. | Energy Industries | Liquid Fuels | CO2 | #6 | #2 | #9 | #3 |
| #7 | 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | #7 | #10 | #4 | #9 |
| #8 | 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | #8 | #3 | #11 | #4 |
| #9 | 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | #9 | #8 | #24 | #22 |
| #10 | 2.F | Product uses as substitutes for ODS | 1. Refrigeration and Air conditioning | HFCs | #10 | #6 | #10 | #5 |
| #11 | 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | #11 | #9 | #29 | #24 |
| #12 | 2.A | Mineral Product | 1. Cement Production | CO2 | #12 | #12 | #23 | #25 |
| #13 | 3.C | Rice Cultivation | | CH4 | #13 | | #28 | |
| #14 | 1.A.3. | Transport | d. Domestic Navigation | CO2 | #14 | | | |
| #15 | 1.A.3. | Transport | a. Domestic Aviation | CO2 | #15 | #22 | | |
| #16 | 5.C | Incineration and Open Burning of Waste | | CO2 | #16 | | #14 | |
| #17 | 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | #17 | #20 | #13 | #17 |
| #18 | 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | #18 | | #15 | |
| #19 | 3.A | Enteric Fermentation | | CH4 | #19 | | #12 | #26 |
| #20 | 1.A.4. | Other Sectors | Solid Fuels | CO2 | #20 | #15 | | #28 |
| #21 | 2.C | Metal Production | 1 Iron and Steel Production | CO2 | #21 | | | |
| #22 | 3.B | Manure Management | | N2O | | | #8 | |
| #23 | 3.D | Agricultural Soils | 1. Direct Emissions | N2O | | | #27 | |
| #24 | 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | | #17 | #18 | #7 |
| #25 | 5.A | Solid Waste Disposal | | CH4 | | #16 | | #13 |
| #26 | 2.F | Product uses as substitutes for ODS | 2. Foam Blowing Agents | HFCs | | #25 | #19 | #12 |
| #27 | 2.B | Chemical Industry | Other products except Anmonia | CO2 | | | #16 | #27 |
| #28 | 2.D | Non-energy Products from Fuels and Solvent Use | | CO2 | | | #20 | #30 |
| #29 | 1.A.1. | Energy Industries | | N2O | | | | #29 |
| #30 | 4.G | Harvested Wood Products | | CO2 | | | | #23 |
| #31 | 5.D | Wastewater Treatment and Discharge | | N2O | | | #31 | |
| #32 | 2.E | Electronics Industry | | PFCs | | | #17 | #31 |
| #33 | 3.D | Agricultural Soils | 2. Indirect Emissions | N2O | | | #7 | #18 |
| #34 | | Indirect CO2 | from IPPU sector | Ind CO2 | | | #30 | #16 |
| #35 | 2.F | Product uses as substitutes for ODS | 5. Solvents | PFCs | | #24 | | |
| #36 | 1.A.3. | Transport | b. Road Transportation | N2O | | | #26 | #15 |
| #37 | 5.C | Incineration and Open Burning of Waste | | N2O | | | #22 | |
| #38 | 4.E | Settlements | 2. Land converted to Settlements | CO2 | | #26 | | #21 |
| #39 | 2.G | Other Product Manufacture and Use | | SF6 | | #13 | #21 | #2 |
| #40 | 4.A | Forest Land | 2. Land converted to Forest Land | CO2 | | #19 | | #19 |
| #41 | 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CH4 | | #21 | | #6 |
| #42 | 2.E | Electronics Industry | | SF6 | | | #25 | |
| #43 | 2.B | Chemical Industry | 4. Caprolactam, Glyoxal and Glyoxylic Acid Production | N2O | | | | #11 |
| #44 | 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | HFCs | | #11 | | |
| #45 | 2.B | Chemical Industry | 3. Adipic Acid Production | N2O | | #14 | | #20 |
| #46 | 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | SF6 | | #23 | | |

Note: Ap1-L: Approach1-Level Assessment, Ap1-T: Approach1-Trend Assessment,
Ap2-L: Approach2-Level Assessment, Ap2-T: Approach2-Trend Assessment
Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table A1-2 Japan's key categories (FY1990)

| | A IPCC Code | B IPCC Category | | C GHGs | Ap1-L | Ap2-L |
|---|---|---|---|---|---|---|
| #1 | 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | #1 | #1 |
| #2 | 1.A.3. | Transport | b. Road Transportation | CO2 | #2 | #3 |
| #3 | 1.A.1. | Energy Industries | Liquid Fuels | CO2 | #3 | #4 |
| #4 | 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | #4 | #6 |
| #5 | 1.A.4. | Other Sectors | Liquid Fuels | CO2 | #5 | #8 |
| #6 | 1.A.1. | Energy Industries | Solid Fuels | CO2 | #6 | #7 |
| #7 | 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | #7 | #19 |
| #8 | 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | #8 | #2 |
| #9 | 2.A | Mineral Product | 1. Cement Production | CO2 | #9 | #21 |
| #10 | 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | #10 | |
| #11 | 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | HFCs | #11 | |
| #12 | 1.A.3. | Transport | d. Domestic Navigation | CO2 | #12 | |
| #13 | 3.C | Rice Cultivation | | CH4 | #13 | #32 |
| #14 | 5.C | Incineration and Open Burning of Waste | | CO2 | #14 | #17 |
| #15 | 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | #15 | |
| #16 | 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | #16 | #9 |
| #17 | 5.A | Solid Waste Disposal | | CH4 | #17 | #15 |
| #18 | 3.A | Enteric Fermentation | | CH4 | #18 | #14 |
| #19 | 2.G | Other Product Manufacture and Use | | SF6 | #19 | #5 |
| #20 | 2.C | Metal Production | 1 Iron and Steel Production | CO2 | #20 | |
| #21 | 2.B | Chemical Industry | 3. Adipic Acid Production | N2O | #21 | |
| #22 | 1.A.3. | Transport | a. Domestic Aviation | CO2 | #22 | |
| #23 | 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | #23 | #22 |
| #24 | 4.A | Forest Land | 2. Land converted to Forest Land | CO2 | #24 | #30 |
| #25 | 2.A | Mineral Product | 2. Lime Production | CO2 | #25 | |
| #26 | 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CH4 | #26 | #12 |
| #27 | 3.D | Agricultural Soils | 1. Direct Emissions | N2O | #27 | #24 |
| #28 | | Indirect CO2 | from IPPU sector | Ind CO2 | | #16 |
| #29 | 4.E | Settlements | 2. Land converted to Settlements | CO2 | | #29 |
| #30 | 3.B | Manure Management | | N2O | | #11 |
| #31 | 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | | #31 |
| #32 | 2.B | Chemical Industry | Other products except Anmonia | CO2 | | #18 |
| #33 | 1.A.3. | Transport | b. Road Transportation | N2O | | #13 |
| #34 | 3.D | Agricultural Soils | 2. Indirect Emissions | N2O | | #10 |
| #35 | 5.D | Wastewater Treatment and Discharge | | N2O | | #28 |
| #36 | 2.D | Non-energy Products from Fuels and Solvent Use | | CO2 | | #27 |
| #37 | 2.B | Chemical Industry | 4. Caprolactam, Glyoxal and Glyoxylic Acid Production | N2O | | #20 |
| #38 | 2.E | Electronics Industry | | PFCs | | #25 |
| #39 | 5.C | Incineration and Open Burning of Waste | | N2O | | #26 |
| #40 | 2.E | Electronics Industry | | SF6 | | #23 |

Note: Ap1-L: Approach1-Level Assessment, Ap2-L: Approach2-Level Assessment
Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

### A1.2.3 Level Assessment

Level assessment involves an identification of categories as a key by calculating the proportion of emissions and removals in each category to the total emissions and removals. The calculated values of proportion are added from the category that accounts for the largest proportion, until the sum reaches 95% for Approach 1 and 90% for Approach 2. Approach 1 level assessment uses emissions and removals from each category directly and Approach 2 level assessment analyzes the emissions and removals of each category, multiplied by the uncertainty of each category.

The key category analysis was first conducted for the inventory excluding LULUCF and the key categories for source sectors were identified (1). Then the key category analysis was repeated again for the full inventory including the LULUCF categories and key categories for LULUCF sector were identified (2). A source category, which was identified as key in (1) but not in (2), was still regarded as

key; while a source category, which was not identified as key in (1) but was done in (2), was not regarded as key (gray rows in tables below).

Approach 1 level assessment of the latest emissions and removals (FY2018) gives the following 21 sub-categories as the key categories (Table A1-3). Approach 2 level assessment of the latest emissions and removals (FY2018) gives the following 31 sub-categories as the key categories (Table A1-4).

Table A1-3 Results of Approach 1 level assessment (FY2018)

| | A<br>IPCC Code | B<br>IPCC Category | | C<br>GHGs | F<br>Current Year Estimate [Gg-CO2 eq.] | H<br>Ap1-L | I<br>% Ap1-L Contrib. | Cumulative contrib. |
|---|---|---|---|---|---|---|---|---|
| #1 | 1.A.1. | Energy Industries | Solid Fuels | CO2 | 258,379.86 | 0.197 | 19.7% | 19.7% |
| #2 | 1.A.3. | Transport | b. Road Transportation | CO2 | 181,333.18 | 0.139 | 13.9% | 33.6% |
| #3 | 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | 170,034.48 | 0.130 | 13.0% | 46.6% |
| #4 | 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | 154,614.23 | 0.118 | 11.8% | 58.4% |
| #5 | 1.A.4. | Other Sectors | Liquid Fuels | CO2 | 79,417.13 | 0.061 | 6.1% | 64.5% |
| #6 | 1.A.1. | Energy Industries | Liquid Fuels | CO2 | 59,469.86 | 0.045 | 4.5% | 69.0% |
| #7 | 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | -58,092.54 | 0.044 | 4.4% | 73.5% |
| #8 | 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | 50,819.48 | 0.039 | 3.9% | 77.3% |
| #9 | 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | 44,269.23 | 0.034 | 3.4% | 80.7% |
| #10 | 2.F | Product uses as substitutes for ODS | 1. Refrigeration and Air conditioning | HFCs | 43,179.50 | 0.033 | 3.3% | 84.0% |
| #11 | 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | 32,191.67 | 0.025 | 2.5% | 86.5% |
| #12 | 2.A | Mineral Product | 1. Cement Production | CO2 | 26,182.94 | 0.020 | 2.0% | 88.5% |
| #13 | 3.C | Rice Cultivation | | CH4 | 13,560.65 | 0.010 | 1.0% | 89.5% |
| #14 | 1.A.3. | Transport | d. Domestic Navigation | CO2 | 10,546.38 | 0.008 | 0.8% | 90.3% |
| #15 | 1.A.3. | Transport | a. Domestic Aviation | CO2 | 10,536.16 | 0.008 | 0.8% | 91.1% |
| #16 | 5.C | Incineration and Open Burning of Waste | | CO2 | 10,238.78 | 0.008 | 0.8% | 91.9% |
| #17 | 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | 9,791.65 | 0.007 | 0.7% | 92.7% |
| #18 | 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | 8,224.13 | 0.006 | 0.6% | 93.3% |
| #19 | 3.A | Enteric Fermentation | | CH4 | 7,465.58 | 0.006 | 0.6% | 93.9% |
| #20 | 1.A.4. | Other Sectors | Solid Fuels | CO2 | 7,336.57 | 0.006 | 0.6% | 94.4% |
| #21 | 2.C | Metal Production | 1 Iron and Steel Production | CO2 | 5,712.42 | 0.004 | 0.4% | 94.9% |
| #22 | 2.A | Mineral Product | 2. Lime Production | CO2 | 5,663.34 | 0.004 | 0.4% | 95.3% |

Note: A source category #22, which was identified as key in (1) but not in (2), was still regarded as key; while a source category, which was not identified as key in (1) but was done in (2), was not regarded as key.

Table A1-4 Results of Approach 2 level assessment (FY2018)

| | A<br>IPCC Code | B<br>IPCC Category | | C<br>GHGs | F<br>Current Year Estimate [Gg-CO2 eq.] | L<br>Source/Sink Uncertainty | N<br>% Ap2-L Contrib. | Cumulative contrib. |
|---|---|---|---|---|---|---|---|---|
| #1 | 1.A.1. | Energy Industries | Solid Fuels | CO2 | 258,379.86 | 6% | 15.1% | 15.1% |
| #2 | 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | 170,034.48 | 6% | 9.9% | 25.1% |
| #3 | 1.A.3. | Transport | b. Road Transportation | CO2 | 181,333.18 | 5% | 8.8% | 33.9% |
| #4 | 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | -58,092.54 | 13% | 7.5% | 41.4% |
| #5 | 1.A.4. | Other Sectors | Liquid Fuels | CO2 | 79,417.13 | 5% | 3.9% | 45.3% |
| #6 | 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | 154,614.23 | 2% | 3.8% | 49.1% |
| #7 | 3.D | Agricultural Soils | 2. Indirect Emissions | N2O | 1,854.45 | 164% | 3.1% | 52.3% |
| #8 | 3.B | Manure Management | | N2O | 3,921.66 | 76% | 3.1% | 55.3% |
| #9 | 1.A.1. | Energy Industries | Liquid Fuels | CO2 | 59,469.86 | 5% | 2.9% | 58.2% |
| #10 | 2.F | Product uses as substitutes for ODS | 1. Refrigeration and Air conditioning | HFCs | 43,179.50 | 6% | 2.9% | 61.1% |
| #11 | 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | 50,819.48 | 5% | 2.5% | 63.6% |
| #12 | 3.A | Enteric Fermentation | | CH4 | 7,465.58 | 26% | 2.0% | 65.6% |
| #13 | 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | 9,791.65 | 19% | 1.9% | 67.5% |
| #14 | 5.C | Incineration and Open Burning of Waste | | CO2 | 10,238.78 | 16% | 1.7% | 69.2% |
| #15 | 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | 8,224.13 | 19% | 1.6% | 70.9% |
| #16 | 2.B | Chemical Industry | Other products except Anmonia | CO2 | 2,762.17 | 55% | 1.6% | 72.4% |
| #17 | 2.E | Electronics Industry | | PFCs | 1,855.03 | 81% | 1.6% | 74.0% |
| #18 | 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | 3,506.81 | 42% | 1.5% | 75.5% |
| #19 | 2.F | Product uses as substitutes for ODS | 2. Foam Blowing Agents | HFCs | 2,921.97 | 50% | 1.5% | 77.0% |
| #20 | 2.D | Non-energy Products from Fuels and Solvent Use | | CO2 | 2,643.96 | 55% | 1.5% | 78.5% |
| #21 | 2.G | Other Product Manufacture and Use | | SF6 | 1,374.70 | 83% | 1.2% | 79.7% |
| #22 | 5.C | Incineration and Open Burning of Waste | | N2O | 1,429.22 | 79% | 1.2% | 80.9% |
| #23 | 2.A | Mineral Product | 1. Cement Production | CO2 | 26,182.94 | 4% | 1.1% | 82.0% |
| #24 | 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | 44,269.23 | 2% | 1.1% | 83.1% |
| #25 | 2.E | Electronics Industry | | SF6 | 349.02 | 300% | 1.1% | 84.2% |
| #26 | 1.A.3. | Transport | b. Road Transportation | N2O | 1,441.90 | 72% | 1.1% | 85.3% |
| #27 | 3.D | Agricultural Soils | 1. Direct Emissions | N2O | 3,557.23 | 26% | 0.9% | 86.2% |
| #28 | 3.C | Rice Cultivation | | CH4 | 13,560.65 | 6% | 0.9% | 87.1% |
| #29 | 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | 32,191.67 | 2% | 0.8% | 87.9% |
| #30 | | Indirect CO2 | from IPPU sector | Ind CO2 | 1,606.10 | 48% | 0.8% | 88.7% |
| #31 | 5.D | Wastewater Treatment and Discharge | | N2O | 1,983.24 | 38% | 0.8% | 89.4% |
| #32 | 5.A | Solid Waste Disposal | | CH4 | 2,930.29 | 22% | 0.7% | 90.1% |

Note: A source category #32, which was identified as key in (1) but not in (2), was still regarded as key; while a source category, which was not identified as key in (1) but was done in (2), was not regarded as key.

Approach1 level assessment of the base year emissions and removals (FY1990) gives the following 27 sub-categories as the key categories (Table A1-5). Approach 2 level assessment of the base year emissions and removals (FY1990) gives the following 32 sub-categories as the key categories (Table A1-6).

Table A1-5 Results of Approach 1 level assessment (FY1990)

| | A IPCC Code | B IPCC Category | | C GHGs | D FY1990 Estimate [Gg-CO2eq.] | H Ap1-L | I % Ap1-L Contrib. | Cumulative contrib. |
|---|---|---|---|---|---|---|---|---|
| #1 | 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | 199,587.36 | 0.145 | 14.5% | 14.5% |
| #2 | 1.A.3. | Transport | b. Road Transportation | CO2 | 179,212.93 | 0.130 | 13.0% | 27.6% |
| #3 | 1.A.1. | Energy Industries | Liquid Fuels | CO2 | 178,959.74 | 0.130 | 13.0% | 40.6% |
| #4 | 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | 134,022.54 | 0.097 | 9.7% | 50.3% |
| #5 | 1.A.4. | Other Sectors | Liquid Fuels | CO2 | 130,347.42 | 0.095 | 9.5% | 59.8% |
| #6 | 1.A.1. | Energy Industries | Solid Fuels | CO2 | 109,537.93 | 0.080 | 8.0% | 67.8% |
| #7 | 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | 80,030.95 | 0.058 | 5.8% | 73.6% |
| #8 | 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | -72,385.80 | 0.053 | 5.3% | 78.8% |
| #9 | 2.A | Mineral Product | 1. Cement Production | CO2 | 38,701.10 | 0.028 | 2.8% | 81.7% |
| #10 | 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | 22,241.56 | 0.016 | 1.6% | 83.3% |
| #11 | 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | HFCs | 15,930.24 | 0.012 | 1.2% | 84.4% |
| #12 | 1.A.3. | Transport | d. Domestic Navigation | CO2 | 13,674.88 | 0.010 | 1.0% | 85.4% |
| #13 | 3.C | Rice Cultivation | | CH4 | 12,770.99 | 0.009 | 0.9% | 86.4% |
| #14 | 5.C | Incineration and Open Burning of Waste | | CO2 | 12,429.49 | 0.009 | 0.9% | 87.3% |
| #15 | 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | 11,894.05 | 0.009 | 0.9% | 88.1% |
| #16 | 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | 10,098.26 | 0.007 | 0.7% | 88.9% |
| #17 | 5.A | Solid Waste Disposal | | CH4 | 9,570.42 | 0.007 | 0.7% | 89.6% |
| #18 | 3.A | Enteric Fermentation | | CH4 | 9,422.90 | 0.007 | 0.7% | 90.2% |
| #19 | 2.G | Other Product Manufacture and Use | | SF6 | 8,814.04 | 0.006 | 0.6% | 90.9% |
| #20 | 2.C | Metal Production | 1 Iron and Steel Production | CO2 | 7,244.20 | 0.005 | 0.5% | 91.4% |
| #21 | 2.B | Chemical Industry | 3. Adipic Acid Production | N2O | 7,210.88 | 0.005 | 0.5% | 91.9% |
| #22 | 1.A.3. | Transport | a. Domestic Aviation | CO2 | 7,162.41 | 0.005 | 0.5% | 92.5% |
| #23 | 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | 6,678.58 | 0.005 | 0.5% | 92.9% |
| #24 | 4.A | Forest Land | 2. Land converted to Forest Land | CO2 | -6,675.49 | 0.005 | 0.5% | 93.4% |
| #25 | 2.A | Mineral Product | 2. Lime Production | CO2 | 6,674.45 | 0.005 | 0.5% | 93.9% |
| #26 | 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CH4 | 4,760.38 | 0.003 | 0.3% | 94.3% |
| #27 | 3.D | Agricultural Soils | 1. Direct Emissions | N2O | 4,701.08 | 0.003 | 0.3% | 94.6% |
| #28 | 2.F | Product uses as substitutes for ODS | 5. Solvents | PFCs | 4,549.94 | 0.003 | 0.3% | 94.9% |
| #29 | | Indirect CO2 | from IPPU sector | Ind CO2 | 4,454.80 | 0.003 | 0.3% | 95.3% |

Note: Source categories #28 and #29, which were identified as key in (1) but not in (2), were still regarded as key; while a source category, which were not identified as key in (1) but were done in (2), were not regarded as keys.

Table A1-6 Results of Approach 2 level assessment (FY1990)

| | A IPCC Code | B IPCC Category | | C GHGs | D FY1990 Estimate [Gg-CO2eq.] | L Source/Sink Uncertainty | N % Ap2-L Contrib. | Cumulative contrib. |
|---|---|---|---|---|---|---|---|---|
| #1 | 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | 199,587.36 | 6% | 9.5% | 9.5% |
| #2 | 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | -72,385.80 | 13% | 7.6% | 17.1% |
| #3 | 1.A.3. | Transport | b. Road Transportation | CO2 | 179,212.93 | 5% | 7.1% | 24.2% |
| #4 | 1.A.1. | Energy Industries | Liquid Fuels | CO2 | 178,959.74 | 5% | 7.1% | 31.3% |
| #5 | 2.G | Other Product Manufacture and Use | | SF6 | 8,814.04 | 83% | 6.2% | 37.5% |
| #6 | 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | 134,022.54 | 5% | 5.3% | 42.8% |
| #7 | 1.A.1. | Energy Industries | Solid Fuels | CO2 | 109,537.93 | 6% | 5.2% | 48.0% |
| #8 | 1.A.4. | Other Sectors | Liquid Fuels | CO2 | 130,347.42 | 5% | 5.2% | 53.1% |
| #9 | 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | 10,098.26 | 42% | 3.6% | 56.8% |
| #10 | 3.D | Agricultural Soils | 2. Indirect Emissions | N2O | 2,414.03 | 164% | 3.3% | 60.1% |
| #11 | 3.B | Manure Management | | N2O | 4,207.98 | 76% | 2.7% | 62.8% |
| #12 | 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CH4 | 4,760.38 | 65% | 2.6% | 65.4% |
| #13 | 1.A.3. | Transport | b. Road Transportation | N2O | 3,457.24 | 72% | 2.1% | 67.5% |
| #14 | 3.A | Enteric Fermentation | | CH4 | 9,422.90 | 26% | 2.1% | 69.5% |
| #15 | 5.A | Solid Waste Disposal | | CH4 | 9,570.42 | 22% | 1.8% | 71.3% |
| #16 | | Indirect CO2 | from IPPU sector | Ind CO2 | 4,454.80 | 48% | 1.8% | 73.1% |
| #17 | 5.C | Incineration and Open Burning of Waste | | CO2 | 12,429.49 | 16% | 1.7% | 74.8% |
| #18 | 2.B | Chemical Industry | Other products except Anmonia | CO2 | 3,623.06 | 55% | 1.7% | 76.5% |
| #19 | 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | 80,030.95 | 2% | 1.6% | 78.1% |
| #20 | 2.B | Chemical Industry | 4. Caprolactam, Glyoxal and Glyoxylic Acid Production | N2O | 1,672.86 | 99% | 1.4% | 79.5% |
| #21 | 2.A | Mineral Product | 1. Cement Production | CO2 | 38,701.10 | 4% | 1.3% | 80.9% |
| #22 | 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | 6,678.58 | 19% | 1.1% | 81.9% |
| #23 | 2.E | Electronics Industry | | SF6 | 418.70 | 300% | 1.1% | 83.0% |
| #24 | 3.D | Agricultural Soils | 1. Direct Emissions | N2O | 4,701.08 | 26% | 1.0% | 84.0% |
| #25 | 2.E | Electronics Industry | | PFCs | 1,454.78 | 81% | 1.0% | 85.0% |
| #26 | 5.C | Incineration and Open Burning of Waste | | N2O | 1,438.04 | 79% | 1.0% | 85.9% |
| #27 | 2.D | Non-energy Products from Fuels and Solvent Use | | CO2 | 2,039.82 | 55% | 0.9% | 86.9% |
| #28 | 5.D | Wastewater Treatment and Discharge | | N2O | 2,387.11 | 38% | 0.8% | 87.7% |
| #29 | 4.E | Settlements | 2. Land converted to Settlements | CO2 | 4,251.07 | 21% | 0.8% | 88.4% |
| #30 | 4.A | Forest Land | 2. Land converted to Forest Land | CO2 | -6,675.49 | 13% | 0.7% | 89.1% |
| #31 | 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | 4,199.02 | 19% | 0.7% | 89.8% |
| #32 | 3.C | Rice Cultivation | | CH4 | 12,770.99 | 6% | 0.7% | 90.4% |

### A1.2.4 Trend Assessment

The difference between the rate of change in emissions and removals in a category and the rate of change in total emissions and removals is calculated. The trend assessment is calculated by multiplying this value by the ratio of contribution of the relevant category to total emissions and removals. The calculated results, regarded as trend assessment values, are added from the category whose proportion to the total of trend assessment values is the largest, until the total reaches 95% for Approach 1 and 90% for Approach 2. At this point, these categories are defined as the key categories. Approach1 level assessment uses emissions and removals from each category directly and Approach 2 level assessment analyzes the emissions and removals of each category, multiplied by the uncertainty of each category.

The key category analysis was first conducted for the inventory excluding LULUCF and the key categories for source sectors were identified (1). Then the key category analysis was repeated again for the full inventory including the LULUCF categories and key categories for LULUCF sector were identified (2). A source category, which was identified as key in (1) but not in (2), was still regarded as key; while a source category, which was not identified as key in (1) but was done in (2), was not regarded as key (gray rows in tables below).

Approach 1 trend assessment of the latest emissions and removals (FY2018) gives the following 26 sub-categories as the key categories (Table A1-7). Approach 2 trend assessment of the latest emissions and removals (FY2018) gives the following 31 sub-categories as the key categories (Table A1-8).

Table A1-7 Results of Approach 1 trend assessment (FY2018)

| | A<br>IPCC Code | B<br>IPCC Category | | C<br>GHGs | D<br>FY1990 Estimate [Gg-CO2eq.] | F<br>Current Year Estimate [Gg-CO2 eq.] | J<br>Ap1-T | K<br>% Ap1-T Contrib. | Cumulative contrib. |
|---|---|---|---|---|---|---|---|---|---|
| #1 | 1.A.1. | Energy Industries | Solid Fuels | CO2 | 109,537.93 | 258,379.86 | 0.110 | 20.5% | 20.5% |
| #2 | 1.A.1. | Energy Industries | Liquid Fuels | CO2 | 178,959.74 | 59,469.86 | 0.084 | 15.7% | 36.2% |
| #3 | 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | 134,022.54 | 50,819.48 | 0.058 | 10.9% | 47.1% |
| #4 | 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | 80,030.95 | 154,614.23 | 0.056 | 10.4% | 57.5% |
| #5 | 1.A.4. | Other Sectors | Liquid Fuels | CO2 | 130,347.42 | 79,417.13 | 0.035 | 6.5% | 64.0% |
| #6 | 2.F | Product uses as substitutes for ODS | 1. Refrigeration and Air conditioning | HFCs | 0.00 | 43,179.50 | 0.031 | 5.9% | 69.8% |
| #7 | 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | 199,587.36 | 170,034.48 | 0.018 | 3.4% | 73.2% |
| #8 | 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | 22,241.56 | 44,269.23 | 0.016 | 3.1% | 76.3% |
| #9 | 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | 11,894.05 | 32,191.67 | 0.015 | 2.8% | 79.1% |
| #10 | 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | -72,385.80 | -58,092.54 | 0.012 | 2.2% | 81.2% |
| #11 | 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | HFCs | 15,930.24 | 100.30 | 0.011 | 2.1% | 83.3% |
| #12 | 2.A | Mineral Product | 1. Cement Production | CO2 | 38,701.10 | 26,182.94 | 0.008 | 1.6% | 84.9% |
| #13 | 2.G | Other Product Manufacture and Use | | SF6 | 8,814.04 | 1,374.70 | 0.005 | 1.0% | 85.9% |
| #14 | 2.B | Chemical Industry | 3. Adipic Acid Production | N2O | 7,210.88 | 58.69 | 0.005 | 0.9% | 86.9% |
| #15 | 1.A.4. | Other Sectors | Solid Fuels | CO2 | 353.86 | 7,336.57 | 0.005 | 0.9% | 87.8% |
| #16 | 5.A | Solid Waste Disposal | | CH4 | 9,570.42 | 2,930.29 | 0.005 | 0.9% | 88.7% |
| #17 | 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | 10,098.26 | 3,506.81 | 0.005 | 0.9% | 89.5% |
| #18 | 1.A.3. | Transport | b. Road Transportation | CO2 | 179,212.93 | 181,333.18 | 0.004 | 0.8% | 90.4% |
| #19 | 4.A | Forest Land | 2. Land converted to Forest Land | CO2 | -6,675.49 | -934.38 | 0.004 | 0.8% | 91.2% |
| #20 | 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | 4,199.02 | 9,791.65 | 0.004 | 0.8% | 91.9% |
| #21 | 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CH4 | 4,760.38 | 478.77 | 0.003 | 0.6% | 92.5% |
| #22 | 1.A.3. | Transport | a. Domestic Aviation | CO2 | 7,162.41 | 10,536.16 | 0.003 | 0.5% | 93.0% |
| #23 | 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | SF6 | 3,470.78 | 45.55 | 0.002 | 0.5% | 93.4% |
| #24 | 2.F | Product uses as substitutes for ODS | 5. Solvents | PFCs | 4,549.94 | 1,505.11 | 0.002 | 0.4% | 93.8% |
| #25 | 2.F | Product uses as substitutes for ODS | 2. Foam Blowing Agents | HFCs | 1.34 | 2,921.97 | 0.002 | 0.4% | 94.2% |
| #26 | 1.A.3. | Transport | d. Domestic Navigation | CO2 | 13,674.88 | 10,546.38 | 0.002 | 0.4% | 94.6% |
| #27 | 4.E | Settlements | 2. Land converted to Settlements | CO2 | 4,251.07 | 1,396.93 | 0.002 | 0.4% | 95.0% |
| #28 | | Indirect CO2 | from IPPU sector | Ind CO2 | 4,454.80 | 1,606.10 | 0.002 | 0.4% | 95.4% |

Note: Source category #26 and #28, which was identified as key in (1) but not in (2), was still regarded as key; while a source category, which was not identified as key in (1) but was done in (2), was not regarded as key.

Table A1-8 Results of Approach 2 trend assessment (FY2018)

| | A<br>IPCC Code | B<br>IPCC Category | | C<br>GHGs | D<br>FY1990 Estimate [Gg-CO2eq.] | F<br>Current Year Estimate [Gg-CO2 eq.] | L<br>Source/Sink Uncertainty | O<br>Ap2-T | P<br>% Ap2-T Contrib. | Cumulative contrib. |
|---|---|---|---|---|---|---|---|---|---|---|
| #1 | 1.A.1. | Energy Industries | Solid Fuels | CO2 | 109,537.93 | 258,379.86 | 6% | 6.20 | 14.0% | 14.0% |
| #2 | 2.G | Other Product Manufacture and Use | | SF6 | 8,814.04 | 1,374.70 | 83% | 4.37 | 9.9% | 23.8% |
| #3 | 1.A.1. | Energy Industries | Liquid Fuels | CO2 | 178,959.74 | 59,469.86 | 5% | 3.95 | 8.9% | 32.7% |
| #4 | 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | 134,022.54 | 50,819.48 | 5% | 2.74 | 6.2% | 38.9% |
| #5 | 2.F | Product uses as substitutes for ODS | 1. Refrigeration and Air conditioning | HFCs | 0.00 | 43,179.50 | 6% | 2.01 | 4.5% | 43.4% |
| #6 | 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CH4 | 4,760.38 | 478.77 | 65% | 1.98 | 4.5% | 47.9% |
| #7 | 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | 10,098.26 | 3,506.81 | 42% | 1.96 | 4.4% | 52.3% |
| #8 | 1.A.4. | Other Sectors | Liquid Fuels | CO2 | 130,347.42 | 79,417.13 | 5% | 1.64 | 3.7% | 56.0% |
| #9 | 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | -72,385.80 | -58,092.54 | 13% | 1.45 | 3.3% | 59.3% |
| #10 | 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | 80,030.95 | 154,614.23 | 2% | 1.32 | 3.0% | 62.3% |
| #11 | 2.B | Chemical Industry | 4. Caprolactam, Glyoxal and Glyoxylic Acid Production | N2O | 1,672.86 | 128.58 | 99% | 1.08 | 2.4% | 64.7% |
| #12 | 2.F | Product uses as substitutes for ODS | 2. Foam Blowing Agents | HFCs | 1.34 | 2,921.97 | 50% | 1.06 | 2.4% | 67.1% |
| #13 | 5.A | Solid Waste Disposal | | CH4 | 9,570.42 | 2,930.29 | 22% | 1.04 | 2.3% | 69.4% |
| #14 | 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | 199,587.36 | 170,034.48 | 6% | 1.03 | 2.3% | 71.8% |
| #15 | 1.A.3. | Transport | b. Road Transportation | N2O | 3,457.24 | 1,441.90 | 72% | 1.01 | 2.3% | 74.0% |
| #16 | | Indirect CO2 | from IPPU sector | Ind CO2 | 4,454.80 | 1,606.10 | 48% | 0.95 | 2.1% | 76.2% |
| #17 | 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | 4,199.02 | 9,791.65 | 19% | 0.78 | 1.8% | 77.9% |
| #18 | 3.D | Agricultural Soils | 2. Indirect Emissions | N2O | 2,414.03 | 1,854.45 | 164% | 0.60 | 1.4% | 79.3% |
| #19 | 4.A | Forest Land | 2. Land converted to Forest Land | CO2 | -6,675.49 | -934.38 | 13% | 0.54 | 1.2% | 80.5% |
| #20 | 2.B | Chemical Industry | 3. Adipic Acid Production | N2O | 7,210.88 | 58.69 | 9% | 0.47 | 1.1% | 81.6% |
| #21 | 4.E | Settlements | 2. Land converted to Settlements | CO2 | 4,251.07 | 1,396.93 | 21% | 0.43 | 1.0% | 82.5% |
| #22 | 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | 22,241.56 | 44,269.23 | 2% | 0.39 | 0.9% | 83.4% |
| #23 | 4.G | Harvested Wood Products | | CO2 | -369.89 | -2,046.01 | 30% | 0.36 | 0.8% | 84.2% |
| #24 | 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | 11,894.05 | 32,191.67 | 2% | 0.36 | 0.8% | 85.0% |
| #25 | 2.A | Mineral Product | 1. Cement Production | CO2 | 38,701.10 | 26,182.94 | 4% | 0.35 | 0.8% | 85.8% |
| #26 | 3.A | Enteric Fermentation | | CH4 | 9,422.90 | 7,465.58 | 26% | 0.33 | 0.7% | 86.6% |
| #27 | 2.B | Chemical Industry | Other products except Anmonia | CO2 | 3,623.06 | 2,762.17 | 55% | 0.31 | 0.7% | 87.3% |
| #28 | 1.A.4. | Other Sectors | Solid Fuels | CO2 | 353.86 | 7,336.57 | 6% | 0.29 | 0.6% | 87.9% |
| #29 | 1.A.1. | Energy Industries | | N2O | 889.46 | 2,166.21 | 30% | 0.28 | 0.6% | 88.6% |
| #30 | 2.D | Non-energy Products from Fuels and Solvent Use | | CO2 | 2,039.82 | 2,643.96 | 55% | 0.26 | 0.6% | 89.1% |
| #31 | 2.E | Electronics Industry | | PFCs | 1,454.78 | 1,855.03 | 81% | 0.25 | 0.6% | 89.7% |
| #32 | 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | 6,678.58 | 8,224.13 | 19% | 0.23 | 0.5% | 90.2% |

Note: Source categories #32, which were identified as key in (1) but not in (2), was still regarded as key; while source categories, which were not identified as key in (1) but were done in (2), were not regarded as keys.

Data utilized for the key category analysis are shown in Table A1-9 and A1-10 as references.

Table A1-9 Data used for the key category analysis (FY2018)

| A IPCC Code | B IPCC Category | | C GHGs | E Absolute Value of FY1990 Estimate [Gg-CO2eq.] | G Absolute Value of Current Year Estimate [Gg-CO2eq.] | H Ap1-L | I % Ap1-L Contrib. | J Ap1-T | K % Ap1-T Contrib. | L Source/Sink Uncertainty | M Ap2-L | N % Ap2-L Contrib. | O Ap2-T | P % Ap2-T Contrib. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.A.1. | Energy Industries | Liquid Fuels | CO2 | 178,959.74 | 59,469.86 | 0.045 | 4.5% | 0.0840 | 15.7% | 5% | 0.029 | 2.9% | 3.95 | 8.9% |
| 1.A.1. | Energy Industries | Solid Fuels | CO2 | 109,537.93 | 258,379.86 | 0.197 | 19.7% | 0.1100 | 20.5% | 6% | 0.151 | 15.1% | 6.20 | 14.0% |
| 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | 80,030.95 | 154,614.23 | 0.118 | 11.8% | 0.0555 | 10.4% | 2% | 0.038 | 3.8% | 1.32 | 3.0% |
| 1.A.1. | Energy Industries | Other Fossil Fuels | CO2 | 0.00 | 24.22 | 0.000 | 0.0% | 0.0000 | 0.0% | 19% | 0.000 | 0.0% | 0.00 | 0.0% |
| 1.A.1. | Energy Industries | | CH4 | 459.35 | 199.60 | 0.000 | 0.0% | 0.0002 | 0.0% | 49% | 0.001 | 0.1% | 0.09 | 0.2% |
| 1.A.1. | Energy Industries | | N2O | 889.46 | 2,166.21 | 0.002 | 0.2% | 0.0009 | 0.2% | 30% | 0.007 | 0.7% | 0.28 | 0.6% |
| 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | 134,022.54 | 50,819.48 | 0.039 | 3.9% | 0.0584 | 10.9% | 5% | 0.025 | 2.5% | 2.74 | 6.2% |
| 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | 199,587.36 | 170,034.48 | 0.130 | 13.0% | 0.0183 | 3.4% | 6% | 0.099 | 9.9% | 1.03 | 2.3% |
| 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | 11,894.05 | 32,191.67 | 0.025 | 2.5% | 0.0150 | 2.8% | 2% | 0.008 | 0.8% | 0.36 | 0.8% |
| 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | 4,199.02 | 9,791.65 | 0.007 | 0.7% | 0.0041 | 0.8% | 19% | 0.019 | 1.9% | 0.78 | 1.8% |
| 1.A.2. | Manufacturing Industries and Construction | | CH4 | 359.71 | 491.85 | 0.000 | 0.0% | 0.0001 | 0.0% | 49% | 0.003 | 0.3% | 0.05 | 0.1% |
| 1.A.2. | Manufacturing Industries and Construction | | N2O | 1,258.65 | 1,599.73 | 0.001 | 0.1% | 0.0003 | 0.1% | 30% | 0.005 | 0.5% | 0.08 | 0.2% |
| 1.A.3. | Transport | a. Domestic Aviation | CO2 | 7,162.41 | 10,536.16 | 0.008 | 0.8% | 0.0026 | 0.5% | 5% | 0.005 | 0.5% | 0.12 | 0.3% |
| 1.A.3. | Transport | a. Domestic Aviation | CH4 | 5.64 | 1.50 | 0.000 | 0.0% | 0.0000 | 0.0% | 79% | 0.000 | 0.0% | 0.00 | 0.0% |
| 1.A.3. | Transport | a. Domestic Aviation | N2O | 64.02 | 91.96 | 0.000 | 0.0% | 0.0000 | 0.0% | 110% | 0.001 | 0.1% | 0.02 | 0.1% |
| 1.A.3. | Transport | b. Road Transportation | CO2 | 179,212.93 | 181,333.18 | 0.139 | 13.9% | 0.0044 | 0.8% | 5% | 0.088 | 8.8% | 0.21 | 0.5% |
| 1.A.3. | Transport | b. Road Transportation | CH4 | 252.59 | 98.87 | 0.000 | 0.0% | 0.0001 | 0.0% | 70% | 0.001 | 0.1% | 0.08 | 0.2% |
| 1.A.3. | Transport | b. Road Transportation | N2O | 3,457.24 | 1,441.90 | 0.001 | 0.1% | 0.0014 | 0.3% | 72% | 0.011 | 1.1% | 1.01 | 2.3% |
| 1.A.3. | Transport | c. Railways | CO2 | 935.40 | 498.78 | 0.000 | 0.0% | 0.0003 | 0.1% | 5% | 0.000 | 0.0% | 0.01 | 0.0% |
| 1.A.3. | Transport | c. Railways | CH4 | 1.34 | 0.70 | 0.000 | 0.0% | 0.0000 | 0.0% | 105% | 0.000 | 0.0% | 0.00 | 0.0% |
| 1.A.3. | Transport | c. Railways | N2O | 109.95 | 57.60 | 0.000 | 0.0% | 0.0000 | 0.0% | 125% | 0.001 | 0.1% | 0.05 | 0.1% |
| 1.A.3. | Transport | d. Domestic Navigation | CO2 | 13,674.88 | 10,546.38 | 0.008 | 0.8% | 0.0021 | 0.4% | 5% | 0.005 | 0.5% | 0.10 | 0.2% |
| 1.A.3. | Transport | d. Domestic Navigation | CH4 | 31.73 | 23.48 | 0.000 | 0.0% | 0.0000 | 0.0% | 52% | 0.000 | 0.0% | 0.00 | 0.0% |
| 1.A.3. | Transport | d. Domestic Navigation | N2O | 108.07 | 79.96 | 0.000 | 0.0% | 0.0000 | 0.0% | 91% | 0.001 | 0.1% | 0.02 | 0.0% |
| 1.A.4. | Other Sectors | Liquid Fuels | CO2 | 130,347.42 | 79,417.13 | 0.061 | 6.1% | 0.0350 | 6.5% | 5% | 0.039 | 3.9% | 1.64 | 3.7% |
| 1.A.4. | Other Sectors | Solid Fuels | CO2 | 353.86 | 7,336.57 | 0.006 | 0.6% | 0.0051 | 0.9% | 6% | 0.004 | 0.4% | 0.29 | 0.6% |
| 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | 22,241.56 | 44,269.23 | 0.034 | 3.4% | 0.0164 | 3.1% | 2% | 0.011 | 1.1% | 0.39 | 0.9% |
| 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | 6,678.58 | 8,224.13 | 0.006 | 0.6% | 0.0012 | 0.2% | 19% | 0.016 | 1.6% | 0.23 | 0.5% |
| 1.A.4. | Other Sectors | | CH4 | 239.23 | 197.98 | 0.000 | 0.0% | 0.0000 | 0.0% | 49% | 0.001 | 0.1% | 0.01 | 0.0% |
| 1.A.4. | Other Sectors | | N2O | 709.45 | 625.37 | 0.000 | 0.0% | 0.0000 | 0.0% | 30% | 0.002 | 0.2% | 0.01 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CO2 | 5.32 | 0.44 | 0.000 | 0.0% | 0.0000 | 0.0% | 68% | 0.000 | 0.0% | 0.00 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CH4 | 4,760.38 | 478.77 | 0.000 | 0.0% | 0.0030 | 0.6% | 65% | 0.003 | 0.3% | 1.98 | 4.5% |
| 1.B | Fugitive Emission from Fuel | 2.a. Oil | CO2 | 0.03 | 0.02 | 0.000 | 0.0% | 0.0000 | 0.0% | 89% | 0.000 | 0.0% | 0.00 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.a. Oil | CH4 | 25.37 | 18.17 | 0.000 | 0.0% | 0.0000 | 0.0% | 69% | 0.000 | 0.0% | 0.00 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.b. Natural Gas | CO2 | 0.63 | 0.83 | 0.000 | 0.0% | 0.0000 | 0.0% | 80% | 0.000 | 0.0% | 0.00 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.b. Natural Gas | CH4 | 174.24 | 232.11 | 0.000 | 0.0% | 0.0000 | 0.0% | 73% | 0.002 | 0.2% | 0.03 | 0.1% |
| 1.B | Fugitive Emission from Fuel | 2.c. Venting & Flaring | CO2 | 81.17 | 242.33 | 0.000 | 0.0% | 0.0001 | 0.0% | 14% | 0.000 | 0.0% | 0.02 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.c. Venting & Flaring | CH4 | 7.96 | 3.76 | 0.000 | 0.0% | 0.0000 | 0.0% | 49% | 0.000 | 0.0% | 0.00 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.c. Venting & Flaring | N2O | 0.11 | 0.07 | 0.000 | 0.0% | 0.0000 | 0.0% | 32% | 0.000 | 0.0% | 0.00 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.d. Other (Geothermal) | CO2 | 104.42 | 169.99 | 0.000 | 0.0% | 0.0000 | 0.0% | 17% | 0.000 | 0.0% | 0.01 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.d. Other (Geothermal) | CH4 | 5.21 | 8.35 | 0.000 | 0.0% | 0.0000 | 0.0% | 17% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.A | Mineral Product | 1. Cement Production | CO2 | 38,701.10 | 26,182.94 | 0.020 | 2.0% | 0.0085 | 1.6% | 4% | 0.011 | 1.1% | 0.35 | 0.8% |
| 2.A | Mineral Product | 2. Lime Production | CO2 | 6,674.45 | 5,663.34 | 0.004 | 0.4% | 0.0006 | 0.1% | 4% | 0.002 | 0.2% | 0.02 | 0.1% |
| 2.A | Mineral Product | 3. Glass Production | CO2 | 312.88 | 201.51 | 0.000 | 0.0% | 0.0001 | 0.0% | 6% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.A | Mineral Product | 4. Other Process Uses of Carbonates | CO2 | 3,542.02 | 1,659.29 | 0.001 | 0.1% | 0.0013 | 0.2% | 6% | 0.001 | 0.1% | 0.08 | 0.2% |
| 2.B | Chemical Industry | 1. Ammonia Production | CO2 | 3,417.74 | 1,457.96 | 0.001 | 0.1% | 0.0014 | 0.3% | 1% | 0.000 | 0.0% | 0.02 | 0.0% |
| 2.B | Chemical Industry | Other products except Anmonia | CO2 | 3,623.06 | 2,762.17 | 0.002 | 0.2% | 0.0006 | 0.1% | 55% | 0.016 | 1.6% | 0.31 | 0.7% |
| 2.B | Chemical Industry | 2. Nitric Acid Production | N2O | 736.06 | 318.48 | 0.000 | 0.0% | 0.0003 | 0.1% | 73% | 0.002 | 0.2% | 0.21 | 0.5% |
| 2.B | Chemical Industry | 3. Adipic Acid Production | N2O | 7,210.88 | 58.69 | 0.000 | 0.0% | 0.0051 | 0.9% | 9% | 0.000 | 0.0% | 0.47 | 1.1% |
| 2.B | Chemical Industry | 4. Caprolactam, Glyoxal and Glyoxylic Acid | N2O | 1,672.86 | 128.58 | 0.000 | 0.0% | 0.0011 | 0.2% | 99% | 0.001 | 0.1% | 1.08 | 2.4% |
| 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | HFCs | 15,930.24 | 100.30 | 0.000 | 0.0% | 0.0113 | 2.1% | 2% | 0.000 | 0.0% | 0.23 | 0.5% |
| 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | PFCs | 330.92 | 87.38 | 0.000 | 0.0% | 0.0002 | 0.0% | 2% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | SF6 | 3,470.78 | 45.55 | 0.000 | 0.0% | 0.0024 | 0.5% | 2% | 0.000 | 0.0% | 0.05 | 0.1% |
| 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | NF3 | 2.79 | 57.96 | 0.000 | 0.0% | 0.0000 | 0.0% | 2% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.B | Chemical Industry | Whole of Chemical Industries | CH4 | 37.49 | 22.71 | 0.000 | 0.0% | 0.0000 | 0.0% | 55% | 0.000 | 0.0% | 0.01 | 0.0% |
| 2.C | Metal Production | 1 Iron and Steel Production | CO2 | 7,244.20 | 5,712.42 | 0.004 | 0.4% | 0.0010 | 0.2% | 4% | 0.002 | 0.2% | 0.04 | 0.1% |
| 2.C | Metal Production | 1 Iron and Steel Production | CH4 | 18.42 | 14.94 | 0.000 | 0.0% | 0.0000 | 0.0% | 163% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.C | Metal Production | 2. Ferroalloys Production | CH4 | 4.63 | 2.85 | 0.000 | 0.0% | 0.0000 | 0.0% | 163% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.C | Metal Production | 3. Aluminium Production | PFCs | 203.66 | 0.00 | 0.000 | 0.0% | 0.0001 | 0.0% | 44% | 0.000 | 0.0% | 0.06 | 0.1% |
| 2.C | Metal Production | 4. SF6 Used in Aluminium and Magnesium oundries | HFCs | 0.00 | 1.72 | 0.000 | 0.0% | 0.0000 | 0.0% | 5% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.C | Metal Production | 4. SF6 Used in Aluminium and Magnesium oundries | SF6 | 146.54 | 273.60 | 0.000 | 0.0% | 0.0001 | 0.0% | 5% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.D | Non-energy Products from Fuels and Solvent Use | | CO2 | 2,039.82 | 2,643.96 | 0.002 | 0.2% | 0.0005 | 0.1% | 55% | 0.015 | 1.5% | 0.26 | 0.6% |
| 2.E | Electronics Industry | | HFCs | 0.73 | 113.15 | 0.000 | 0.0% | 0.0001 | 0.0% | 100% | 0.001 | 0.1% | 0.08 | 0.2% |
| 2.E | Electronics Industry | | PFCs | 1,454.78 | 1,855.03 | 0.001 | 0.1% | 0.0003 | 0.1% | 81% | 0.016 | 1.6% | 0.25 | 0.6% |
| 2.E | Electronics Industry | | SF6 | 418.70 | 349.02 | 0.000 | 0.0% | 0.0000 | 0.0% | 300% | 0.011 | 1.1% | 0.13 | 0.3% |
| 2.E | Electronics Industry | | NF3 | 29.82 | 224.53 | 0.000 | 0.0% | 0.0001 | 0.0% | 71% | 0.002 | 0.2% | 0.10 | 0.2% |
| 2.F | Product uses as substitutes for ODS | 1. Refrigeration and Air conditioning | HFCs | 0.00 | 43,179.50 | 0.033 | 3.3% | 0.0314 | 5.9% | 6% | 0.029 | 2.9% | 2.01 | 4.5% |
| 2.F | Product uses as substitutes for ODS | 2. Foam Blowing Agents | HFCs | 1.34 | 2,921.97 | 0.002 | 0.2% | 0.0021 | 0.4% | 50% | 0.015 | 1.5% | 1.06 | 2.4% |
| 2.F | Product uses as substitutes for ODS | 3. Fire Extinguishers | HFCs | 0.00 | 9.84 | 0.000 | 0.0% | 0.0000 | 0.0% | 16% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.F | Product uses as substitutes for ODS | 4. Aerosols | HFCs | 0.00 | 543.92 | 0.000 | 0.0% | 0.0004 | 0.1% | 10% | 0.001 | 0.1% | 0.04 | 0.1% |
| 2.F | Product uses as substitutes for ODS | 5. Solvents | HFCs | 0.00 | 117.27 | 0.000 | 0.0% | 0.0001 | 0.0% | 11% | 0.000 | 0.0% | 0.01 | 0.0% |
| 2.F | Product uses as substitutes for ODS | 5. Solvents | PFCs | 4,549.94 | 1,505.11 | 0.001 | 0.1% | 0.0021 | 0.4% | 10% | 0.002 | 0.2% | 0.21 | 0.5% |
| 2.G | Other Product Manufacture and Use | | N2O | 290.86 | 370.01 | 0.000 | 0.0% | 0.0001 | 0.0% | 4% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.G | Other Product Manufacture and Use | | PFCs | 0.00 | 39.27 | 0.000 | 0.0% | 0.0000 | 0.0% | 10% | 0.000 | 0.0% | 0.00 | 0.0% |
| 2.G | Other Product Manufacture and Use | | SF6 | 8,814.04 | 1,374.70 | 0.001 | 0.1% | 0.0053 | 1.0% | 83% | 0.012 | 1.2% | 4.37 | 9.9% |
| 2.H | Other | Use of Dry Ice | CO2 | 64.61 | 105.33 | 0.000 | 0.0% | 0.0000 | 0.0% | 4% | 0.000 | 0.0% | 0.00 | 0.0% |
| 3.A | Enteric Fermentation | | CH4 | 9,422.90 | 7,465.58 | 0.006 | 0.6% | 0.0013 | 0.2% | 26% | 0.020 | 2.0% | 0.33 | 0.7% |
| 3.B | Manure Management | | CH4 | 3,120.55 | 2,323.55 | 0.002 | 0.2% | 0.0005 | 0.1% | 17% | 0.004 | 0.4% | 0.09 | 0.2% |
| 3.B | Manure Management | | N2O | 4,207.98 | 3,921.66 | 0.003 | 0.3% | 0.0001 | 0.0% | 76% | 0.031 | 3.1% | 0.11 | 0.2% |
| 3.C | Rice Cultivation | | CH4 | 12,770.99 | 13,560.65 | 0.010 | 1.0% | 0.0008 | 0.1% | 6% | 0.009 | 0.9% | 0.05 | 0.1% |
| 3.D | Agricultural Soils | 1. Direct Emissions | N2O | 4,701.08 | 3,557.23 | 0.003 | 0.3% | 0.0008 | 0.1% | 26% | 0.009 | 0.9% | 0.19 | 0.4% |
| 3.D | Agricultural Soils | 2. Indirect Emissions | N2O | 2,414.03 | 1,854.45 | 0.001 | 0.1% | 0.0004 | 0.1% | 164% | 0.031 | 3.1% | 0.60 | 1.4% |
| 3.F | Field Burning of Agricultural Residues | | CH4 | 127.03 | 63.39 | 0.000 | 0.0% | 0.0000 | 0.0% | 296% | 0.002 | 0.2% | 0.13 | 0.3% |
| 3.F | Field Burning of Agricultural Residues | | N2O | 39.26 | 19.59 | 0.000 | 0.0% | 0.0000 | 0.0% | 300% | 0.001 | 0.1% | 0.04 | 0.1% |
| 3.G | Liming | | CO2 | 550.24 | 293.54 | 0.000 | 0.0% | 0.0002 | 0.0% | 50% | 0.002 | 0.2% | 0.09 | 0.2% |
| 3.H | Urea Application | | CO2 | 58.64 | 192.81 | 0.000 | 0.0% | 0.0001 | 0.0% | 50% | 0.001 | 0.1% | 0.05 | 0.1% |

## Table A1-9 Data used for the key category analysis (FY2018) (Continued)

| A IPCC Code | B IPCC Category | | C GHGs | E Absolute Value of FY1990 Estimate [Gg-CO2eq.] | G Absolute Value of Current Year Estimate [Gg-CO2eq.] | H Ap1-L | I % Ap1-L Contrib. | J Ap1-T | K % Ap1-T Contrib. | L Source/Sink Uncertainty | M Ap2-L | N % Ap2-L Contrib. | O Ap2-T | P % Ap2-T Contrib. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | 72,385.80 | 58,092.54 | 0.044 | 4.4% | 0.0116 | 2.2% | 13% | 0.075 | 7.5% | 1.45 | 3.3% |
| 4.A | Forest Land | 2. Land converted to Forest Land | CO2 | 6,675.49 | 934.38 | 0.001 | 0.1% | 0.0043 | 0.8% | 13% | 0.001 | 0.1% | 0.54 | 1.2% |
| 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | 10,098.26 | 3,506.81 | 0.003 | 0.3% | 0.0046 | 0.9% | 42% | 0.015 | 1.5% | 1.96 | 4.4% |
| 4.B | Cropland | 2. Land converted to Cropland | CO2 | 1,598.43 | 23.44 | 0.000 | 0.0% | 0.0011 | 0.2% | 18% | 0.000 | 0.0% | 0.20 | 0.5% |
| 4.C | Grassland | 1. Grassland remaining Grassland | CO2 | 881.36 | 333.17 | 0.000 | 0.0% | 0.0009 | 0.2% | 9% | 0.000 | 0.0% | 0.08 | 0.2% |
| 4.C | Grassland | 2. Land converted to Grassland | CO2 | 180.80 | 66.96 | 0.000 | 0.0% | 0.0001 | 0.0% | 20% | 0.000 | 0.0% | 0.02 | 0.0% |
| 4.D | Wetlands | 1.1 Peat Extraction Remaining Peat Extraction | CO2 | 0.00 | 0.00 | 0.000 | 0.0% | 0.0000 | 0.0% | 21% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.D | Wetlands | 1.2 Flooded Land Remaining Flooded Land | CO2 | 0.00 | 0.00 | 0.000 | 0.0% | 0.0000 | 0.0% | 21% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.D | Wetlands | 1.3 Other Wetlands Remaining Other Wetlands | CO2 | 0.00 | 0.00 | 0.000 | 0.0% | 0.0000 | 0.0% | 21% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.D | Wetlands | 2. Land converted to Wetlands | CO2 | 90.51 | 17.30 | 0.000 | 0.0% | 0.0001 | 0.0% | 21% | 0.000 | 0.0% | 0.01 | 0.0% |
| 4.E | Settlements | 1. Settlements remaining Settlements | CO2 | 1,386.01 | 1,423.79 | 0.001 | 0.1% | 0.0000 | 0.0% | 33% | 0.005 | 0.5% | 0.00 | 0.0% |
| 4.E | Settlements | 2. Land converted to Settlements | CO2 | 4,251.07 | 1,396.93 | 0.001 | 0.1% | 0.0020 | 0.4% | 21% | 0.003 | 0.3% | 0.43 | 1.0% |
| 4.F | Other Land | 1. Other Land remaining Other Land | CO2 | 0.00 | 0.00 | 0.000 | 0.0% | 0.0000 | 0.0% | 20% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.F | Other Land | 2. Land converted to Other Land | CO2 | 1,180.13 | 163.84 | 0.000 | 0.0% | 0.0007 | 0.1% | 20% | 0.000 | 0.0% | 0.14 | 0.3% |
| 4.G | Harvested Wood Products | | CO2 | 369.89 | 2,046.01 | 0.002 | 0.2% | 0.0012 | 0.2% | 30% | 0.006 | 0.6% | 0.36 | 0.8% |
| 4.H | Other (Organic soil in settlements converted from other land-use categories) | | CH4 | 13.90 | 6.18 | 0.000 | 0.0% | 0.0000 | 0.0% | 71% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.H | Other (Organic soil in settlements converted from other land-use categories) | | N2O | 0.84 | 0.38 | 0.000 | 0.0% | 0.0000 | 0.0% | 138% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.(I) | Direct N2O emissions from N inputs to managed | | N2O | 0.84 | 0.51 | 0.000 | 0.0% | 0.0000 | 0.0% | 31% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.(II) | Drainage and rewetting | | CO2 | 0.00 | 0.00 | 0.000 | 0.0% | 0.0000 | 0.0% | 0% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.(II) | Drainage and rewetting | | CH4 | 38.23 | 37.46 | 0.000 | 0.0% | 0.0000 | 0.0% | 71% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.(II) | Drainage and rewetting | | N2O | 0.00 | 0.00 | 0.000 | 0.0% | 0.0000 | 0.0% | 0% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.(III) | Direct N2O emissions from N mineralization/immobilization | | N2O | 153.67 | 137.41 | 0.000 | 0.0% | 0.0000 | 0.0% | 138% | 0.002 | 0.2% | 0.01 | 0.0% |
| 4.(IV) | Indirect N2O Emissions from Managed Soils | | N2O | 41.19 | 33.03 | 0.000 | 0.0% | 0.0000 | 0.0% | 318% | 0.001 | 0.1% | 0.02 | 0.0% |
| 4.(V) | Biomass Burning | | CO2 | 0.00 | 0.00 | 0.000 | 0.0% | 0.0000 | 0.0% | 0% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.(V) | Biomass Burning | | CH4 | 47.20 | 30.78 | 0.000 | 0.0% | 0.0000 | 0.0% | 28% | 0.000 | 0.0% | 0.00 | 0.0% |
| 4.(V) | Biomass Burning | | N2O | 22.15 | 18.80 | 0.000 | 0.0% | 0.0000 | 0.0% | 31% | 0.000 | 0.0% | 0.00 | 0.0% |
| 5.A | Solid Waste Disposal | | CH4 | 9,570.42 | 2,930.29 | 0.002 | 0.2% | 0.0047 | 0.9% | 22% | 0.007 | 0.7% | 1.04 | 2.3% |
| 5.B | Biological Treatment of Soild Waste | | CH4 | 53.99 | 88.99 | 0.000 | 0.0% | 0.0000 | 0.0% | 84% | 0.001 | 0.1% | 0.02 | 0.0% |
| 5.B | Biological Treatment of Soild Waste | | N2O | 180.77 | 296.03 | 0.000 | 0.0% | 0.0001 | 0.0% | 170% | 0.005 | 0.5% | 0.15 | 0.3% |
| 5.C | Incineration and Open Burning of Waste | | CO2 | 12,429.49 | 10,238.78 | 0.008 | 0.8% | 0.0014 | 0.3% | 16% | 0.017 | 1.7% | 0.23 | 0.5% |
| 5.C | Incineration and Open Burning of Waste | | CH4 | 27.78 | 10.28 | 0.000 | 0.0% | 0.0000 | 0.0% | 170% | 0.000 | 0.0% | 0.02 | 0.0% |
| 5.C | Incineration and Open Burning of Waste | | N2O | 1,438.04 | 1,429.22 | 0.001 | 0.1% | 0.0000 | 0.0% | 79% | 0.012 | 1.2% | 0.01 | 0.0% |
| 5.D | Wastewater Treatment and Discharge | | CH4 | 2,941.55 | 1,616.54 | 0.001 | 0.1% | 0.0009 | 0.2% | 21% | 0.004 | 0.4% | 0.20 | 0.4% |
| 5.D | Wastewater Treatment and Discharge | | N2O | 2,387.11 | 1,983.24 | 0.002 | 0.2% | 0.0003 | 0.0% | 38% | 0.008 | 0.8% | 0.10 | 0.2% |
| 5.E | Other | | CO2 | 702.83 | 673.34 | 0.001 | 0.1% | 0.0000 | 0.0% | 10% | 0.001 | 0.1% | 0.00 | 0.0% |
| | Indirect CO2 | from Energy sector | Ind CO2 | 1,027.51 | 456.92 | 0.000 | 0.0% | 0.0004 | 0.1% | 32% | 0.002 | 0.2% | 0.13 | 0.3% |
| | Indirect CO2 | from IPPU sector | Ind CO2 | 4,454.80 | 1,606.10 | 0.001 | 0.1% | 0.0020 | 0.4% | 48% | 0.008 | 0.8% | 0.95 | 2.1% |
| Absolute Figure Total (including LULUCF) | | | | 1,374,938.04 | 1,308,675.43 | 1.00 | 100.0% | 0.54 | 100% | | 1.00 | 100.0% | 44.4 | 100.0% |

## Table A1-10 Data used for the key category analysis (FY1990)

| A IPCC Code | B IPCC Category | | C GHGs | E Absolute Value of FY1990 Estimate [Gg-CO2eq.] | H Ap1-L | I % Ap1-L Contrib. | L Source/Sink Uncertainty | M Ap2-L | N % Ap2-L Contrib. |
|---|---|---|---|---|---|---|---|---|---|
| 1.A.1. | Energy Industries | Liquid Fuels | CO2 | 178,959.74 | 0.130 | 13.0% | 5% | 0.071 | 7.1% |
| 1.A.1. | Energy Industries | Solid Fuels | CO2 | 109,537.93 | 0.080 | 8.0% | 6% | 0.052 | 5.2% |
| 1.A.1. | Energy Industries | Gaseous Fuels | CO2 | 80,030.95 | 0.058 | 5.8% | 2% | 0.016 | 1.6% |
| 1.A.1. | Energy Industries | Other Fossil Fuels | CO2 | 0.00 | 0.000 | 0.0% | 19% | 0.000 | 0.0% |
| 1.A.1. | Energy Industries | | CH4 | 459.35 | 0.000 | 0.0% | 49% | 0.002 | 0.2% |
| 1.A.1. | Energy Industries | | N2O | 889.46 | 0.001 | 0.1% | 30% | 0.002 | 0.2% |
| 1.A.2. | Manufacturing Industries and Construction | Liquid Fuels | CO2 | 134,022.54 | 0.097 | 9.7% | 5% | 0.053 | 5.3% |
| 1.A.2. | Manufacturing Industries and Construction | Solid Fuels | CO2 | 199,587.36 | 0.145 | 14.5% | 6% | 0.095 | 9.5% |
| 1.A.2. | Manufacturing Industries and Construction | Gaseous Fuels | CO2 | 11,894.05 | 0.009 | 0.9% | 2% | 0.002 | 0.2% |
| 1.A.2. | Manufacturing Industries and Construction | Other Fossil Fuels | CO2 | 4,199.02 | 0.003 | 0.3% | 19% | 0.007 | 0.7% |
| 1.A.2. | Manufacturing Industries and Construction | | CH4 | 359.71 | 0.000 | 0.0% | 49% | 0.001 | 0.1% |
| 1.A.2. | Manufacturing Industries and Construction | | N2O | 1,258.65 | 0.001 | 0.1% | 30% | 0.003 | 0.3% |
| 1.A.3. | Transport | a. Domestic Aviation | CO2 | 7,162.41 | 0.005 | 0.5% | 5% | 0.003 | 0.3% |
| 1.A.3. | Transport | a. Domestic Aviation | CH4 | 5.64 | 0.000 | 0.0% | 79% | 0.000 | 0.0% |
| 1.A.3. | Transport | a. Domestic Aviation | N2O | 64.02 | 0.000 | 0.0% | 110% | 0.001 | 0.1% |
| 1.A.3. | Transport | b. Road Transportation | CO2 | 179,212.93 | 0.130 | 13.0% | 5% | 0.071 | 7.1% |
| 1.A.3. | Transport | b. Road Transportation | CH4 | 252.59 | 0.000 | 0.0% | 70% | 0.001 | 0.1% |
| 1.A.3. | Transport | b. Road Transportation | N2O | 3,457.24 | 0.003 | 0.3% | 72% | 0.021 | 2.1% |
| 1.A.3. | Transport | c. Railways | CO2 | 935.40 | 0.001 | 0.1% | 5% | 0.000 | 0.0% |
| 1.A.3. | Transport | c. Railways | CH4 | 1.34 | 0.000 | 0.0% | 105% | 0.000 | 0.0% |
| 1.A.3. | Transport | c. Railways | N2O | 109.95 | 0.000 | 0.0% | 125% | 0.001 | 0.1% |
| 1.A.3. | Transport | d. Domestic Navigation | CO2 | 13,674.88 | 0.010 | 1.0% | 5% | 0.005 | 0.5% |
| 1.A.3. | Transport | d. Domestic Navigation | CH4 | 31.73 | 0.000 | 0.0% | 52% | 0.000 | 0.0% |
| 1.A.3. | Transport | d. Domestic Navigation | N2O | 108.07 | 0.000 | 0.0% | 91% | 0.001 | 0.1% |
| 1.A.4. | Other Sectors | Liquid Fuels | CO2 | 130,347.42 | 0.095 | 9.5% | 5% | 0.052 | 5.2% |
| 1.A.4. | Other Sectors | Solid Fuels | CO2 | 353.86 | 0.000 | 0.0% | 6% | 0.000 | 0.0% |
| 1.A.4. | Other Sectors | Gaseous Fuels | CO2 | 22,241.56 | 0.016 | 1.6% | 2% | 0.004 | 0.4% |
| 1.A.4. | Other Sectors | Other Fossil Fuels | CO2 | 6,678.58 | 0.005 | 0.5% | 19% | 0.011 | 1.1% |
| 1.A.4. | Other Sectors | | CH4 | 239.23 | 0.000 | 0.0% | 49% | 0.001 | 0.1% |
| 1.A.4. | Other Sectors | | N2O | 709.45 | 0.001 | 0.1% | 30% | 0.002 | 0.2% |
| 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CO2 | 5.32 | 0.000 | 0.0% | 68% | 0.000 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 1.Fugitive emissions from Solid Fuels | CH4 | 4,760.38 | 0.003 | 0.3% | 65% | 0.026 | 2.6% |
| 1.B | Fugitive Emission from Fuel | 2.a. Oil | CO2 | 0.03 | 0.000 | 0.0% | 89% | 0.000 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.a. Oil | CH4 | 25.37 | 0.000 | 0.0% | 69% | 0.000 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.b. Natural Gas | CO2 | 0.63 | 0.000 | 0.0% | 80% | 0.000 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.b. Natural Gas | CH4 | 174.24 | 0.000 | 0.0% | 73% | 0.001 | 0.1% |
| 1.B | Fugitive Emission from Fuel | 2.c. Venting & Flaring | CO2 | 81.17 | 0.000 | 0.0% | 14% | 0.000 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.c. Venting & Flaring | CH4 | 7.96 | 0.000 | 0.0% | 49% | 0.000 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.c. Venting & Flaring | N2O | 0.11 | 0.000 | 0.0% | 32% | 0.000 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.d. Other (Geothermal) | CO2 | 104.42 | 0.000 | 0.0% | 17% | 0.000 | 0.0% |
| 1.B | Fugitive Emission from Fuel | 2.d. Other (Geothermal) | CH4 | 5.21 | 0.000 | 0.0% | 17% | 0.000 | 0.0% |

Table A1-10 Data used for the key category analysis (FY1990) (Continued)

| A IPCC Code | B IPCC Category | | C GHGs | E Absolute Value of FY1990 Estimate [Gg-CO2eq.] | H Ap1-L | I % Ap1-L Contrib. | L Source/Sink Uncertainty | M Ap2-L | N % Ap2-L Contrib. |
|---|---|---|---|---|---|---|---|---|---|
| 2.A | Mineral Product | 1. Cement Production | CO2 | 38,701.10 | 0.028 | 2.8% | 4% | 0.013 | 1.3% |
| 2.A | Mineral Product | 2. Lime Production | CO2 | 6,674.45 | 0.005 | 0.5% | 4% | 0.002 | 0.2% |
| 2.A | Mineral Product | 3. Glass Production | CO2 | 312.88 | 0.000 | 0.0% | 6% | 0.000 | 0.0% |
| 2.A | Mineral Product | 4. Other Process Uses of Carbonates | CO2 | 3,542.02 | 0.003 | 0.3% | 6% | 0.002 | 0.2% |
| 2.B | Chemical Industry | 1. Ammonia Production | CO2 | 3,417.74 | 0.002 | 0.2% | 1% | 0.000 | 0.0% |
| 2.B | Chemical Industry | Other products except Anmonia | CO2 | 3,623.06 | 0.003 | 0.3% | 55% | 0.017 | 1.7% |
| 2.B | Chemical Industry | 2. Nitric Acid Production | N2O | 736.06 | 0.001 | 0.1% | 73% | 0.005 | 0.5% |
| 2.B | Chemical Industry | 3. Adipic Acid Production | N2O | 7,210.88 | 0.005 | 0.5% | 9% | 0.006 | 0.6% |
| 2.B | Chemical Industry | 4. Caprolactam, Glyoxal and Glyoxylic Acid Production | N2O | 1,672.86 | 0.001 | 0.1% | 99% | 0.014 | 1.4% |
| 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | HFCs | 15,930.24 | 0.012 | 1.2% | 2% | 0.003 | 0.3% |
| 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | PFCs | 330.92 | 0.000 | 0.0% | 2% | 0.000 | 0.0% |
| 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | SF6 | 3,470.78 | 0.003 | 0.3% | 2% | 0.001 | 0.1% |
| 2.B | Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | NF3 | 2.79 | 0.000 | 0.0% | 2% | 0.000 | 0.0% |
| 2.B | Chemical Industry | Whole of Chemical Industries | CH4 | 37.49 | 0.000 | 0.0% | 55% | 0.000 | 0.0% |
| 2.C | Metal Production | 1 Iron and Steel Production | CO2 | 7,244.20 | 0.005 | 0.5% | 4% | 0.002 | 0.2% |
| 2.C | Metal Production | 1 Iron and Steel Production | CH4 | 18.42 | 0.000 | 0.0% | 163% | 0.000 | 0.0% |
| 2.C | Metal Production | 2. Ferroalloys Production | CH4 | 4.63 | 0.000 | 0.0% | 163% | 0.000 | 0.0% |
| 2.C | Metal Production | 3. Aluminium Production | PFCs | 203.66 | 0.000 | 0.0% | 44% | 0.001 | 0.1% |
| 2.C | Metal Production | 4. SF6 Used in Aluminium and Magnesium oundries | HFCs | 0.00 | 0.000 | 0.0% | 5% | 0.000 | 0.0% |
| 2.C | Metal Production | 4. SF6 Used in Aluminium and Magnesium oundries | SF6 | 146.54 | 0.000 | 0.0% | 5% | 0.000 | 0.0% |
| 2.D | Non-energy Products from Fuels and Solvent Use | | CO2 | 2,039.82 | 0.001 | 0.1% | 55% | 0.009 | 0.9% |
| 2.E | Electronics Industry | | HFCs | 0.73 | 0.000 | 0.0% | 100% | 0.000 | 0.0% |
| 2.E | Electronics Industry | | PFCs | 1,454.78 | 0.001 | 0.1% | 81% | 0.010 | 1.0% |
| 2.E | Electronics Industry | | SF6 | 418.70 | 0.000 | 0.0% | 300% | 0.011 | 1.1% |
| 2.E | Electronics Industry | | NF3 | 29.82 | 0.000 | 0.0% | 71% | 0.000 | 0.0% |
| 2.F | Product uses as substitutes for ODS | 1. Refrigeration and Air conditioning | HFCs | 0.00 | 0.000 | 0.0% | 6% | 0.000 | 0.0% |
| 2.F | Product uses as substitutes for ODS | 2. Foam Blowing Agents | HFCs | 1.34 | 0.000 | 0.0% | 50% | 0.000 | 0.0% |
| 2.F | Product uses as substitutes for ODS | 3. Fire Extinguishers | HFCs | 0.00 | 0.000 | 0.0% | 16% | 0.000 | 0.0% |
| 2.F | Product uses as substitutes for ODS | 4. Aerosols | HFCs | 0.00 | 0.000 | 0.0% | 10% | 0.000 | 0.0% |
| 2.F | Product uses as substitutes for ODS | 5. Solvents | HFCs | 0.00 | 0.000 | 0.0% | 11% | 0.000 | 0.0% |
| 2.F | Product uses as substitutes for ODS | 5. Solvents | PFCs | 4,549.94 | 0.003 | 0.3% | 10% | 0.004 | 0.4% |
| 2.G | Other Product Manufacture and Use | | N2O | 290.86 | 0.000 | 0.0% | 4% | 0.000 | 0.0% |
| 2.G | Other Product Manufacture and Use | | PFCs | 0.00 | 0.000 | 0.0% | 10% | 0.000 | 0.0% |
| 2.G | Other Product Manufacture and Use | | SF6 | 8,814.04 | 0.006 | 0.6% | 83% | 0.062 | 6.2% |
| 2.H | Other | Use of Dry Ice | CO2 | 64.61 | 0.000 | 0.0% | 4% | 0.000 | 0.0% |
| 3.A | Enteric Fermentation | | CH4 | 9,422.90 | 0.007 | 0.7% | 26% | 0.021 | 2.1% |
| 3.B | Manure Management | | CH4 | 3,120.55 | 0.002 | 0.2% | 17% | 0.005 | 0.5% |
| 3.B | Manure Management | | N2O | 4,207.98 | 0.003 | 0.3% | 76% | 0.027 | 2.7% |
| 3.C | Rice Cultivation | | CH4 | 12,770.99 | 0.009 | 0.9% | 6% | 0.007 | 0.7% |
| 3.D | Agricultural Soils | 1. Direct Emissions | N2O | 4,701.08 | 0.003 | 0.3% | 26% | 0.010 | 1.0% |
| 3.D | Agricultural Soils | 2. Indirect Emissions | N2O | 2,414.03 | 0.002 | 0.2% | 164% | 0.033 | 3.3% |
| 3.F | Field Burning of Agricultural Residues | | CH4 | 127.03 | 0.000 | 0.0% | 296% | 0.003 | 0.3% |
| 3.F | Field Burning of Agricultural Residues | | N2O | 39.26 | 0.000 | 0.0% | 300% | 0.001 | 0.1% |
| 3.G | Liming | | CO2 | 550.24 | 0.000 | 0.0% | 50% | 0.002 | 0.2% |
| 3.H | Urea Application | | CO2 | 58.64 | 0.000 | 0.0% | 50% | 0.000 | 0.0% |
| 4.A | Forest Land | 1. Forest Land remaining Forest Land | CO2 | 72,385.80 | 0.053 | 5.3% | 13% | 0.076 | 7.6% |
| 4.A | Forest Land | 2. Land converted to Forest Land | CO2 | 6,675.49 | 0.005 | 0.5% | 13% | 0.007 | 0.7% |
| 4.B | Cropland | 1. Cropland remaining Cropland | CO2 | 10,098.26 | 0.007 | 0.7% | 42% | 0.036 | 3.6% |
| 4.B | Cropland | 2. Land converted to Cropland | CO2 | 1,598.43 | 0.001 | 0.1% | 18% | 0.002 | 0.2% |
| 4.C | Grassland | 1. Grassland remaining Grassland | CO2 | 881.36 | 0.001 | 0.1% | 9% | 0.001 | 0.1% |
| 4.C | Grassland | 2. Land converted to Grassland | CO2 | 180.80 | 0.000 | 0.0% | 20% | 0.000 | 0.0% |
| 4.D | Wetlands | 1.1 Peat Extraction Remaining Peat Extraction | CO2 | 0.00 | 0.000 | 0.0% | 21% | 0.000 | 0.0% |
| 4.D | Wetlands | 1.2 Flooded Land Remaining Flooded Land | CO2 | 0.00 | 0.000 | 0.0% | 21% | 0.000 | 0.0% |
| 4.D | Wetlands | 1.3 Other Wetlands Remaining Other Wetlands | CO2 | 0.00 | 0.000 | 0.0% | 21% | 0.000 | 0.0% |
| 4.D | Wetlands | 2. Land converted to Wetlands | CO2 | 90.51 | 0.000 | 0.0% | 21% | 0.000 | 0.0% |
| 4.E | Settlements | 1. Settlements remaining Settlements | CO2 | 1,386.01 | 0.001 | 0.1% | 33% | 0.004 | 0.4% |
| 4.E | Settlements | 2. Land converted to Settlements | CO2 | 4,251.07 | 0.003 | 0.3% | 21% | 0.008 | 0.8% |
| 4.F | Other Land | 1. Other Land remaining Other Land | CO2 | 0.00 | 0.000 | 0.0% | 20% | 0.000 | 0.0% |
| 4.F | Other Land | 2. Land converted to Other Land | CO2 | 1,180.13 | 0.001 | 0.1% | 20% | 0.002 | 0.2% |
| 4.G | Harvested Wood Products | | CO2 | 369.89 | 0.000 | 0.0% | 30% | 0.001 | 0.1% |
| 4.H | Other (Organic soil in settlements converted from other land-use categories) | | CH4 | 13.90 | 0.000 | 0.0% | 71% | 0.000 | 0.0% |
| 4.H | Other (Organic soil in settlements converted from other land-use categories) | | N2O | 0.84 | 0.000 | 0.0% | 138% | 0.000 | 0.0% |
| 4.(I) | Direct N2O emissions from N inputs to manage | | N2O | 0.84 | 0.000 | 0.0% | 31% | 0.000 | 0.0% |
| 4.(II) | Drainage and rewetting | | CO2 | 0.00 | 0.000 | 0.0% | 0% | 0.000 | 0.0% |
| 4.(II) | Drainage and rewetting | | CH4 | 38.23 | 0.000 | 0.0% | 71% | 0.000 | 0.0% |
| 4.(II) | Drainage and rewetting | | N2O | 0.00 | 0.000 | 0.0% | 0% | 0.000 | 0.0% |
| 4.(III) | Direct N2O emissions from N mineralization/immobilization | | N2O | 153.67 | 0.000 | 0.0% | 138% | 0.002 | 0.2% |
| 4.(IV) | Indirect N2O Emissions from Managed Soils | | N2O | 41.19 | 0.000 | 0.0% | 318% | 0.001 | 0.1% |
| 4.(V) | Biomass Burning | | CO2 | 0.00 | 0.000 | 0.0% | 0% | 0.000 | 0.0% |
| 4.(V) | Biomass Burning | | CH4 | 47.20 | 0.000 | 0.0% | 28% | 0.000 | 0.0% |
| 4.(V) | Biomass Burning | | N2O | 22.15 | 0.000 | 0.0% | 31% | 0.000 | 0.0% |
| 5.A | Solid Waste Disposal | | CH4 | 9,570.42 | 0.007 | 0.7% | 22% | 0.018 | 1.8% |
| 5.B | Biological Treatment of Soild Waste | | CH4 | 53.99 | 0.000 | 0.0% | 84% | 0.000 | 0.0% |
| 5.B | Biological Treatment of Soild Waste | | N2O | 180.77 | 0.000 | 0.0% | 170% | 0.003 | 0.3% |
| 5.C | Incineration and Open Burning of Waste | | CO2 | 12,429.49 | 0.009 | 0.9% | 16% | 0.017 | 1.7% |
| 5.C | Incineration and Open Burning of Waste | | CH4 | 27.78 | 0.000 | 0.0% | 170% | 0.000 | 0.0% |
| 5.C | Incineration and Open Burning of Waste | | N2O | 1,438.04 | 0.001 | 0.1% | 79% | 0.010 | 1.0% |
| 5.D | Wastewater Treatment and Discharge | | CH4 | 2,941.55 | 0.002 | 0.2% | 21% | 0.005 | 0.5% |
| 5.D | Wastewater Treatment and Discharge | | N2O | 2,387.11 | 0.002 | 0.2% | 38% | 0.008 | 0.8% |
| 5.E | Other | | CO2 | 702.83 | 0.001 | 0.1% | 10% | 0.001 | 0.1% |
| | Indirect CO2 | from Energy sector | Ind CO2 | 1,027.51 | 0.001 | 0.1% | 32% | 0.003 | 0.3% |
| | Indirect CO2 | from IPPU sector | Ind CO2 | 4,454.80 | 0.003 | 0.3% | 48% | 0.018 | 1.8% |
| Total (including LULUCF) | | | | 1,374,938.04 | 1.00 | 100.0% | | 1.00 | 100% |

# Annex 2. Assessment of Uncertainty

## A2.1. Methodology of Uncertainty Assessment

"Uncertainty" is a conceptual framework which represents the differences between emissions/ removals inventory estimates and true underlying values, resulting from lack of data or representativeness, sampling error, or, errors in measurement values, etc. In the paragraph 15 and 42 in the "*UNFCCC reporting guidelines on annual greenhouse gas inventories"* (Decision 24/CP.19 Annex I), it is noted that Annex I Parties shall quantitatively estimate and report the uncertainty of inventories. The assessment of uncertainties is intended to contribute to improve the accuracy of national inventories continuously and to guide decisions on methodological choice but not to evaluate justification of inventories nor make a comparison of accuracy of inventories among the parties.

The fundamental methodological issues of uncertainties assessment are provided in the IPCC guidelines; however, uncertainty assessment for specific emission sources and removal sinks is mainly subject to country-specific method determined by each party depending on country's own circumstances. In Japan, uncertainty assessments have been reviewed by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2001, FY2006, FY2012 and FY2014. For the National Inventory Reports submitted this time, the uncertainties in emission/removal inventories were assessed based on the country-specific guidelines revised in 2013.

## A2.2. Results of Uncertainty Assessment

### A2.2.2 Uncertainty of Japan's Total Emissions

In FY2018, total net emissions in Japan were approximately 1,183 million tons (carbon dioxide equivalents). Uncertainty of total net emissions in FY2018 has been assessed at -4% to +2% and uncertainty introduced into the trend in total net emissions has been assessed at -5% to +3%. Thus, the uncertainty level was low in Japan, mainly because $CO_2$ emissions from low-uncertainty fuel combustion (1.A.) accounted for 92% of the net emissions.

Table A2-1 Uncertainty of Japan's total net emissions

| A | B | C | D | G-1990 | | G-2018 | | I | J | |
|---|---|---|---|---|---|---|---|---|---|---|
| Category | GHGs | 1990 emissions / removals | 2018 emissions / removals | Combined uncertainty in 1990 | | Combined uncertainty in 2018 | | Inventory trend in national emissions for 2018 increase with respect to 1990 | Uncertainty introduced into the trend in total national emissions | |
| | | kt-$CO_2$ eq. | kt-$CO_2$ eq. | (-) % | (+) % | (-) % | (+) % | % | (-) % | (+) % |
| 1A. Fuel Combustion ($CO_2$) | $CO_2$ | 1,078,839 | 1,077,487 | -5% | +2% | -4% | +2% | -0.1% | -4.9% | +2.6% |
| 1A. Fuel Combustion (Stationary:$CH_4$,$N_2O$) | $CH_4$, $N_2O$ | 3,916 | 5,281 | -23% | +29% | -25% | +28% | 34.9% | 0.0% | +0.0% |
| 1A. Fuel Combustion (Transport:$CH_4$,$N_2O$) | $CH_4$, $N_2O$ | 4,031 | 1,796 | -32% | +92% | -30% | +87% | -55.4% | 0.0% | +0.0% |
| 1B. Fugitive Emissions from Fuels | $CO_2$, $CH_4$, $N_2O$ | 5,165 | 1,155 | -40% | +80% | -23% | +39% | -77.6% | 0.0% | +0.0% |
| 2. IPPU ($CO_2$,$CH_4$,$N_2O$) | $CO_2$, $CH_4$, $N_2O$ | 75,591 | 47,305 | -4% | +4% | -5% | +5% | -37.4% | -0.1% | +0.1% |
| 2. IPPU (HFCs,PFCs,$SF_6$,$NF_3$) | HFCs, PFCs, $SF_6$, $NF_3$ | 35,354 | 52,800 | -7% | +36% | -7% | +8% | 49.3% | -0.5% | +0.5% |
| 3. Agriculture | $CO_2$, $CH_4$, $N_2O$ | 37,413 | 33,252 | -10% | +25% | -9% | +21% | -11.1% | 0.0% | +0.0% |
| 4. LULUCF | $CO_2$, $CH_4$, $N_2O$ | -62,219 | -57,390 | -16% | +16% | -13% | +13% | -7.8% | -0.4% | +0.4% |
| 5. Waste | $CO_2$, $CH_4$, $N_2O$ | 29,732 | 19,267 | -10% | +11% | -12% | +12% | -35.2% | -0.2% | +0.2% |
| Indirect $CO_2$ | Ind $CO_2$ | 5,482 | 2,063 | -28% | +50% | -27% | +48% | -62.4% | 0.0% | +0.0% |
| Total Net Emissions | | 1,213,304 | 1,183,016 | -4.5% | +2.3% | -3.7% | +2.1% | -2.5% | -4.9% | +2.6% |

Data used for estimating emissions in each category are as follows:

# Table A2-2 Data used for uncertainty assessment (Energy)

| A | | B | C | D | E | | F | | G | | H-1990 | | H-2018 | | T | I | J | K | | L | | M | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | | GHG | 1990 emissions / removals | 2018 emissions / removals | Activity data uncertainty | | Emission factor/ estimation parameter uncertainty | | Combined uncertainty | | Combined Uncertainty as % of Total National Emissions in 1990 | | Combined Uncertainty as % of Total National Emissions in 2018 | | Emission increase rate | Type A sensitivity | Type B sensitivity | Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty | | Uncertainty in trend in national emissions introduced by activity data uncertainty | | Uncertainty introduced into the trend in total national emissions | |
| | | | Input Data | Input Data | Input Data | | Input Data | | $(E^2+F^2)^{1/2}$ | | G*C/ΣC | | G*D/ΣD | | D/C | Note A | D/ΣC | I*F | | J*E*√2 | | $(K^2+L^2)^{1/2}$ | |
| | | | kt-$CO_2$ eq. | kt-$CO_2$ eq. | (-) % | (+) % | (-) % | (+) % | (-) % | (+) % | (-) | (+) | (-) | (+) | % | % | % | (-) % | (+) % | (-) % | (+) % | (-) % | (+) % |
| Total | | | 1,213,304 | 1,183,016 | | | | | | | -4.5% | +2.3% | -3.7% | +2.1% | -2.5% | | | | | | | -4.9% | +2.6% |
| 1.A. Fuel Combustion | Liquid Fuels | CO2 | 644,312 | 392,517 | -8% | -2% | - | - | -8% | +2% | -4.1% | 0.9% | -2.5% | 0.6% | -39.1% | 0.2% | 32.4% | 0.0% | 0.0% | -3.5% | -0.8% | 3.5% | 0.8% |
| 1.A. Fuel Combustion | Solid Fuels | CO2 | 309,482 | 435,755 | -7% | +5% | - | - | -7% | +5% | -1.7% | 1.2% | -2.4% | 1.7% | 40.8% | 0.1% | 35.9% | 0.0% | 0.0% | -3.3% | 2.4% | 3.3% | 2.4% |
| 1.A. Fuel Combustion | Gaseous Fuels | CO2 | 114,167 | 231,175 | -3% | +1% | - | - | -3% | +2% | -0.3% | 0.2% | -0.6% | 0.3% | 102.5% | 0.1% | 19.1% | 0.0% | 0.0% | -0.8% | 0.4% | 0.8% | 0.4% |
| 1.A. Fuel Combustion | Other Fossil Fuels | CO2 | 10,878 | 18,040 | - | - | - | - | -19% | +19% | -0.2% | 0.2% | -0.3% | 0.3% | 65.8% | 0.0% | 1.5% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.A. Stationary Combustion | | CH4 | 1,058 | 889 | - | - | - | - | -29% | +69% | 0.0% | 0.1% | 0.0% | 0.1% | -16.0% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1.A. Stationary Combustion | | N2O | 2,858 | 4,391 | - | - | - | - | -30% | +30% | -0.1% | 0.1% | -0.1% | 0.1% | 53.7% | 0.0% | 0.4% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1.A.3. Transport | a. Domestic Aviation | CH4 | 6 | 2 | -5% | +5% | -57% | +100% | -57% | +100% | 0.0% | 0.0% | 0.0% | 0.0% | -73.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1.A.3. Transport | a. Domestic Aviation | N2O | 64 | 92 | -5% | +5% | -70% | +150% | -70% | +150% | 0.0% | 0.0% | 0.0% | 0.0% | 43.6% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1.A.3. Transport | b. Road Transportation | CH4 | 253 | 99 | - | - | - | - | -36% | +104% | 0.0% | 0.0% | 0.0% | 0.0% | -60.9% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.A.3. Transport | b. Road Transportation | N2O | 3,457 | 1,442 | - | - | - | - | -37% | +107% | -0.1% | 0.3% | 0.0% | 0.1% | -58.3% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1.A.3. Transport | c. Railways | CH4 | 1 | 1 | -5% | +5% | -60% | +151% | -60% | +151% | 0.0% | 0.0% | 0.0% | 0.0% | -47.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1.A.3. Transport | c. Railways | N2O | 110 | 58 | -5% | +5% | -50% | +200% | -50% | +200% | 0.0% | 0.0% | 0.0% | 0.0% | -47.6% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1.A.3. Transport | d. Domestic Navigation | CH4 | 32 | 23 | -13% | +13% | -50% | +50% | -52% | +52% | 0.0% | 0.0% | 0.0% | 0.0% | -26.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1.A.3. Transport | d. Domestic Navigation | N2O | 108 | 80 | -13% | +13% | -40% | +140% | -42% | +141% | 0.0% | 0.0% | 0.0% | 0.0% | -26.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 1.Solid Fuels | CO2 | 5 | 0 | - | - | - | - | -46% | +89% | 0.0% | 0.0% | 0.0% | 0.0% | -91.8% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 1.Solid Fuels | CH4 | 4,760 | 479 | - | - | - | - | -43% | +87% | -0.2% | 0.3% | 0.0% | 0.0% | -89.9% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 2.a. Oil | CO2 | 0 | 0 | - | - | - | - | -89% | +89% | 0.0% | 0.0% | 0.0% | 0.0% | -45.5% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 2.a. Oil | CH4 | 25 | 18 | - | - | - | - | -69% | +69% | 0.0% | 0.0% | 0.0% | 0.0% | -28.4% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 2.b. Natural Gas | CO2 | 1 | 1 | - | - | - | - | -80% | +80% | 0.0% | 0.0% | 0.0% | 0.0% | 31.7% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 2.b. Natural Gas | CH4 | 174 | 232 | - | - | - | - | -70% | +76% | 0.0% | 0.0% | 0.0% | 0.0% | 33.2% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 2.c. Venting & Flaring | CO2 | 81 | 242 | - | - | - | - | -14% | +14% | 0.0% | 0.0% | 0.0% | 0.0% | 198.5% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 2.c. Venting & Flaring | CH4 | 8 | 4 | - | - | - | - | -49% | +49% | 0.0% | 0.0% | 0.0% | 0.0% | -52.8% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 2.c. Venting & Flaring | N2O | 0 | 0 | - | - | - | - | -32% | +32% | 0.0% | 0.0% | 0.0% | 0.0% | -32.3% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 2.d. Other (Geothermal) | CO2 | 104 | 170 | -7% | +7% | -15% | +15% | -17% | +17% | 0.0% | 0.0% | 0.0% | 0.0% | 62.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1.B Fugitive Emission from Fuel | 2.d. Other (Geothermal) | CH4 | 5 | 8 | -7% | +7% | -15% | +15% | -17% | +17% | 0.0% | 0.0% | 0.0% | 0.0% | 60.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

Table A2-3 Data used for uncertainty assessment (Industrial processes and product use)

| A | | B | C | D | E | | F | | G | | H-1990 | | H-2018 | | T | I | J | K | | L | | M | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | | GHG | 1990 emissions / removals | 2018 emissions / removals | Activity data uncertainty | | Emission factor/ estimation parameter uncertainty | | Combined uncertainty | | Combined Uncertainty as % of Total National Emissions in 1990 | | Combined Uncertainty as % of Total National Emissions in 2018 | | Emission increase rate | Type A sensitivity | Type B sensitivity | Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty | | Uncertainty in trend in national emissions introduced by activity data uncertainty | | Uncertainty introduced into the trend in total national emissions | |
| | | | Input Data | Input Data | Input Data | | Input Data | | $(E^2+F^2)^{\wedge}1/2$ | | G*C/ΣC | | G*D/ΣD | | D/C | Note A | D/ΣC | I*F | | J*E*√2 | | $(K^2+L^2)^{\wedge}1/2$ | |
| | | | kt-$CO_2$ eq. | kt-$CO_2$ eq. | (-) % | (+) % | (-) % | (+) % | (-) % | (+) % | (-) | (+) | (-) | (+) | % | % | % | (-) % | (+) % | (-) % | (+) % | (-) % | (+) % |
| 2.A Mineral Product | 1. Cement Production | CO2 | 38,701 | 26,183 | -2% | +2% | -4% | +4% | -4% | +4% | -0.1% | 0.1% | -0.1% | 0.1% | -32.3% | 0.0% | 2.2% | 0.0% | 0.0% | -0.1% | 0.1% | 0.1% | 0.1% |
| 2.A Mineral Product | 2. Lime Production | CO2 | 6,674 | 5,663 | -3% | +3% | -2% | +2% | -4% | +4% | 0.0% | 0.0% | 0.0% | 0.0% | -15.1% | 0.0% | 0.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.A Mineral Product | 3. Glass Production | CO2 | 313 | 202 | -3% | +3% | -5% | +5% | -6% | +6% | 0.0% | 0.0% | 0.0% | 0.0% | -35.6% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.A Mineral Product | 4. Other Process Uses of Carbonates | CO2 | 3,542 | 1,659 | -3% | +3% | -5% | +5% | -6% | +6% | 0.0% | 0.0% | 0.0% | 0.0% | -53.2% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.B Chemical Industry | 1. Ammonia Production | CO2 | 3,418 | 1,458 | - | - | - | - | -2% | +1% | 0.0% | 0.0% | 0.0% | 0.0% | -57.3% | 0.0% | 0.1% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.B Chemical Industry | Other Production Except Anmonia | CO2 | 3,623 | 2,762 | - | - | - | - | -55% | +55% | -0.2% | 0.2% | -0.1% | 0.1% | -23.8% | 0.0% | 0.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.B Chemical Industry | 2. Nitric Acid Production | N2O | 736 | 318 | -2% | +2% | -73% | +73% | -73% | +73% | 0.0% | 0.0% | 0.0% | 0.0% | -56.7% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.B Chemical Industry | 3. Adipic Acid Production | N2O | 7,211 | 59 | -2% | +2% | -9% | +9% | -9% | +9% | -0.1% | 0.1% | 0.0% | 0.0% | -99.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.B Chemical Industry | 4. Caprolactam Production | N2O | 1,673 | 129 | -2% | +2% | -99% | +99% | -99% | +99% | -0.1% | 0.1% | 0.0% | 0.0% | -92.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.B Chemical Industry | Whole of Chemical Industries | CH4 | 37 | 23 | - | - | - | - | -58% | +51% | 0.0% | 0.0% | 0.0% | 0.0% | -39.4% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.C Metal Production | 1 Iron and Steel Production | CO2 | 7,244 | 5,712 | - | - | - | - | -4% | +4% | 0.0% | 0.0% | 0.0% | 0.0% | -21.1% | 0.0% | 0.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.C Metal Production | 1 Iron and Steel Production | CH4 | 18 | 15 | -5% | +5% | -163% | +163% | -163% | +163% | 0.0% | 0.0% | 0.0% | 0.0% | -18.9% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.C Metal Production | 2. Ferroalloys Production | CH4 | 5 | 3 | -5% | +5% | -163% | +163% | -163% | +163% | 0.0% | 0.0% | 0.0% | 0.0% | -38.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.D Non-energy Products from Fuels and Solvent Use | | CO2 | 2,040 | 2,644 | - | - | - | - | -55% | +55% | -0.1% | 0.1% | -0.1% | 0.1% | 29.6% | 0.0% | 0.2% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.G Other Product Manufacture and Use | | N2O | 291 | 370 | - | - | - | - | -4% | +4% | 0.0% | 0.0% | 0.0% | 0.0% | 27.2% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.H Other | Use of Dry Ice | CO2 | 65 | 105 | - | - | - | - | -4% | +4% | 0.0% | 0.0% | 0.0% | 0.0% | 63.0% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.B Chemical Industry | 9. Fluorochemical Production (By-product emissions) | HFCs | 15,929 | 12 | - | - | - | - | -2% | +2% | 0.0% | 0.0% | 0.0% | 0.0% | -99.9% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.B Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | HFCs | 2 | 88 | - | - | - | - | -2% | +2% | 0.0% | 0.0% | 0.0% | 0.0% | 5755.2% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.B Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | PFCs | 331 | 87 | - | - | - | - | -2% | +2% | 0.0% | 0.0% | 0.0% | 0.0% | -73.6% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.B Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | SF6 | 3,471 | 46 | - | - | - | - | -2% | +2% | 0.0% | 0.0% | 0.0% | 0.0% | -98.7% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.B Chemical Industry | 9. Fluorochemical Production (Fugitive Emissions) | NF3 | 3 | 58 | - | - | - | - | -2% | +2% | 0.0% | 0.0% | 0.0% | 0.0% | 1978.2% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.C Metal Production | 3. Aluminium Production | PFCs | 204 | 0 | -2% | +2% | -44% | +44% | -44% | +44% | 0.0% | 0.0% | 0.0% | 0.0% | -100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.C Metal Production | 4. SF6 Used in Aluminium and Magnesium oundries | HFCs | 0 | 2 | - | - | - | - | -5% | +5% | 0.0% | 0.0% | 0.0% | 0.0% | NA | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.C Metal Production | 4. SF6 Used in Aluminium and Magnesium oundries | SF6 | 147 | 274 | - | - | - | - | -5% | +5% | 0.0% | 0.0% | 0.0% | 0.0% | 86.7% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.E Electronics Industry | | HFCs | 1 | 113 | -10% | +10% | -100% | +100% | -100% | +100% | 0.0% | 0.0% | 0.0% | 0.0% | 15356% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.E Electronics Industry | | PFCs | 1,455 | 1,855 | -10% | +10% | -80% | +80% | -81% | +81% | -0.1% | 0.1% | -0.1% | 0.1% | 27.5% | 0.0% | 0.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.E Electronics Industry | | SF6 | 419 | 349 | -10% | +10% | -300% | +300% | -300% | +300% | -0.1% | 0.1% | -0.1% | 0.1% | -16.6% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.E Electronics Industry | | NF3 | 30 | 225 | -10% | +10% | -70% | +70% | -71% | +71% | 0.0% | 0.0% | 0.0% | 0.0% | 652.9% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.F Product uses as substitutes for ODS | 1. Refrigeration and Air conditioning | HFCs | 0 | 43,179 | - | - | - | - | -6% | +6% | 0.0% | 0.0% | -0.2% | 0.2% | NA | 0.0% | 3.6% | 0.0% | 0.0% | -0.5% | 0.5% | 0.5% | 0.5% |
| 2.F Product uses as substitutes for ODS | 2. Foam Blowing Agents | HFCs | 1 | 2,922 | - | - | - | - | -50% | +50% | 0.0% | 0.0% | -0.1% | 0.1% | 217643% | 0.0% | 0.2% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.F Product uses as substitutes for ODS | 3. Fire Extinguishers | HFCs | NO | 10 | - | - | - | - | -16% | +16% | NA | NA | 0.0% | 0.0% | NA | NA | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.F Product uses as substitutes for ODS | 4. Aerosols | HFCs | 0 | 544 | - | - | - | - | -10% | +10% | 0.0% | 0.0% | 0.0% | 0.0% | NA | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 2.F Product uses as substitutes for ODS | 5. Solvents | HFCs | 0 | 117 | -10% | +10% | -5% | +5% | -11% | +11% | 0.0% | 0.0% | 0.0% | 0.0% | NA | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.F Product uses as substitutes for ODS | 5. Solvents | PFCs | 4,550 | 1,505 | -10% | +10% | - | - | -10% | +10% | 0.0% | 0.0% | 0.0% | 0.0% | -66.9% | 0.0% | 0.1% | NA | NA | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.G Other Product Manufacture and Use | | PFCs | 0 | 39 | -10% | +10% | - | - | -10% | +10% | 0.0% | 0.0% | 0.0% | 0.0% | NA | 0.0% | 0.0% | NA | NA | 0.0% | 0.0% | 0.0% | 0.0% |
| 2.G Other Product Manufacture and Use | | SF6 | 8,814 | 1,375 | - | - | - | - | -21% | +145% | -0.2% | 1.1% | 0.0% | 0.2% | -84.4% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

# Table A2-4 Data used for uncertainty assessment (Agriculture)

| A | | B | C | D | E | | F | | G | | H-1990 | | H-2018 | | T | I | J | K | | L | | M | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | | GHG | 1990 emissions / removals | 2018 emissions / removals | Activity data uncertainty | | Emission factor/ estimation parameter uncertainty | | Combined uncertainty | | Combined Uncertainty as % of Total National Emissions in 1990 | | Combined Uncertainty as % of Total National Emissions in 2018 | | Emission increase rate | Type A sensitivity | Type B sensitivity | Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty | | Uncertainty in trend in national emissions introduced by activity data uncertainty | | Uncertainty introduced into the trend in total national emissions | |
| | | | Input Data | Input Data | Input Data | | Input Data | | $(E^2+F^2)^{\wedge}1/2$ | | G*C/ΣC | | G*D/ΣD | | D/C | Note A | D/ΣC | I*F | | J*E*√2 | | $(K^2+L^2)^{\wedge}1/2$ | |
| | | | kt-$CO_2$ eq. | kt-$CO_2$ eq. | (-) % | (+) % | (-) % | (+) % | (-) % | (+) % | (-) | (+) | (-) | (+) | % | % | % | (-) % | (+) % | (-) % | (+) % | (-) % | (+) % |
| 3.A Enteric Fermentation | Dairy cattle | CH4 | 4,803 | 3,336 | -1% | +1% | -26% | +32% | -26% | +32% | -0.1% | 0.1% | -0.1% | 0.1% | -30.5% | 0.0% | 0.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.A Enteric Fermentation | Non-dairy cattle | CH4 | 4,164 | 3,767 | -1% | +1% | -40% | +49% | -40% | +49% | -0.1% | 0.2% | -0.1% | 0.2% | -9.5% | 0.0% | 0.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.A Enteric Fermentation | Sheep | CH4 | 4 | 4 | -9% | +9% | -50% | +50% | -51% | +51% | 0.0% | 0.0% | 0.0% | 0.0% | -2.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.A Enteric Fermentation | Swine | CH4 | 397 | 320 | -1% | +1% | -69% | +69% | -69% | +69% | 0.0% | 0.0% | 0.0% | 0.0% | -19.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.A Enteric Fermentation | Other Livestock | CH4 | 56 | 38 | -9% | +9% | -50% | +50% | -51% | +51% | 0.0% | 0.0% | 0.0% | 0.0% | -32.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Dairy cattle | CH4 | 2,667 | 1,996 | -1% | +1% | -20% | +20% | -20% | +20% | 0.0% | 0.0% | 0.0% | 0.0% | -25.2% | 0.0% | 0.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Dairy cattle | N2O | 632 | 680 | -1% | +1% | -71% | +112% | -71% | +112% | 0.0% | 0.1% | 0.0% | 0.1% | 7.7% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Non-dairy cattle | CH4 | 108 | 135 | -1% | +1% | -20% | +20% | -20% | +20% | 0.0% | 0.0% | 0.0% | 0.0% | 25.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Non-dairy cattle | N2O | 691 | 717 | -1% | +1% | -71% | +112% | -71% | +112% | 0.0% | 0.1% | 0.0% | 0.1% | 3.8% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Sheep | CH4 | 0 | 0 | -9% | +9% | -30% | +30% | -31% | +31% | 0.0% | 0.0% | 0.0% | 0.0% | -2.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Sheep | N2O | NO | NO | -9% | +9% | -71% | +112% | -72% | +112% | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.0% | 0.0% |
| 3.B Manure Management | Swine | CH4 | 278 | 118 | -1% | +1% | -20% | +20% | -20% | +20% | 0.0% | 0.0% | 0.0% | 0.0% | -57.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Swine | N2O | 1,101 | 1,261 | -1% | +1% | -71% | +112% | -71% | +112% | -0.1% | 0.1% | -0.1% | 0.1% | 14.5% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Poultry | CH4 | 58 | 70 | -9% | +9% | -20% | +20% | -22% | +22% | 0.0% | 0.0% | 0.0% | 0.0% | 20.7% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Poultry | N2O | 411 | 360 | -9% | +9% | -71% | +112% | -72% | +112% | 0.0% | 0.0% | 0.0% | 0.0% | -12.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Other Livestock | CH4 | 10 | 5 | -9% | +9% | -30% | +30% | -31% | +31% | 0.0% | 0.0% | 0.0% | 0.0% | -50.7% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | Other Livestock | N2O | 8 | 1 | -9% | +9% | -71% | +112% | -72% | +112% | 0.0% | 0.0% | 0.0% | 0.0% | -82.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.B Manure Management | 5. Indirect Emissions | N2O | 1,364 | 901 | -9% | +9% | -106% | +447% | -106% | +447% | -0.1% | 0.5% | -0.1% | 0.3% | -33.9% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.C Rice Cultivation | | CH4 | 12,771 | 13,561 | -1% | +1% | -6% | +6% | -6% | +6% | -0.1% | 0.1% | -0.1% | 0.1% | 6.2% | 0.0% | 1.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.D Agricultural Soils | a.1. Inorganic Fertilizers | N2O | 1,843 | 1,150 | -1% | +1% | -31% | +31% | -31% | +31% | 0.0% | 0.0% | 0.0% | 0.0% | -37.6% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.D Agricultural Soils | a.2. Organic Fertilizers | N2O | 1,571 | 1,357 | - | - | - | - | -24% | +24% | 0.0% | 0.0% | 0.0% | 0.0% | -13.6% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.D Agricultural Soils | a.3. Pasture, Range and Paddock | N2O | 54 | 42 | -1% | +1% | -65% | +200% | -65% | +200% | 0.0% | 0.0% | 0.0% | 0.0% | -21.6% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.D Agricultural Soils | a.4. Crop Residue | N2O | 707 | 533 | -1% | +1% | -70% | +200% | -70% | +200% | 0.0% | 0.1% | 0.0% | 0.1% | -24.6% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.D Agricultural Soils | a.5. Mineralization | N2O | 406 | 358 | -1% | +1% | -31% | +31% | -31% | +31% | 0.0% | 0.0% | 0.0% | 0.0% | -12.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.D Agricultural Soils | a.6. Plowing of Organic Soils | N2O | 120 | 117 | -1% | +1% | -75% | +200% | -75% | +200% | 0.0% | 0.0% | 0.0% | 0.0% | -1.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.D Agricultural Soils | b.1. Atomospheric Deposition | N2O | 792 | 621 | -9% | +9% | -106% | +447% | -106% | +447% | -0.1% | 0.3% | -0.1% | 0.2% | -21.5% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.D Agricultural Soils | b.2. N leaching and Run-off | N2O | 1,622 | 1,233 | -9% | +9% | -115% | +287% | -115% | +287% | -0.2% | 0.4% | -0.1% | 0.3% | -24.0% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.F Field Burning of Agricultural Residues | | CH4 | 127 | 63 | -1% | +1% | -296% | +296% | -296% | +296% | 0.0% | 0.0% | 0.0% | 0.0% | -50.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.F Field Burning of Agricultural Residues | | N2O | 39 | 20 | -1% | +1% | -300% | +300% | -300% | +300% | 0.0% | 0.0% | 0.0% | 0.0% | -50.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.G Liming | | CO2 | 550 | 294 | -1% | +1% | -50% | +50% | -50% | +50% | 0.0% | 0.0% | 0.0% | 0.0% | -46.7% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3.H Urea Application | | CO2 | 59 | 193 | -1% | +1% | -50% | +50% | -50% | +50% | 0.0% | 0.0% | 0.0% | 0.0% | 228.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

# Table A2-5 Data used for uncertainty assessment (LULUCF)

| A | | B | C | D | E | | F | | G | | H-1990 | | H-2018 | | T | I | J | K | | L | | M | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | | GHG | 1990 emissions / removals | 2018 emissions / removals | Activity data uncertainty | | Emission factor/ estimation parameter uncertainty | | Combined uncertainty | | Combined Uncertainty as % of Total National Emissions in 1990 | | Combined Uncertainty as % of Total National Emissions in 2018 | | Emission increase rate | Type A sensitivity | Type B sensitivity | Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty | | Uncertainty in trend in national emissions introduced by activity data uncertainty | | Uncertainty introduced into the trend in total national emissions | |
| | | | Input Data | Input Data | Input Data | | Input Data | | $(E^2+F^2)^{\wedge}1/2$ | | G*C/ΣC | | G*D/ΣD | | D/C | Note A | D/ΣC | I*F | | J*E*√2 | | $(K^2+L^2)^{\wedge}1/2$ | |
| | | | kt-$CO_2$ eq. | kt-$CO_2$ eq. | (-) % | (+) % | (-) % | (+) % | (-) % | (+) % | (-) | (+) | (-) | (+) | % | % | % | (-) % | (+) % | (-) % | (+) % | (-) % | (+) % |
| 4.A Forest Land | 1. Forest Land remaining Forest Land | CO2 | -72,386 | -58,093 | - | - | - | - | -13% | +13% | -0.7% | 0.7% | -0.6% | 0.6% | -19.7% | 0.0% | 4.8% | 0.0% | 0.0% | -0.4% | 0.4% | 0.4% | 0.4% |
| 4.A Forest Land | 2. Land converted to Forest Land | CO2 | -6,675 | -934 | - | - | - | - | -13% | +13% | 0.1% | -0.1% | 0.0% | 0.0% | -86.0% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 4.B Cropland | 1. Cropland remaining Cropland | CO2 | 10,098 | 3,507 | - | - | - | - | -42% | +42% | -0.4% | 0.4% | -0.1% | 0.1% | -65.3% | 0.0% | 0.3% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.B Cropland | 2. Land converted to Cropland | CO2 | 1,598 | 23 | - | - | - | - | -18% | +18% | 0.0% | 0.0% | 0.0% | 0.0% | -98.5% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.C Grassland | 1. Grassland remaining Grassland | CO2 | 881 | -333 | - | - | - | - | -9% | +9% | 0.0% | 0.0% | 0.0% | 0.0% | -137.8% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.C Grassland | 2. Land converted to Grassland | CO2 | 181 | 67 | - | - | - | - | -20% | +20% | 0.0% | 0.0% | 0.0% | 0.0% | -63.0% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.D Wetlands | 1. Wetland remaining Wetland | CO2 | NO,NE,NA | NO,NE,NA | - | - | - | - | - | - | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.D Wetlands | 2. Land converted to Wetlands | CO2 | 91 | 17 | - | - | - | - | -21% | +21% | 0.0% | 0.0% | 0.0% | 0.0% | -80.9% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.E Settlements | 1. Settlements remaining Settlements | CO2 | -1,386 | -1,424 | - | - | - | - | -33% | +33% | 0.0% | 0.0% | 0.0% | 0.0% | 2.7% | 0.0% | 0.1% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.E Settlements | 2. Land converted to Settlements | CO2 | 4,251 | 1,397 | - | - | - | - | 0% | +% | 0.0% | 0.0% | 0.0% | 0.0% | -67.1% | 0.0% | 0.1% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.F Other Land | 1. Other Land remaining Other Land | CO2 | 0 | 0 | - | - | - | - | - | - | NA | NA | NA | NA | NA | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.F Other Land | 2. Land converted to Other Land | CO2 | 1,180 | 164 | - | - | - | - | -20% | +20% | 0.0% | 0.0% | 0.0% | 0.0% | -86.1% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.G Harvested Wood Products | | CO2 | -370 | -2,046 | - | - | - | - | -30% | +30% | 0.0% | 0.0% | 0.1% | -0.1% | 453.1% | 0.0% | 0.2% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4.H Other (Organic soil in settlements converted from other land-use categories) | | CH4 | 14 | 6 | -1% | +1% | -71% | +71% | -71% | +71% | 0.0% | 0.0% | 0.0% | 0.0% | -55.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 4.H Other (Organic soil in settlements converted from other land-use categories) | | N2O | 1 | 0 | -1% | +1% | -75% | +200% | -75% | +200% | 0.0% | 0.0% | 0.0% | 0.0% | -55.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 4(I). Direct N2O emissions from N inputs to managed soils | | N2O | 1 | 1 | - | - | - | - | -31% | +31% | 0.0% | 0.0% | 0.0% | 0.0% | -38.7% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4(II). Emissions and removals from drainage and rewetting | | CH4 | 38 | 37 | -1% | +1% | -71% | +71% | -71% | +71% | 0.0% | 0.0% | 0.0% | 0.0% | -2.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 4(II). Emissions and removals from drainage and rewetting | | N2O | NO,NA | NO,NA | -1% | +1% | -71% | +71% | -71% | +71% | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.0% | 0.0% |
| 4(III).Direct N2O emissions from N mineralization/immobilization | Forest | N2O | IE | IE | -27% | +27% | -70% | +200% | -75% | +202% | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.0% | 0.0% |
| 4(III).Direct N2O emissions from N mineralization/immobilization | Other land | N2O | IE | IE | -27% | +27% | -70% | +200% | -75% | +202% | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.0% | 0.0% |
| 4(III).Direct N2O emissions from N mineralization/immobilization | Cropland | N2O | 154 | 137 | - | - | - | - | -31% | +31% | 0.0% | 0.0% | 0.0% | 0.0% | -10.6% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4(III).Direct N2O emissions from N mineralization/immobilization | Grassland | N2O | IE | IE | - | - | - | - | -31% | +31% | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.0% | 0.0% |
| 4(IV) Indirect N2O Emissions from Managed Soils | Fertilization on forest | N2O | 41 | 33 | -31% | +31% | -140% | +492% | -143% | +493% | 0.0% | 0.0% | 0.0% | 0.0% | -19.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 4(IV) Indirect N2O Emissions from Managed Soils | Mineralization | N2O | IE | IE | -31% | +31% | -115% | +287% | -119% | +288% | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.0% | 0.0% |
| 4(V) Biomass Burning | Forest | CH4 | 10 | 2 | -12% | +12% | -25% | +25% | -28% | +28% | 0.0% | 0.0% | 0.0% | 0.0% | -75.7% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 4(V) Biomass Burning | Cropland (orchard pruning) | CH4 | 25 | 16 | - | - | - | - | -296% | +296% | 0.0% | 0.0% | 0.0% | 0.0% | -36.0% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4(V) Biomass Burning | Forest | N2O | 1 | 0 | -12% | +12% | -29% | +29% | -31% | +31% | 0.0% | 0.0% | 0.0% | 0.0% | -75.7% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 4(V) Biomass Burning | Cropland (orchard pruning) | N2O | 8 | 5 | - | - | - | - | -300% | +300% | 0.0% | 0.0% | 0.0% | 0.0% | -36.0% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4(V) Biomass Burning | Grassland | CH4 | 13 | 13 | - | - | - | - | -56% | +56% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 4(V) Biomass Burning | Grassland | N2O | 14 | 14 | - | - | - | - | -63% | +63% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |

# Table A2-6 Data used for uncertainty assessment (Waste, Indirect $CO_2$)

| A | | B | C | D | E | | F | | G | | H-1990 | | H-2018 | | T | I | J | K | | L | | M | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | | GHG | 1990 emissions / removals | 2018 emissions / removals | Activity data uncertainty | | Emission factor/ estimation parameter uncertainty | | Combined uncertainty | | Combined Uncertainty as % of Total National Emissions in 1990 | | Combined Uncertainty as % of Total National Emissions in 2018 | | Emission increase rate | Type A sensitivity | Type B sensitivity | Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty | | Uncertainty in trend in national emissions introduced by activity data uncertainty | | Uncertainty introduced into the trend in total national emissions | |
| | | | Input Data | Input Data | Input Data | | Input Data | | $(E^2+F^2)^{\wedge}1/2$ | | G*C/ Σ C | | G*D/ Σ D | | D/C | Note A | D/ Σ C | I*F | | J*E*√2 | | $(K^2+L^2)^{\wedge}1/2$ | |
| | | | kt-$CO_2$ eq. | kt-$CO_2$ eq. | (-) % | (+) % | (-) % | (+) % | (-) % | (+) % | (-) | (+) | (-) | (+) | % | % | % | (-) % | (+) % | (-) % | (+) % | (-) % | (+) % |
| 5.A Solid Waste Disposal | 1. Managed disposal site (MSW) | CH4 | 5,919 | 1,686 | - | - | - | - | -32% | +32% | -0.2% | 0.2% | 0.0% | 0.0% | -71.5% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.A Solid Waste Disposal | 1. Managed disposal site (IW) | CH4 | 3,643 | 1,206 | - | - | - | - | -29% | +29% | -0.1% | 0.1% | 0.0% | 0.0% | -66.9% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.A Solid Waste Disposal | 3. Uncategorized (Inappropriate disposal) | CH4 | 9 | 39 | -60% | +60% | -42% | +41% | -74% | +73% | 0.0% | 0.0% | 0.0% | 0.0% | 346.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.B Biological Treatment of Soild Waste | 1. Composting | CH4 | 54 | 89 | -30% | +30% | -79% | +79% | -84% | +84% | 0.0% | 0.0% | 0.0% | 0.0% | 64.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.B Biological Treatment of Soild Waste | 1. Composting | N2O | 181 | 296 | -30% | +30% | -167% | +167% | -170% | +170% | 0.0% | 0.0% | 0.0% | 0.0% | 63.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (MSW) | CO2 | 5,704 | 2,000 | - | - | - | - | -8% | +10% | 0.0% | 0.0% | 0.0% | 0.0% | -64.9% | 0.0% | 0.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (IW oil) | CO2 | 3,670 | 3,466 | -30% | +30% | -2% | +2% | -30% | +30% | -0.1% | 0.1% | -0.1% | 0.1% | -5.6% | 0.0% | 0.3% | 0.0% | 0.0% | -0.1% | 0.1% | 0.1% | 0.1% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (IW solid) | CO2 | 2,134 | 3,771 | - | - | - | - | -30% | +30% | -0.1% | 0.1% | -0.1% | 0.1% | 76.7% | 0.0% | 0.3% | 0.0% | 0.0% | -0.1% | 0.1% | 0.1% | 0.1% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (Specially-Contorolled IW) | CO2 | 916 | 1,001 | -60% | +60% | -2% | +2% | -60% | +60% | 0.0% | 0.0% | -0.1% | 0.1% | 9.3% | 0.0% | 0.1% | 0.0% | 0.0% | -0.1% | 0.1% | 0.1% | 0.1% |
| 5.C Incineration and Open Burning of Waste | 2. Open burning (IW) | CO2 | 5 | 0 | -30% | +30% | -2% | +2% | -30% | +30% | 0.0% | 0.0% | 0.0% | 0.0% | -98.6% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (MSW) | CH4 | 12 | 1 | - | - | - | - | -29% | +52% | 0.0% | 0.0% | 0.0% | 0.0% | -92.8% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (IW oil) | CH4 | 0 | 0 | -30% | +30% | -100% | +181% | -104% | +184% | 0.0% | 0.0% | 0.0% | 0.0% | -18% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (IW sludge) | CH4 | 2 | 0 | -30% | +30% | -100% | +201% | -104% | +203% | 0.0% | 0.0% | 0.0% | 0.0% | -86.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (IW solid) | CH4 | 2 | 8 | - | - | - | - | -84% | +334% | 0.0% | 0.0% | 0.0% | 0.0% | 255.5% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (Specially-Contorolled IW) | CH4 | 0 | 1 | -60% | +60% | -100% | +216% | -117% | +224% | 0.0% | 0.0% | 0.0% | 0.0% | 344.6% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 2. Open burning (IW) | CH4 | 12 | 0 | -30% | +30% | -100% | +100% | -104% | +104% | 0.0% | 0.0% | 0.0% | 0.0% | -99.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (MSW) | N2O | 306 | 83 | - | - | - | - | -27% | +27% | 0.0% | 0.0% | 0.0% | 0.0% | -73.0% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (IW oil) | N2O | 5 | 24 | -30% | +30% | -76% | +76% | -81% | +81% | 0.0% | 0.0% | 0.0% | 0.0% | 418.9% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (IW sludge) | N2O | 1,056 | 1,275 | -30% | +30% | -84% | +84% | -89% | +89% | -0.1% | 0.1% | -0.1% | 0.1% | 20.8% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (IW solid) | N2O | 64 | 39 | - | - | - | - | -50% | +50% | 0.0% | 0.0% | 0.0% | 0.0% | -38.4% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 1. Incineration (Specially-Contorolled IW) | N2O | 6 | 8 | -60% | +60% | -44% | +44% | -74% | +74% | 0.0% | 0.0% | 0.0% | 0.0% | 47.6% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.C Incineration and Open Burning of Waste | 2. Open burning (IW) | N2O | 3 | 0 | -30% | +30% | -100% | +100% | -104% | +104% | 0.0% | 0.0% | 0.0% | 0.0% | -99.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 1. DWW (Sewage treatment plant) | CH4 | 216 | 301 | -5% | +5% | -31% | +31% | -31% | +31% | 0.0% | 0.0% | 0.0% | 0.0% | 39.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 1. DWW (Domestic wastewater treatment plant) | CH4 | 759 | 810 | - | - | - | - | -31% | +31% | 0.0% | 0.0% | 0.0% | 0.0% | 6.6% | 0.0% | 0.1% | NA | NA | NA | NA | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 1. DWW (Human waste treatment plant) | CH4 | 131 | 8 | -10% | +10% | -84% | +84% | -84% | +84% | 0.0% | 0.0% | 0.0% | 0.0% | -94.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 1. DWW (Natural decomposition) | CH4 | 1,543 | 358 | -10% | +10% | -58% | +58% | -59% | +59% | -0.1% | 0.1% | 0.0% | 0.0% | -76.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 2. IWW (Industrial wastewater treatment) | CH4 | 56 | 42 | -30% | +30% | -60% | +60% | -67% | +67% | 0.0% | 0.0% | 0.0% | 0.0% | -24.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 2. IWW (Natural decomposition) | CH4 | 206 | 93 | -30% | +30% | -58% | +58% | -66% | +66% | 0.0% | 0.0% | 0.0% | 0.0% | -54.9% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 2. IWW (Landfill leachate treatment) | CH4 | 31 | 5 | -100% | +100% | -39% | +39% | -107% | +107% | 0.0% | 0.0% | 0.0% | 0.0% | -83.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 1. DWW (Sewage treatment plant) | N2O | 416 | 431 | -5% | +5% | -100% | +146% | -100% | +146% | 0.0% | 0.0% | 0.0% | 0.1% | 3.7% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 1. DWW (Domestic wastewater treatment plant) | N2O | 453 | 461 | - | - | - | - | -42% | +42% | 0.0% | 0.0% | 0.0% | 0.0% | 1.8% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 1. DWW (Human waste treatment plant) | N2O | 67 | 4 | -10% | +10% | -87% | +87% | -88% | +88% | 0.0% | 0.0% | 0.0% | 0.0% | -94.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 1. DWW (Natural decomposition) | N2O | 830 | 585 | -10% | +10% | -58% | +58% | -59% | +59% | 0.0% | 0.0% | 0.0% | 0.0% | -29.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 2. IWW (Industrial wastewater treatment) | N2O | 298 | 336 | -30% | +30% | -95% | +95% | -100% | +100% | 0.0% | 0.0% | 0.0% | 0.0% | 12.9% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 2. IWW (Natural decomposition) | N2O | 316 | 165 | -30% | +30% | -58% | +58% | -66% | +66% | 0.0% | 0.0% | 0.0% | 0.0% | -47.7% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.D Wastewater Treatment and Discharge | 2. IWW (Landfill leachate treatment) | N2O | 8 | 1 | -100% | +100% | -39% | +39% | -107% | +107% | 0.0% | 0.0% | 0.0% | 0.0% | -83.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 5.E Other | Decomposition of petroleum-derived surfactants | CO2 | 703 | 673 | -10% | +10% | -1% | +1% | -10% | +10% | 0.0% | 0.0% | 0.0% | 0.0% | -4.2% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

| A | | B | C | D | E | | F | | G | | H-1990 | | H-2018 | | T | I | J | K | | L | | M | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indirect CO2 | from Energy sector | Ind CO2 | 1,028 | 457 | - | - | - | - | -23% | +40% | 0.0% | 0.0% | 0.0% | 0.0% | -55.5% | 0.0% | 0.0% | NA | NA | NA | NA | 0.0% | 0.0% |
| Indirect CO2 | from IPPU sector | Ind CO2 | 4,455 | 1,606 | - | - | - | - | -35% | +61% | -0.1% | 0.2% | 0.0% | 0.1% | -63.9% | 0.0% | 0.1% | NA | NA | NA | NA | 0.0% | 0.0% |

Note A: Type A sensitivity : $\frac{0.01\times D_x+\sum D_i-(0.01\times C_x+\sum C_i)}{(0.01\times C_x+\sum C_i)}\times 100-\frac{\sum D_i-\sum C_i}{\sum C_i}\times 100$

Where: $C_x$, $D_x$ = entry of row *x* of column C and D respectively in the table A2

$\sum C_i$, $\sum D_i$ = sum of column C and D respectively

## *References*


1. IPCC, *2006 IPCC Guidelines for National Greenhouse Inventories*, 2006
2. UNFCCC, *UNFCCC reporting guidelines on annual greenhouse gas inventories* (Decision 24/CP.19 Annex I), 2013
3. Ministry of the Environment, *Guidelines for Uncertainty Assessment of GHG inventories in Japan*, 2013

# Annex 3. Detailed Methodological Descriptions for Individual Source or Sink Categories

## A3.1. Methodology for Estimating Emissions of Precursors

In addition to the mandatory greenhouse gases ($CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, $NF_3$), Japan reports on the emissions of precursors ($NO_X$, CO, Non-Methane Volatile Organic Compounds [NMVOCs], and $SO_X$[1]) calculated by established methods. This section explains the categories for which estimation methodologies were established, and emissions are reported.

### A3.1.1 Energy Sector

#### A3.1.1.1. Stationary Combustion (1.A.1., 1.A.2., 1.A.4.: $NO_X$, CO, NMVOCs, and $SO_X$)

#### A3.1.1.1.a. Energy Industries (1.A.1), Manufacturing Industries and Construction (1.A.2), Commercial/institutional (1.A.4.a) and Agriculture/forestry/fishing (1.A.4.c)

***a) Category Description***

This section provides the estimation methods for emissions of precursors and other substances ($NO_X$, CO, NMVOCs, and $SO_X$) from Energy industries (1.A.1), Manufacturing industries and construction (1.A.2), Commercial/institutional (1.A.4.a) and Agriculture/forestry/fishing (1.A.4.c).

***b) Methodological Issues***

***1) $NO_X$ and $SO_X$***

- ***Methodology for Estimating Emissions***

➢ ***Facilities emitting soot and smokes***

*General Survey of the Emissions of Air Pollutants* by the Ministry of the Environment (MOE) was used as data source for $NO_X$ and $SO_X$ emissions from fuel combustion of the "facilities emitting soot and smokes" specified in laws such as the Air Pollution Control Act. To ensure consistency with the categorization of the common reporting format (CRF), the emissions from the energy sector were isolated from the emissions listed in the *General Survey of the Emissions of Air Pollutants* by the following operation:

1. All emissions from the following facilities and industry sectors are reported under Energy:

   Facility: [0101–0103: Boilers]; [0601–0618: Metal rolling furnaces, metal furnaces, and metal forge furnaces]; [1101–1106: Drying ovens]; [2901–3202: Gas turbines, diesel engines, gas engines, and gasoline engines]

   Industry sector: [A–D: Accommodation/eating establishments, health care/educational and academic institutions, public bathhouses, laundry services]; [F–L: Agriculture/fisheries, mining, construction, electricity, gas, heat distribution, building heating/other operations]

[1] Most $SO_X$ consists of $SO_2$. For major sources, $SO_2$ emissions are estimated.

2. For emissions from the facilities and industry sectors other than the above and [1301–1304: Waste incinerators], after emissions from the Industrial Processes and Product Use (IPPU) sector were identified, the emissions from the Energy sector are estimated by subtracting the emissions of the IPPU sector from the emissions listed in the *General Survey of the Emissions of Air Pollutants.* For estimation method in the IPPU sector, see A3.1.2.1. Mineral Industry, Chemical Industry, Metal Production, and Other Production (2.A., 2.B., 2.C., 2.D.: $NO_X$, $SO_X$).

➢ ***Small facilities***

$NO_X$ and $SO_X$ emitted by the "small facilities" (i.e. the facilities in commercial/institutional and manufacturing categories that do not correspond to the facilities emitting soot and smokes) were calculated by multiplying the energy consumption in each facility type by Japan's country-specific emission factor.

- ***Emission factors***

➢ ***Facilities emitting soot and smokes***

Not applicable.

➢ ***Small facilities***

Emission factors were established for each fuel type for [0102: Heating system boilers] for facilities listed in [L: Heating systems for buildings/other places of business] in the *General Survey of the Emissions of Air Pollutants* by aggregating emissions and energy consumption by fuel type.

- ***Activity data***

➢ ***Facilities emitting soot and smokes***

Not applicable.

➢ ***Small facilities***

Energy consumption by small facilities by fuel type was calculated by subtracting energy consumption by fuel type, identified by the *General Survey of the Emissions of Air Pollutants*, from energy consumption by fuel type provided in the *General Energy Statistics* (Agency for Natural Resources and Energy). If the activity data shown in the *General Survey of the Emissions of Air Pollutants* exceeded the activity data provided in the *General Energy Statistics*, the activity data for the specified sources was deemed to be zero. The fuels covered were city gas, LPG, kerosene, and fuel oil A.

***2) CO and NMVOCs***

- ***Estimation Method***

Emissions of CO and NMVOCs from the specified sources were calculated by multiplying the energy consumption in each facility type by Japan's country-specific emission factor.

- ***Emission factors***

CO emission factors were established based on the summary data of the Japan Society for Atmospheric Environment (1997).

NMVOC emission factors for each facility by fuel type were established by multiplying the $CH_4$ emission factor by the ratio of the NMVOC emission factor to the $CH_4$ emission factor. The $CH_4$ emission factors are elaborated in Chapter 3. The NMVOC/$CH_4$ emission ratios were determined from Japan Environmental Sanitation Center (1989), Institute of Behavioral Science (1984), and United States Environmental Protection Agency (1985).

- ***Activity data***

Energy consumption calculated for estimation of $CH_4$ and $N_2O$ was used for activity data. (see Chapter 3.)

### A3.1.1.1.b. Residential sector (1.A.4.b)

#### *a) Category Description*

This section provides the estimation methods for emissions of precursors and other substances ($NO_X$, CO, NMVOCs, and $SO_X$) from fuel combustion of households.

#### *b) Methodological Issues*

- ***Estimation Method***

$NO_X$, CO, NMVOCs, and $SO_X$ emissions from the target source were calculated by multiplying energy consumed of each fuel type by Japan's country-specific emission factors or the default emission factors from *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016*.

- ***Emission factors***

#### *1) $NO_X$*

For solid fuels (steam coal and coal briquettes) and biomass, emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid (kerosene) and gaseous (LPG and city gas) fuels, the emission factors by usage by fuel type provided in a report by Air Quality Management Bureau, Environmental Agency (1996) were used. This report calculated the emission factors by taking the average of the concentration of $NO_X$ emissions by product, obtained through questionnaires and interviews in the household gas appliances industry, weighted by the number of products sold.

#### *2) CO*

For solid fuels (steam coal, and coal briquettes), and biomass, emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid (kerosene) and gaseous (LPG and city gas) fuels, the emission factors by usage by fuel type provided in the report by Institute of Behavioral Science (1997) were used. This report tabulated the emission factors by usage by fuel type from the actual values measured in Tokyo, Yokohama City and Chiba Prefecture.

#### *3) NMVOCs*

For solid fuels (steam coal and coal briquettes), liquid fuels (kerosene), gaseous fuels (LPG and city gas), and biomass, emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

#### *4) $SO_X$*

For solid fuels (steam coal and coal briquettes), and biomass, emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid fuel (kerosene), emission factors were calculated from energy consumption, specific gravity and sulfur content based on the fuel characteristics of kerosene described in information material compiled by the Petroleum Association of Japan.

- ***Activity data***

Fuel consumption by fuel type for residential use in the *General Energy Statistics* has been taken for the activity data. The fuels covered were steam coal, coal briquettes, kerosene, LPG, and city gas. For the ratio of consumption by fuel type by type of use in households, the *Handbook of Energy & Economic Statistics in Japan* (Energy Data and Modeling Center) is used.

### A3.1.1.1.c. Incineration of waste for energy purposes and with energy recovery

Emissions of $NO_X$, CO, NMVOCs and $SO_X$ from the incineration of waste for energy purposes and from the incineration of waste with energy recovery are reported in the data input cells for "Other fossil fuels" under the relevant subcategories of 1.A.1 and 1.A.2. Explanations for estimation method, emission factors, and activity data are all given in the section "A3.1.5Waste".

### A3.1.1.2. Mobile Combustion (1.A.3: $NO_X$, CO, NMVOCs, and $SO_X$)

### A3.1.1.2.a. Domestic Aviation (1.A.3.a: NOx, CO, and NMVOCs)

#### *a) Category Description*

This section provides the estimation methods for emissions of precursors (NOx, CO, and NMVOCs) from combustion of aviation fuel.

#### *b) Methodological Issues*

- ***Estimation Method***

$NO_X$, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *2006 IPCC Guidelines* and the *Revised 1996 IPCC Guidelines*.

- ***Emission factors***

Data in the following table are used.

Table A 3-1 IPCC default emission factors for domestic aviation

| Gas | EF [g/MJ(NCV)] |
|---|---|
| $NO_X$ | 0.25 [1)] |
| CO | 0.12 [2)] |
| NMVOCs | 0.018 [2)] |

Reference: 1) *2006 IPCC Guidelines*, Vol. 2; Page 3.64, Table 3.6.5
2) *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.90, Table 1-47, Jet and Turboprop Aircraft

- ***Activity data***

Figures for jet fuel consumption (for domestic scheduled flights and others [commuter, sightseeing and charter flights]) converted to net calorific value from data described in the *Statistical Yearbook of Air Transport* (Ministry of Land, Infrastructure, Transport and Tourism) are used.

***c) Completeness***

For aviation gasoline, emissions of $NO_X$, CO, and NMVOCs are reported as "NE".

### A3.1.1.2.b. Road Transportation (1.A.3.b.): Fuel combustion ($NO_X$, CO, NMVOCs, and $SO_X$)

***a) Description of emission source categories***

This section provides the estimation methods for emissions of precursors and other substances ($NO_X$, CO, NMVOCs, and $SO_X$) from fuel combustion of vehicles.

***b) Methodological Issues***

***1) $NO_X$, CO, and NMVOCs***

- ***Estimation Method***

$NO_X$, CO, and NMVOC emissions from the specified mobile sources are calculated by multiplying the distance traveled per year for each vehicle type per fuel by Japan's country-specific emission factor.

- ***Emission factors***

Emission factors are established for each vehicle class per fuel type based on the *Survey for Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles* (Ministry of the Environment, 2002) and the *Survey for Consideration of Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles* (Ministry of the Environment, 2004, 2007, 2008, and every year after 2011). The NMVOC emission factors, however, are calculated by multiplying the emission factor of total hydrocarbon (THC) of the Survey by the percentage of NMVOCs in the THC emissions (60% for gasoline and LPG vehicles and 99% for diesel vehicles; surveyed by the Ministry of the Environment).

The trend of these emission factors over the years includes not only the impact of replacement to vehicles compatible with the latest exhaust gas regulation, but also the impact of the methodological change in the calculation of the emission factors among the survey years.

For reference, Table A 3-5 shows the outline of motor vehicle exhaust emission standards of air pollutants.

- ***Activity data***

For the activity data, the travel distance per year for each vehicle class by fuel type, estimated for $CH_4$ and $N_2O$ emissions, are used. (See Chapter 3)

Table A 3-2 $NO_X$ emission factors for automobiles

| Fuel | Vehicle type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | Light vehicle | g-NOx/km | 0.23 | 0.16 | 0.16 | 0.08 | 0.04 | 0.15 | 0.12 | 0.12 | 0.10 | 0.08 | 0.06 | 0.09 | 0.07 | 0.07 |
| | Passenger vehicle (including LPG) | g-NOx/km | 0.24 | 0.20 | 0.20 | 0.08 | 0.04 | 0.14 | 0.12 | 0.09 | 0.07 | 0.06 | 0.05 | 0.09 | 0.08 | 0.06 |
| | Light cargo truck | g-NOx/km | 0.87 | 0.66 | 0.38 | 0.20 | 0.13 | 0.27 | 0.23 | 0.27 | 0.23 | 0.19 | 0.18 | 0.32 | 0.32 | 0.25 |
| | Small cargo truck | g-NOx/km | 1.12 | 0.90 | 0.48 | 0.09 | 0.04 | 0.15 | 0.11 | 0.09 | 0.08 | 0.07 | 0.06 | 0.14 | 0.10 | 0.07 |
| | Regular cargo truck | g-NOx/km | 1.83 | 1.09 | 0.56 | 0.16 | 0.05 | 0.33 | 0.26 | 0.25 | 0.23 | 0.23 | 0.20 | 0.24 | 0.20 | 0.16 |
| | Bus | g-NOx/km | 4.45 | 3.65 | 2.44 | 0.09 | 0.06 | 0.15 | 0.09 | 0.07 | 0.06 | 0.06 | 0.05 | 0.08 | 0.08 | 0.10 |
| | Special-purpose vehicle | g-NOx/km | 1.47 | 0.87 | 0.43 | 0.12 | 0.04 | 0.32 | 0.26 | 0.19 | 0.17 | 0.15 | 0.12 | 0.31 | 0.22 | 0.17 |
| Diesel | Passenger vehicle | g-NOx/km | 0.64 | 0.53 | 0.44 | 0.45 | 0.37 | 0.47 | 0.46 | 0.44 | 0.38 | 0.34 | 0.26 | 0.40 | 0.39 | 0.35 |
| | Small cargo truck | g-NOx/km | 1.33 | 1.10 | 1.01 | 1.00 | 0.81 | 1.06 | 1.00 | 0.93 | 0.89 | 0.79 | 0.73 | 1.87 | 1.02 | 0.96 |
| | Regular cargo truck | g-NOx/km | 5.35 | 4.59 | 4.33 | 4.50 | 4.06 | 3.26 | 3.09 | 2.86 | 2.73 | 2.64 | 2.40 | 3.05 | 2.50 | 2.28 |
| | Bus | g-NOx/km | 4.23 | 3.83 | 3.60 | 4.07 | 3.52 | 3.38 | 3.48 | 3.39 | 3.23 | 3.13 | 2.96 | 3.74 | 3.46 | 3.25 |
| | Special-purpose vehicle | g-NOx/km | 3.38 | 2.76 | 2.15 | 3.63 | 2.99 | 2.97 | 2.75 | 2.50 | 2.41 | 2.24 | 2.05 | 3.21 | 2.97 | 2.75 |

Table A 3-3 CO emission factors for automobiles

| Fuel | Vehicle Type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | Light vehicle | g-CO/km | 1.75 | 1.55 | 1.54 | 0.97 | 0.72 | 1.51 | 1.33 | 1.47 | 1.22 | 1.08 | 0.94 | 1.39 | 1.32 | 1.29 |
| | Passenger vehicle (including LPG) | g-CO/km | 2.32 | 2.06 | 2.03 | 0.94 | 0.58 | 1.37 | 1.19 | 1.07 | 0.92 | 0.81 | 0.75 | 1.33 | 1.27 | 1.16 |
| | Light cargo truck | g-CO/km | 10.42 | 8.54 | 5.51 | 2.77 | 2.10 | 2.87 | 2.41 | 3.17 | 2.76 | 2.38 | 2.27 | 2.46 | 2.48 | 2.06 |
| | Small cargo truck | g-CO/km | 9.66 | 10.08 | 8.31 | 2.05 | 1.08 | 2.73 | 2.13 | 1.85 | 1.61 | 1.40 | 1.25 | 1.67 | 1.19 | 1.05 |
| | Regular cargo truck | g-CO/km | 12.62 | 10.60 | 8.95 | 3.62 | 1.67 | 7.53 | 5.73 | 5.67 | 5.04 | 4.77 | 4.36 | 4.18 | 3.06 | 2.89 |
| | Bus | g-CO/km | 26.21 | 25.08 | 21.94 | 2.07 | 1.45 | 2.62 | 1.88 | 1.77 | 1.78 | 1.65 | 1.57 | 1.79 | 1.72 | 1.60 |
| | Special-purpose vehicle | g-CO/km | 12.47 | 10.67 | 8.92 | 2.30 | 1.19 | 5.34 | 4.24 | 3.69 | 3.44 | 3.09 | 2.76 | 3.51 | 2.23 | 1.79 |
| Diesel | Passenger vehicle | g-CO/km | 0.48 | 0.43 | 0.43 | 0.37 | 0.30 | 0.39 | 0.37 | 0.36 | 0.29 | 0.22 | 0.17 | 0.24 | 0.23 | 0.20 |
| | Small cargo truck | g-CO/km | 0.98 | 0.90 | 0.81 | 0.59 | 0.37 | 0.45 | 0.42 | 0.36 | 0.34 | 0.30 | 0.25 | 0.54 | 0.34 | 0.28 |
| | Regular cargo truck | g-CO/km | 3.22 | 2.99 | 2.44 | 2.04 | 1.47 | 1.10 | 0.97 | 0.80 | 0.72 | 0.65 | 0.55 | 0.50 | 0.36 | 0.31 |
| | Bus | g-CO/km | 2.58 | 2.53 | 2.20 | 2.03 | 1.44 | 1.24 | 1.18 | 1.14 | 1.05 | 0.98 | 0.89 | 0.86 | 0.76 | 0.66 |
| | Special-purpose vehicle | g-CO/km | 2.11 | 1.89 | 1.30 | 1.60 | 1.00 | 0.93 | 0.79 | 0.63 | 0.58 | 0.50 | 0.43 | 0.53 | 0.48 | 0.41 |

Table A 3-4 NMVOC emission factors for automobiles

| Fuel | Vehicle Type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | Light vehicle | g-NMVOC/km | 0.08 | 0.03 | 0.03 | 0.03 | 0.02 | 0.08 | 0.07 | 0.06 | 0.05 | 0.04 | 0.04 | 0.05 | 0.05 | 0.04 |
| | Passenger vehicle (including LPG) | g-NMVOC/km | 0.11 | 0.07 | 0.06 | 0.02 | 0.01 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.06 | 0.06 | 0.06 |
| | Light cargo truck | g-NMVOC/km | 0.64 | 0.37 | 0.16 | 0.09 | 0.06 | 0.14 | 0.13 | 0.13 | 0.12 | 0.10 | 0.10 | 0.12 | 0.11 | 0.08 |
| | Small cargo truck | g-NMVOC/km | 0.71 | 0.53 | 0.21 | 0.04 | 0.02 | 0.07 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.10 | 0.05 | 0.04 |
| | Regular cargo truck | g-NMVOC/km | 0.99 | 0.58 | 0.28 | 0.06 | 0.02 | 0.17 | 0.14 | 0.14 | 0.13 | 0.14 | 0.11 | 0.14 | 0.07 | 0.06 |
| | Bus | g-NMVOC/km | 2.16 | 1.90 | 1.32 | 0.04 | 0.02 | 0.07 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.06 | 0.05 | 0.06 |
| | Special-purpose vehicle | g-NMVOC/km | 0.97 | 0.47 | 0.19 | 0.05 | 0.02 | 0.16 | 0.13 | 0.10 | 0.10 | 0.09 | 0.08 | 0.24 | 0.09 | 0.08 |
| Diesel | Passenger vehicle | g-NMVOC/km | 0.11 | 0.10 | 0.10 | 0.09 | 0.08 | 0.10 | 0.10 | 0.10 | 0.08 | 0.07 | 0.05 | 0.06 | 0.05 | 0.04 |
| | Small cargo truck | g-NMVOC/km | 0.39 | 0.34 | 0.26 | 0.20 | 0.10 | 0.14 | 0.13 | 0.10 | 0.09 | 0.08 | 0.07 | 0.14 | 0.09 | 0.07 |
| | Regular cargo truck | g-NMVOC/km | 1.62 | 1.47 | 1.03 | 0.75 | 0.50 | 0.35 | 0.30 | 0.23 | 0.21 | 0.19 | 0.15 | 0.14 | 0.08 | 0.06 |
| | Bus | g-NMVOC/km | 1.26 | 1.24 | 0.98 | 0.80 | 0.53 | 0.43 | 0.39 | 0.38 | 0.34 | 0.32 | 0.28 | 0.32 | 0.26 | 0.21 |
| | Special-purpose vehicle | g-NMVOC/km | 1.09 | 0.96 | 0.52 | 0.57 | 0.32 | 0.27 | 0.23 | 0.17 | 0.16 | 0.13 | 0.12 | 0.14 | 0.11 | 0.08 |

# Table A 3-5 Outline of motor vehicle exhaust emission standards (for reference)

| | | | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2007 | 2008 | 2009 | 2010 | 2011 | 2016 | 2018 | 2019 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline and LPG | Light passenger vehicle and passenger vehicle | | CO | 2.1 | 2.1 | | | | | | | | 0.67 | | | | | 1.15 | | 1.15 | | | 1.15 | | 1.15 | | |
| | | | HC | 0.25 | 0.25 | | | | | | | | 0.08 | | | | | 0.05 | | 0.05 | | | 0.05 | | 0.1 | | |
| | | | NOx | 0.25 | 0.25 | | | | | | | | 0.08 | | | | | 0.05 | | 0.05 | | | 0.05 | | 0.05 | | |
| | | | Unit | g/km | g/km | | | | | | | | g/km | | | | | g/km | | g/km | | | g/km | | g/km | | |
| | | | Mode | 10 | 10·15 | | | | | | | | 10·15 | | | | | 10·15+11 | | 10·15+JC08C | | | JC08H+JC08C | | WLTC | | |
| | | | CO | 60 | | | | | | | | | 19 | | | | | | | | | | | | | | |
| | | | HC | 7 | | | | | | | | | 2.2 | | | | | | | | | | | | | | |
| | | | NOx | 4.4 | | | | | | | | | 1.4 | | | | | | | | | | | | | | |
| | | | Unit | g/test | | | | | | | | | << | | | | | | | | | | | | | | |
| | | | Mode | 11 | | | | | | | | | << | | | | | | | | | | | | | | |
| | Truck and bus | Light cargo truck | CO | 13 | 13 | | | | | | 6.5 | | | | 3.3 | | | | 4.02 | 4.02 | | | 4.02 | | | 4.02 | |
| | | | HC | 2.1 | 2.1 | | | | | | 0.25 | | | | 0.13 | | | | 0.05 | 0.05 | | | 0.05 | | | 0.1 | |
| | | | NOx | 0.5 | 0.5 | | | | | | 0.25 | | | | 0.13 | | | | 0.05 | 0.05 | | | 0.05 | | | 0.05 | |
| | | | Unit | g/km | g/km | | | | | | g/km | | | | g/km | | | | 10·15+JC08C | | | | g/km | | | g/km | |
| | | | Mode | 10 | 10·15 | | | | | | 10·15 | | | | 10·15 | | | | 10·15+11 | | | | JC08H+JC08C | | | WLTC | |
| | | | CO | 100 | | | | | | | 76 | | | | 38 | | | | | | | | | | | | |
| | | | HC | 13 | | | | | | | 7 | | | | 3.5 | | | | | | | | | | | | |
| | | | NOx | 5.5 | | | | | | | 4.4 | | | | 2.2 | | | | | | | | | | | | |
| | | | Unit | g/test | | | | | | | g/test | | | | g/test | | | | | | | | | | | | |
| | | | Mode | 11 | | | | | | | 11 | | | | 11 | | | | | | | | | | | | |
| | | Light duty | CO | 2.1 | 2.1 | | | | | | | | 0.67 | | | | | 1.15 | | 1.15 | | | 1.15 | | 1.15 | | |
| | | | HC | 0.25 | 0.25 | | | | | | | | 0.08 | | | | | 0.05 | | 0.05 | | | 0.05 | | 0.1 | | |
| | | | NOx | 0.25 | 0.25 | | | | | | | | 0.08 | | | | | 0.05 | | 0.05 | | | 0.05 | | 0.05 | | 7) |
| | | | Unit | g/km | g/km | | | | | | | | g/km | | | | | g/km | | g/km | | | g/km | | g/km | | |
| | | | Mode | 10 | 10·15 | | | | | | | | 10·15 | | | | | 10·15+11 | | 10·15+JC08C | | | JC08H+JC08C | | WLTC | | |
| | | | CO | 60 | | | | | | | | | 19 | | | | | | | | | | | | | | |
| | | | HC | 7 | | | | | | | | | 2.2 | | | | | | | | | | | | | | |
| | | | NOx | 4.4 | | | | | | | | | 1.4 | | | | | | | | | | | | | | |
| | | | Unit | g/test | | | | | | | | | g/test | | | | | | | | | | | | | | |
| | | | Mode | 11 | | | | | | | | | 11 | | | | | | | | | | | | | | |
| | | Medium duty | CO | 13 | 13 | | | 13 | | | 6.5 | | | 2.1 | | | | 2.55 | | 2.55 | | | 2.55 | | | 2.55 | |
| | | | HC | 2.1 | 2.1 | | | 2.1 | | | 0.25 | | | 0.08 | | | | 0.05 | | 0.05 | | | 0.05 | | | 0.15 | |
| | | | NOx | 0.7 | 0.7 | | | 0.4 | | | 0.4 | | | 0.13 | | | | 0.07 | | 0.07 | | | 0.07 | | | 0.07 | 7) |
| | | | Unit | g/km | g/km | | | g/km | | | g/km | | | g/km | | | | g/km | | g/km | | | g/km | | | g/km | |
| | | | Mode | 10 | 10·15 | | | 10·15 | | | 10·15 | | | 10·15 | | | | 10·15+11 | | 10·15+JC08C | | | JC08H+JC08C | | | WLTC | |
| | | | CO | 100 | | | | 100 | | | 76 | | | 24 | | | | | | | | | | | | | |
| | | | HC | 13 | | | | 13 | | | 7 | | | 2.2 | | | | | | | | | | | | | |
| | | | NOx | 6.5 | | | | 5 | | | 5 | | | 1.6 | | | | | | | | | | | | | |
| | | | Unit | g/test | | | | g/test | | | g/test | | | g/test | | | | | | | | | | | | | |
| | | | Mode | 11 | | | | 11 | | | 11 | | | 11 | | | | | | | | | | | | | |
| | | Heavy duty | CO | 1.2 | | 102 | | | 102 | | 51 | | | 16 | | | | 16 | | | | | | | | | |
| | | | HC | 410 | | 6.2 | | | 6.2 | | 1.8 | | | 0.58 | | | | 0.23 | | | | | | | | | |
| | | | NOx | 650 | | 5.5 | | | 4.5 | | 4.5 | | | 1.4 | | | | 0.7 | | | | | | | | | 7) |
| | | | Unit | ppm | | g/kWh | | | g/kWh | | g/kWh | | | g/kWh | | | | g/kWh | | | | | | | | | 8) |
| | | | Mode | 6 | | G13 | | | G13 | | G13 | | | G13 | | | | JE05 | | | | | | | | | |
| | Common name | | | | | | | Short-term regulation | | | Long-term regulation | | | New short-term regulation | | | | New long-term regulation | | | | | | | | | |

| | | | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2007 | 2008 | 2009 | 2010 | 2011 | 2016 | 2018 | 2019 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diesel | Passenger vehicle | | CO | 2.1 | 2.1 | 2.1 | | | | 2.1 | 2.1 | | | | 0.63 | | | 0.63 | | 0.63 | 0.63 | | | | 0.63 | | |
| | | | HC | 0.4 | 0.4 | 0.4 | | | | 0.4 | 0.4 | | | | 0.12 | | | 0.024 | | 0.024 | 0.024 | | | | 0.024 | | |
| | | | NOx | 0.5\|0.9 | 0.5\|0.9 | 0.5\|0.6 | | | | 0.4\|0.6 | 0.4 | | | | 0.28\|0.3 | | | 0.14\|0.15 | | 0.14\|0.1 | 0.08 | | | | 0.15 | | 9) |
| | | | Unit | g/km | g/km | g/km | | | | g/km | g/km | | | | g/km | | | g/km | | 10·15+JC08C | | | | | g/km | | |
| | | | Mode | 10 | 10·15 | 10·15 | | | | 10·15 | 10·15 | | | | 10·15 | | | 10·15+11 | | JC08H+JC08C | | | | | WLTC | | |
| | Truck and bus | Light duty | CO | 2.1 | 2.1 | | 2.1 | | | 2.1 | | | | | 0.63 | | | 0.63 | | 0.63 | 0.63 | | | | 0.63 | | |
| | | | HC | 0.4 | 0.4 | | 0.4 | | | 0.4 | | | | | 0.12 | | | 0.024 | | 0.024 | 0.024 | | | | 0.024 | | |
| | | | NOx | 0.9 | 0.9 | | 0.6 | | | 0.4 | | | | | 0.28 | | | 0.14 | | 0.14 | 0.08 | | | | 0.15 | | 10) |
| | | | Unit | g/km | g/km | | g/km | | | g/km | | | | | g/km | | | g/km | | 10·15+JC08C | | | | | g/km | | |
| | | | Mode | 10 | 10·15 | | 10·15 | | | 10·15 | | | | | 10·15 | | | 10·15+11 | | JC08H+JC08C | | | | | WLTC | | |
| | | Medium duty | CO | 790 | | | 2.1 | | | 2.1 | | | | | | 0.63 | | 0.63 | | 0.63 | 0.63 | | | | | 0.63 | |
| | | | HC | 510 | | | 0.4 | | | 0.4 | | | | | | 0.12 | | 0.024 | | 0.024 | 0.024 | | | | | 0.024 | |
| | | | NOx | 380/260 | | | 1.3 | | | 0.7 | | | | | | 0.49 | | 0.25 | | 0.25 | 0.15 | | | | | 0.24 | 10) |
| | | | Unit | ppm | | | g/km | | | g/km | | | | | | g/km | | g/km | | 10·15+JC08C | | | | | | g/km | 11) |
| | | | Mode | 6 | | | 10·15 | | | 10·15 | | | | | | 10·15 | | 10·15+11 | | JC08H+JC08C | | | | | | WLTC | |
| | | Heavy duty | CO | 790 | | | | 7.4 | | 7.4 | 7.4 | 7.4 | | | | 2.22 | 2.22 | 2.22 | | | 2.22 | 2.22 | | 2.22 | 2.22 | 2.22 | |
| | | | HC | 510 | | | | 2.9 | | 2.9 | 2.9 | 2.9 | | | | 0.87 | 0.87 | 0.17 | | | 0.17 | 0.17 | | 0.17 | 0.17 | 0.17 | |
| | | | NOx | 400/260 | | | | 6/5 | | 4.5 | 4.5 | 4.5 | | | | 3.38 | 3.38 | 2 | | | 0.7 | 0.7 | | 0.4 | 0.4 | 0.4 | 10) |
| | | | Unit | ppm | | | | g/kWh | | (2.5-3.5t) | (3.5-12t) | (>12t) | | | | (2.5-12t) | (>12t) | g/kWh | | | (>12t) | (3.5-12t) | | (>7.5t) | (trac-tor) | (3.5-7.5t) | 11) |
| | | | Mode | 6 | | | | D13 | | | | | | | | | | JE05 | | | JE05 | | | WHDC | | | |
| | Common name | | | | | | | Short-term regulation | | | Long-term regulation | | | | New short-term regulation | | | New long-term regulation | | | Post new long-term regulation | | | | | | |

Note
1) This table is compiled based on the materials prepared by Ministry of the Environment and Ministry of Land, Infrastructure, Transport and Tourism.
2) This table omits the regulations of particular matter (PM) and fuel evaporation for the vehicles above and the regulations of exhaust gas for motorcycles and off-road vehicles.
3) The values in this table represent average value for new vehicle type.
4) 1990 column represents the regulations as of 1990 and other columns represent the years the regulations started for new vehicle type.
5) The shaded letters show the difference from the previous regulation.
6) HC do not include methane since the regulations enforced since 2005.
7) For gasoline and LPG vehicles, "light duty vehicles" are vehicles with gross vehicle weight (GVW) of 1.7t or less.
Until 2000, "middle duty vehicles" are vehicles with GVW of 1.7-2.5t and "heavy duty vehicles" are vehicles with GVW of more than 2.5t.
Since 2001, "middle duty vehicles" are vehicles with GVW of 1.7-3.5t and "heavy duty vehicles" are vehicles with GVW of more than 3.5t.
8) Different regulations are adopted for LPG heavy duty vehicles until 1997, but omitted from this table for simplicity.
9) 0.5|0.9 in diesel passenger vehicles stands for "0.5 for small size vehicles (vehicle weight of 1,265 kg or less) and 0.9 for medium size vehicles (vehicle weight of more than 1,265 kg)".
10) For diesel vehicles, "light duty vehicles" are vehicles with GVW of 1.7t or less.
Until 2004, "middle duty vehicles" are vehicles with GVW of 1.7-2.5t and "heavy duty vehicles" are vehicles with GVW of more than 2.5t.
Since 2005, "middle duty vehicles" are vehicles with GVW of 1.7-3.5t and "heavy duty vehicles" are vehicles with GVW of more than 3.5t.
11) "380/260" for diesel truck and bus in 1990s stands for "380 for direct injection and 260 for indirect injection".

### *2) $SO_X$*

- ***Estimation Method***

The emissions of $SO_X$ from these sources are calculated by multiplying the fuel consumption of each fuel type by Japan's country-specific emission factors.

- ***Emission factors***

Sulfur content (by weight) by fuel type was used.

Table A 3-6 Sulfur content (by weight) by fuel type

| Fuel | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | 0.008% | 0.008% | 0.008% | 0.005% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% |
| Diesel | 0.350% | 0.136% | 0.050% | 0.005% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% | 0.001% |
| LPG | 0.002% | 0.002% | 0.002% | 0.002% | 0.002% | 0.002% | 0.002% | 0.002% | 0.002% | 0.002% | 0.002% | 0.002% | 0.002% | 0.002% |

Reference: Gasoline – The Institute of Behavioral Science (until 2004); Upper limits of regulations (2005 onward),
Diesel oil – Petroleum Association of Japan (until 1997); Upper limits of regulations (1998 onward)
LPG – The Institute of Behavioral Science

- ***Activity data***

Activity data, fuel consumption data of weight value, are calculated by multiplying the fuel consumption of each fuel type, reported in in the *General Energy Statistics* (Agency for Natural Resources and Energy), by the specific gravity of each fuel type.

### *c) Completeness*

Emissions of $NO_X$, CO, NMVOCs, and $SO_X$ from natural gas vehicles and motorcycles are reported as "NE".

## A3.1.1.2.c. Road transportation (1.A.3.b.): fuel volatilization (excluding motorcycle) (NMVOCs)

### *a) Description of emission source categories*

This section provides the estimation methods for emissions of NMVOCs caused by fuel volatilization of vehicles. NMVOCs are emitted from vehicles which run on gasoline, by volatilization of the gasoline component in the tank. Fuel evaporative emission is classified into the following three types. Evaporating gas in filling gasoline is included in the calculation of fugitive emissions from fuels at gas stations (1.b.2.a.v.).

Table A 3-7 Classification of fuel evaporative gases

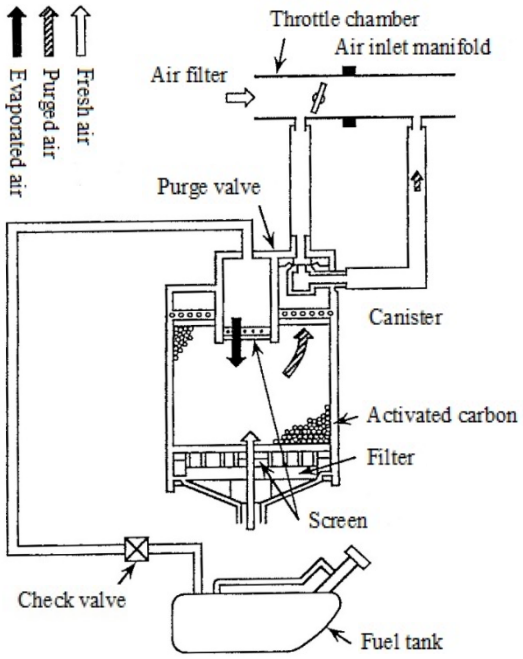
| Types | Description |
|---|---|
| Diurnal Breathing Loss (DBL) | Evaporated gas which is generated when gasoline vapor, generated mainly due to the change in temperature during parking, is vented to the atmosphere after breakthrough[1)] from the canister[2)]. |
| Hot Soak Loss (HSL) | Evaporated gas which is generated from gasoline attached to the induction pipe within one hour after shutdown of an engine. |
| Running Loss (RL) | Evaporated gas which is generated when the temperature of gasoline rises during driving and it goes beyond the limitation of canister purging[3)]. |

1) "Breakthrough" means going through the absorption process without being absorbed when the amount of gas/gasoline goes beyond the absorption capacity of canister.
2) Canister is absorption equipment in which activated carbon and other substances are included to prevent

generating evaporated gas in the fuel system of gasoline car. Evaporated gas during parking is absorbed by the canister; absorbed evaporated gas is delivered to the intake manifold during driving, then, absorption capacity of the canister recovers.

3) Purge means delivering evaporated gas, together with air, to intake manifold.

Reference: *Estimation Methods for Releases from Sources not Required to Report under PRTR (Pollutant Release and Transfer Register)* (Ministry of Economy, Trade and Industry, and Ministry of the Environment, 2012)




Reference: Society of Automotive Engineers of Japan, Inc. (2008)

Figure A 3-1 Structure of fuel tank and canister

### *b) Methodological issues*

Fuel evaporated emissions are estimated by adjusting THC emission data of DBL, HSL, and RL in 2002 by the annual number of cars owned and annual travel distance. The emissions in 2002 are provided in *Development Research of New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)* (Ministry of the Environment, FY2003). This methodology is similar to that described in the *Estimation Methods for Releases from Sources not Required to Report under PRTR* (Ministry of Economy, Trade and Industry, and Ministry of the Environment).

In estimating emissions in RL, PRTR emission data is used after 2003.

It was assumed that THC emissions = NMVOC emissions, since methane is not included in fuel evaporated gas[2]. The outline of estimation method for each emission source and used data is shown in Table A 3-8.

[2] Regarding concrete volatile element composition, please refer to Yokota *et al.* (2011) for example.

Table A 3-8 Descriptions for estimating emissions from evaporated gas by mobile fuel combustion

| Category | Equation | Data for calculation |
|---|---|---|
| DBL | $E_n = \sum_p \sum_q \sum_r \left( E_{2002} \times \frac{N_{n,p,q,r}}{N_{2002,p,q,r}} \right)$<br>$E_n$ : DBL emissions in fiscal year (FY) $n$ [t-NMVOC]<br>$N_{n,p,q,r}$: Number of gasoline vehicles owned in FY $n$ in a prefecture $p$, by vehicle type $q$, by status if regulated or not $r$ | $E_{2002}$: THC emission amount in FY2002 provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)* (Ministry of the Environment, FY2003)<br><br>$N$: Based on *Monthly Report Statistics of Vehicle*s (Japan Automobile Manufacturers Association, Inc. (JAMA)) and *Statistics of AIRIA/ Number of Motor Vehicles* (Automobile Inspection & Registration Information Association (AIRIA)). |
| HSL | $E_n = \sum_p \sum_q \left( E_{2002} \times \frac{N_{n,p,q}}{N_{2002,p,q}} \right)$<br>$E_n$: DBL emissions in FY $n$ [t-NMVOC]<br>$N_{n,p,q}$: Number of gasoline vehicles owned in FY $n$ in a prefecture $p$, by usage $q$ | $E_{2002}$: THC emission amount in FY2002 provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)*<br><br>$N$: Based on *Monthly Report Statistics of Vehicle*s and *Statistics of AIRIA/ Number of Motor Vehicles*. |
| RL | [1990-2002]<br>$E_n = \sum_p \sum_q \left( E_{2002} \times \frac{N_{n,p,q}}{N_{2002,p,q}} \times \frac{M_{n,p}}{M_{2002,p}} \right)$<br>$E_n$: RL emissions in FY $n$ [t-NMVOC]<br>$N_{n,p,q}$: Number of gasoline vehicles owned in FY $n$ in a prefecture $p$, by status if regulated or not $q$<br>$M_{n,p}$: Travel distance of motorcycle [km] in FY $n$ in a prefecture $p$<br><br>[2003-]<br>PRTR emissions were used. | $E_{2002}$: THC emission amount in FY2002 provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road Vehicle)*<br><br>$N$: Based on *Monthly Report Statistics of Vehicle*s and *Statistics of AIRIA/ Number of Motor Vehicles*.<br><br>$M$: Based on *Monthly Report of Motor Vehicle Transport Statistics* and *Monthly Report Statistics of Vehicle*s. |

### A3.1.1.2.d. Road transportation (1.A.3.b.): fuel volatilization (motorcycle) (NMVOCs)

#### *a) Description of emission source categories*

This section provides the estimation methods for emissions of NMVOCs by motorcycle caused by fuel volatilization. NMVOCs are emitted from motorcycles which run on gasoline, by volatilization of the gasoline component in the tank due to changes in temperature as described in the above section. This section provides the estimation method for DBL and HSL as described in the *PRTR*.

#### *b) Methodological issues*

Fuel evaporated emissions from motorcycle are estimated by using THC emissions in 2001, provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)* (Ministry of the Environment, FY2002), which are yearly-adjusted by the activity data, number of motorcycles owned and travel distance, using the same methodology as that in the *Estimation Methods for Releases from Sources not Required to Report under PRTR* (Ministry of Economy, Trade and Industry, and Ministry of the Environment).

Table A 3-9 Description of estimating emissions from evaporated gas by motorcycle fuel combustion

| Category | Equation | Data for calculation |
|---|---|---|
| DBL | $E_n = \sum_p \sum_q \left( E_{2001} \times \frac{M_{n,p,q}}{M_{2001,p,q}} \right)$<br>$E_n$: DBL emissions in FY $n$ [t-NMVOC]<br>$M_{n,p,q}$: travel distance of motorcycle [km] in FY $n$ in a prefecture $p$, by vehicle type $q$ | $E_{2001}$: THC emission amount in FY2001 estimated based on *Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)* (Ministry of the Environment, FY2002).<br><br>$M$: Based on *Monthly Report Statistics of Vehicle*s (Japan Automobile Manufacturers Association, Inc. (JAMA)), and *Survey of Motorcycle Market Trends* (JAMA). |
| HSL | $E_n = \sum_p \sum_q \left( E_{2001} \times \frac{M_{n,p}}{M_{2001,p}} \times R_{n,p} \right)$<br>$E_n$: DBL emissions in FY $n$ [t-NMVOC]<br>$M_{n,p}$: travel distance of motorcycle [km] in FY $n$ by vehicle type $p$<br>$R$: Use factor adjustment ratio in FY $n$ by vehicle type $p$ | $E_{2001}$: THC emission amount in FY2001 estimated based on *Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)*.<br><br>$M$: Based on *Monthly Report Statistics of Vehicles*, and *Survey of Motorcycle Market Trends*.<br><br>$R$: Estimated by multiplying the sales unit for domestic sales of each vehicle type (Website of JAMA) by survival rate of each elapsed year (Ministry of the Environment), by the usage factor of each elapsed year (*Estimation Methods for Releases from Sources not Required to Report under PRTR* ). |

### A3.1.1.2.e. Railways (1.A.3.c.: $NO_X$, CO, and NMVOCs)

#### *a) Category Description*

This section provides the estimation methods for emissions of precursors (NOx, CO, and NMVOCs) caused by combustion of diesel railway fuel.

#### *b) Methodological Issues*

$NO_X$, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *Revised 1996 IPCC Guidelines*.

- ***Emission factors***

The default emission factors provided for the "Locomotives" category in the *Revised 1996 IPCC Guidelines* are used.

Table A 3-10 IPCC default emission factors for locomotives

| Gas | Emission factor [g/MJ(NCV)] |
|---|---|
| $NO_X$ | 1.8 |
| CO | 0.61 |
| NMVOCs | 0.13 |

Reference: *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.89, Table 1-47

- ***Activity data***

The diesel oil consumption by railways in the *General Energy Statistics* (Agency for Natural Resources and Energy) is used.

### A3.1.1.2.f. Domestic Navigation (1.A.3.d.: $NO_X$, CO, NMVOCs, and $SO_X$)

#### *a) Category Description*

This section provides the estimation methods for emissions of precursors (NOx, CO, and NMVOCs) and $SO_X$ from combustion of marine fuel.

#### *b) Methodological Issues*

#### *1) $NO_X$, CO, and NMVOCs*

- ***Estimation Method***

$NO_X$, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *Revised 1996 IPCC Guidelines*.

- ***Emission factors***

The default emission factors provided in the "Ocean-Going Ships" category in the *Revised 1996 IPCC Guidelines* are used.

Table A 3-11 IPCC default emission factors for ocean-going ships

| Gas | Emission factor [g/MJ(NCV)] |
|---|---|
| $NO_X$ | 1.8 |
| CO | 0.18 |
| NMVOCs | 0.052 |

Reference: *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.90, Table 1-48

- ***Activity data***

The marine fuel consumption data converted to net calorific value by fuel type (diesel oil, fuel oil A, fuel oil B, and fuel oil C) from the *General Energy Statistics* (Agency for Natural Resources and Energy) are used.

#### *2) $SO_X$*

- ***Estimation Method***

Emissions from the specified sources are calculated by multiplying the fuel consumption by the emission factors.

- ***Emission factors***

Emission factors are calculated by multiplying the specific gravity of each marine fuel by the sulfur ratio of each fuel by the molecular weight ratio of sulfur dioxide[3] versus sulfur. The sulfur ratio of each fuel is restricted by domestic law and *Japanese Industrial Standard*. Therefore, the regulation values are used for the sulfur ratio in the estimation.

[3] Most $SO_X$ consists of $SO_2$. For major sources, $SO_2$ emissions are estimated.

Table A 3-12 Specific gravity and sulfur ratio of fuel for ocean-going ships

| Fuel | Specific Gravity [kg/L] | Sulfur Ratio [% in weight] |
|---|---|---|
| Diesel Oil | 0.83 | 0.5 (1990-1991)<br>0.2 (1992-1997)<br>0.05 (1998-2004)<br>0.005 (2005-2006)<br>0.001 (2007 onward) |
| Fuel Oil A | 0.84 | 2.0 |
| Fuel Oil B | 0.91 | 3.0 |
| Fuel Oil C | 0.93 | 3.5 |

Reference: Sulfur ratio of diesel oil based on Petroleum Association of Japan (2015)
Sulfur ratio of each fuel oil based on *Japanese Industrial Standard* K2205
Specific gravity based on Environmental Research and Control Center (2000)

- ***Activity data***

The marine fuel consumption data of each fuel type (diesel oil, fuel oil A, fuel oil B, and fuel oil C) provided in the *General Energy Statistics* (Agency for Natural Resources and Energy) are used for the activity data.

### A3.1.1.3. Fugitive emissions from fuel (Oil and natural gas) (1.B.2: NMVOCs)

### A3.1.1.3.a. Oil production (1.B.2.a.ii)

#### *a) Category Description*

This section provides the estimation methods for NMVOC emissions occurring during production of crude oil in oil fields. As for the NMVOC emissions when lowering measuring instruments into operating wells at servicing, the estimation methods are provided in the section "Fugitive emissions during servicing of operating gas fields" (1.B.2.b.ii).

#### *b) Methodological Issues*

In order to keep consistency with the methods to estimate $CH_4$ and $CO_2$, the emissions from offshore and onshore oil fields are estimated separately.

- ***Estimation Method***

Using the equation below, the emission amount of NMVOCs in this category is estimated by multiplying the amounts of crude oil production from offshore oil fields and onshore oil fields by the default emission factors for offshore and onshore given in the *2006 IPCC Guidelines*.

$$E = \sum_i (AD_i \times EF_i)$$

$E$ : NMVOC fugitive emissions caused by crude oil production [kt-NMVOC]
$AD_i$ : Amount of crude oil production (excluding condensate) from offshore oil fields or onshore oil fields [1000 kL]
$EF_i$ : Emission factor for crude oil production from offshore oil fields or onshore oil fields [kt-NMVOC/1000 kL]

- ***Emission factors***

For NMVOC emission factors of fugitive emissions from oil production, the default values for fugitive emissions of conventional oil from onshore and offshore oil fields (onshore: $2.25\times10^{-3}$, offshore: $7.4\times10^{-7}$ kt-NMVOC/$10^3$ kL), which are indicated in the *2006 IPCC Guidelines*, are

used. As for the emission factor for onshore fields, the median of the default values ($1.80\times10^{-6}$ - $4.50\times10^{-3}$) is used.

- ***Activity Data***

The amount of crude oil production (excluding condensate) by offshore and onshore oil field is used for activity data.

As for the amount of crude oil production (excluding condensate) in offshore oil fields, the condensate production in offshore gas fields is estimated by multiplying the production amount of condensate by the ratio of natural gas production amount in offshore fields to the total production amount of natural gas, and then subtracted from the crude oil production amount in offshore fields.

The amount of crude oil production (excluding condensate) in offshore fields estimated above is deducted from the total amount of domestic crude oil production (excluding condensate) to obtain the production amount of crude oil (excluding condensate) in onshore oil fields.

Total production volumes of natural gas, crude oil, and condensate are obtained from the data given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* (FY1990-2000), the *Yearbook of Mineral Resources and Petroleum Products* (FY2001-2010), and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* (FY2011 onward), all by the Ministry of Economy, Trade and Industry (METI). The production amounts of natural gas and crude oil from offshore are obtained from *Natural Gas Data Year Book* compiled by the Japan Natural Gas Association.

### A3.1.1.3.b. Oil transport (1.B.2.a.iii): distribution of crude oil

#### *a) Category Description*

This section provides the estimation methods for NMVOC emissions which are, like evaporating gas, emitted in losses from breathing and acceptance for storage tank, and loading to lorry tank during distributing domestic crude oil.

#### *b) Methodological Issues*

- ***Estimation Method***

Emission amount of NMVOCs in this category is estimated by multiplying the amount of domestic production of crude oil by the emission factor for NMVOCs per production volume.

$$E = AD \times EF$$

$E$ : NMVOC emissions caused by oil transport [t-NMVOC]
$AD$ : Amount of domestic crude oil production [1000 kL]
$EF$ : Emission factor per crude oil production [t-NMVOC/1000 kL]

- ***Emission factors***

Emission factors are established by using the emission amount from crude oil (evaporating gas) estimated in *Study to Develop the National Emission Inventory for Volatile Organic Compounds* (hereafter, "*Study on the VOC Emission Inventory*"), Ministry of the Environment. Since emission

data indicated in the *Study on the VOC Emission Inventory* is limited only to FY2000 and FY2005 onward, emission factors in and before FY2004 are evaluated as shown in Table A 3-13, based on evaluated emissions by Japan Natural Gas Association[4].

Table A 3-13 Emission factors for oil transport

| Fiscal Year (FY) | Method of establishing emission factors |
|---|---|
| FY1990-2004 | Established by dividing the estimated total emissions provided by Japan Natural Gas Association by the activity data (amount of crude oil production). |
| FY2005- | Established by dividing the estimated total emissions in the *Study on the VOC Emission Inventory* by the activity data (amount of crude oil production). |

- ***Activity Data***

The activity data for this category are the amount of crude oil production (including condensate) which is provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

### A3.1.1.3.c. Oil transport (1.B.2.a.iii): Navigation

#### *a) Category Description*

NMVOCs are emitted in the process of ocean transportation of liquid cargo including gasoline, gas-free operation, and ship loading. This section provides the estimation methods for NMVOCs which are emitted from cargo operations by two types of tanker, crude oil tanker and product tanker.

Naphtha is also highly volatile and NMVOCs are likely to be emitted. However, naphtha is delivered by confined chemical tankers and is prohibited from being delivered by product tankers which are not enough treated for electrostatic generation so as to avoid the risk of auto-ignition. Therefore, it is considered that naphtha is not emitted into the air during delivering, thus, it is not used for estimation. (Although chemical agents are usually delivered by chemical tankers, sometimes they are delivered by product tankers, so all chemical agents are used for estimation to avoid underestimation).

VOC emissions from “crude oil” and “oil products (gasoline)” are also included in “1.b.2.a.iv. Refining and storage of oil”. Therefore, the emissions are subtracted from the total emissions in “1.B.2.a.iv. Refining and storage of oil” and included and reported in this category.

VOC emissions from “chemical agent” are also estimated in “A3.1.2.2.n Chemicals Manufacture” in “2.Industrial Process and Product Use”. Therefore, the emissions are subtracted from the total emissions in “Chemicals Manufacture” and included and reported in this category.

[4] Japan Natural Gas Association provided the emissions from the following five sources: “breathing and acceptance”, “shipping (lorry)”, “reboiler vent (GDH)”, “gas release” and “$CO_2$ venting”. The first two sources were chosen as the emissions from this subcategory and the rest of the sources were chosen as the emissions from processing of natural gas (1.B.2.b.iii) in accordance with the *Studies on VOC Emission Inventories*.

### *b) Methodological Issues*

- ***Estimation Method***

The NMVOC emissions are estimated by multiplying the amount of exported or domestically transported "crude oil", "oil products (gasoline)", and "chemical agents" which are reported in the tables entitled "Export cargo volume by type of goods, by destination" and "Delivery cargo volume by type of goods, by destination" in the *Statistical Yearbook of Port* (Ministry of Land, Infrastructure, Transport and Tourism), by the emission factors.

The following equation is used:

$$E = \sum_i (AD_i \times EF_i)$$

$E$ : Emission amount of NMVOCs from evaporation in vessels [t -NMVOC]
$AD_i$ : Traffic volume of cargo $i$ (export volume + transport volume) [t]
$EF_i$ : Emission factor for cargo $i$ [kg-NMVOC/t]
$i$ : Type of cargo (crude oil, gasoline, chemical agent)

- ***Emission factors***

Emission factors for this category are established as can be seen in Table A 3-14.

Table A 3-14 Emission factors for evaporation from vessels

| Activity data | | Emission factors [kg-NMVOC/t] |
|---|---|---|
| Crude oil | With vapor recovery (only in port of Kiire for FY2007 onward) | 0.03 |
| | Without vapor recovery | 0.14 |
| Gasoline | During loading | 0.12 |
| | During gas-freeing | 0.14 |
| Chemical agent | Benzene | 0.011 |
| | Methanol | 0.006 |
| | Toluene | 0.004 |
| | Dichloroethane | 0.016 |
| | Acetone | 0.023 |

Reference: Ocean Policy Research Foundation (2006)

- ***Activity Data***

Based on the tables entitled "Export cargo volume by type of goods, by destination" and "Delivery cargo volume by type of goods, by destination" in the *Statistical Yearbook of Port*, the following methods in Table A 3-15 are used for activity data for this category.

Table A 3-15 Activity data for NMVOC emissions from vessels

| Activity data | Description |
|---|---|
| Crude oil | The volume of export and transport of crude oil is used. |
| Gasoline | Estimated by multiplying the volume of export and transport of crude petroleum products by the percentage of gasoline in the volume of domestic sales and export of petroleum products provided in the *Yearbook of Mineral Resources and Petroleum Products Statistics*. |
| Chemical agent | Estimated by multiplying the volume of export and transport of chemical agents by the percentage of NMVOCs in chemical agents. The percentage of the actual export amount in 2003 of five chemical agents (benzene, methanol, toluene, dichloroethane, and acetone), probable emission sources of NMVOCs (Ocean Policy Research Foundation, 2012), is adopted for the percentage of NMVOCs in chemical agents. |

Note: Each activity data is based on calendar year (CY); therefore, CY-based-activity data are converted into FY-based data by combining 75% of the data from corresponding CY and 25% of the data from the subsequent CY.

### A3.1.1.3.d. Refining and storage of oil (1.B.2.a.iv): Fugitive emissions from oil refinery

#### *a) Category Description*

This section provides the estimation methods for NMVOC emissions from fugitive emissions in the process of refining crude oil and producing oil products.

#### *b) Methodological Issues*

- ***Estimation Method***

The NMVOC emissions are estimated by multiplying BPSD (Barrel per Stream Day), production amount per Steam day of crude oil distillation unit at normal pressure, by Steam day per year by the emission factor. Steam day per year are estimated by multiplying the number of days per year (365 days, but 366 days in leap years) by the annual operating rate.

$$E = AD \times D \times R \times EF$$

| | |
|---|---|
| $E$ | : NMVOC emissions from fugitive emissions in refinery [g-NMVOC/year] |
| $AD$ | : Fugitive Barrel per Stream Day [BPSD] |
| $D$ | : Number of working days in a year (365 days, but 366 days in leap years) |
| $R$ | : Annual operating rate [%] |
| $EF$ | : Emission factor [g-NMVOC/BPSD] |

- ***Emission factors***

Emission factor for this category is established at 5.675 [kg/day/$10^5$BPSD] which is provided in Institute of Behavioral Sciences (2000), in accordance with the *Study on the VOC Emission Inventory*.

- ***Activity Data***

In accordance with the *Study on the VOC Emission Inventory*, the capacity of oil refineries (BPSD: Barrels per Stream Day) by *Sekiyu Shiryô* (Sekiyu Tsushin) is used for activity data. Stream days in a year are calculated by multiplying 365 days (366 days for leap years: FY1991, 1995, 1999, 2003, 2007, 2011, 2015) by the annual operating ratio of the crude oil distillation units at normal pressure, which is provided by *Sekiyu Shiryô* (=annual processing amount [bbl/year] / annual capacity[bbl/year].

### A3.1.1.3.e. Refining and storage of oil (1.B.2.a.iv): Production of lubricant oil

#### *a) Category Description*

This section provides the estimation methods for NMVOC emissions from fugitive emissions in the process of dewaxing and deasphalting during production of lubricants.

#### *b) Methodological Issues*

- ***Estimation Method***

NMVOC emissions from the specified sources are calculated by multiplying the amount of gross sales of lubricants to consumers by Japan's country-specific emission factors for toluene and methyl ethyl ketone.

- ***Emission factors***

Based on measurements in Japan, emission factors are established for toluene and methyl ethyl ketone.

Table A 3-16 Toluene and methyl ethyl ketone emission factors in lubricant oil production

| Gas | Emission factor [g/kL] |
|---|---|
| Toluene | 333.2 |
| Methyl ethyl ketone | 415.5 |

Reference: Institute of Behavioral Science (1987)

- ***Activity data***

The activity data for this category are the gross sales amount of lubricants to consumers, provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*.

## A3.1.1.3.f. Refining and storage of oil (1.B.2.a.iv): fugitive emissions from storage/shipping facilities

### *a) Category Description*

NMVOCs are emitted, with accompanying fuel-evaporated fugitive gases, by storage and shipping of fuel (e.g., gasoline, crude oil, and naphtha) in crude oil transshipment stations, refineries, and oil tank facilities.

NMVOC emissions from storage facilities include losses from breathing and acceptance for fixed-roof type tanks and shipping losses from floating-roof type storage tanks at refineries, and the NMVOC emissions from shipping facilities include shipping losses in loading crude oil or oil products to tanker, tank car, or tank lorry.

### *b) Methodological Issues*

- ***Estimation Method***

NMVOC emissions from storage and shipping of fuel in crude oil transshipment stations, refineries and oil tank facilities are estimated by multiplying the activity data of received amount of crude oil, gasoline and naphtha, by the emission factor per received amount.

$$E = (AD_1 + AD_2 + AD_3) \times EF$$

$E$ : Fugitive NMVOC emissions at fuel storage and shipping facilities [kg-NMVOC]
$AD_1$ : Received amount of crude oil [kL]
$AD_2$ : Received amount of gasoline [kL]
$AD_3$ : Received amount of naphtha [kL]
$EF$ : Emission factor per received amount of petroleum products [kg-NMVOC/kL]

The above-estimated NMVOC emissions include emissions during loading “crude oil” and “oil products (gasoline)” to tankers, which are included and reported in “Oil transport (1.B.2.a.iii)”; therefore, these emissions are subtracted from this category.

- ***Emission factors***

The emission amount in fuel storage and shipping in crude oil transshipment stations, refineries, and oil tank facilities, which has been estimated in the *Study on the VOC Emission Inventory*, and

the following activity data (the received amounts of crude oil, gasoline and naphtha) are applied for establishing emission factors for this category. The emission amount provided in the *Study on the VOC Emission Inventory* are limited to FY2000 and from FY2005 onward, therefore, the emission factor for each FY is established as indicated in Table A 3-17.

No relevant information for FY1990-1999 is available since no measures based on voluntary action plan on environment had been implemented during the period. Therefore, the emission factor for FY2000 is adopted for this period.

For FY2001-2003, emission factors are established by interpolation under the assumption of linearly decreasing emissions factors, since member companies of Petroleum Association of Japan had been continuously implementing voluntary measures for reducing emissions.

Table A 3-17 Emission factors in fuel storage and shipping in crude oil transshipment stations, refineries, and oil tank facilities

| Fiscal Year (FY) | Method of establishing emission factors |
|---|---|
| 1990-1999 | Emission factor for FY2000 is applied for this period |
| 2000 | Established by dividing the emissions provided in the *Study on the VOC Emission Inventory*, by the activity data (the total of received amounts of crude oil, gasoline and naphtha) |
| 2001-2003 | Calculated by interpolating the figures in FY2000 and FY2004. |
| 2004 | Established by dividing the emissions reported in Petroleum Association of Japan's voluntary action plan by the activity data (the total of received amounts of crude oil, gasoline and naphtha). |
| 2005- | Established by dividing the emissions provided in the *Study on the VOC Emission Inventory*, by the activity data (the total of received amounts of crude oil, gasoline and naphtha) |

- ***Activity Data***

The activity data are the processed amount of crude oil, and the received amounts of gasoline and naphtha provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*. As for the crude oil, the received amount has not yet been identified, therefore the processed amount is used instead.

### A3.1.1.3.g. Distribution of oil products (1.B.2.a.v): fugitive emissions from gas stations

#### *a) Category Description*

NMVOCs are emitted by evaporation from underground gasoline storage tanks (loss from acceptance) or by filling gasoline in cars (loss from filling gasoline).

#### *b) Methodological Issues*

- ***Estimation Method***

The NMVOC emissions by prefecture and by month in this category are estimated by multiplying the sales volume of each prefecture and month of gasoline by the emission factors per sales volume of each prefecture and month of gasoline. By such estimation by prefecture and by month, the influences of monthly temperature difference and of vapor pressure drop of gasoline for summer season to the emissions are taken into consideration.

$$E = \sum_{i,j} \left( AD_{i,j} \times EF_{i,j} \right)$$

$E$ : NMVOC emissions at gas filling stations [kg-NMVOC]
$AD_{i,j}$ : Sales amount of gasoline in prefecture $i$ in month $j$ [kL]
$EF_{i,j}$ : Emission factor per sales amount of gasoline in prefecture $i$ in month $j$ (loss from acceptance, loss from filling gas) [kg-NMVOC/kL]

- ***Emission factors***

***1) Loss from acceptance***

Emission factors are established, taking into consideration the temperature difference among prefectures and months, according to the following equation which is based on Agency for Natural Resources and Energy (1975).

The average monthly temperature in each prefectural capital provided in *Weather Statistics Information* (Japan Meteorological Agency) is used for calculation.

$$EF_{i,j} = (0.46 \times T_{i,j} + 13.92)/21$$

$EF_{i,j}$ : Emission factor for loss from acceptance in prefecture $i$ in month $j$ [kg-NMVOC/kL]
$T_{i,j}$ : Average of temperature in prefecture $i$ in month $j$ [degree C]

As for seven prefectures (Saitama, Tokyo, Kanagawa, Fukui, Aichi, Kyoto and Osaka) where the installation of vapor recovery instrument for acceptance is required by ordinance, by following the *Study on the VOC Emission Inventory*, the emission factors for losses from acceptance are established by multiplying the established emission factors by 0.15, taking into consideration of the 85% emission reduction by vapor recovery instrument.

Also in summer season, the gasoline vapor control action is performed, therefore the emission factors from June to September are consistently multiplied by the value of 0.9, according to the *Study on the VOC Emission Inventory*.

***2) Loss from filling gasoline***

The NMVOC emission factors for loss from filling gasoline are established by using the formula below which is developed in the *Study on the VOC Emission Inventory* based on the domestic test results. The average temperature by prefecture and by month used for parameter setting are the same as those used for emission factors for loss from acceptance.

$$EF_{i,j} = 0.0359 \times A_{i,j} - 0.0486 \times B_{i,j} - 0.0092 \times C + 0.0149 \times D - 0.1804$$

$EF_{i,j}$ : Emission factor for loss from filling gasoline in prefecture $i$ in month $j$ [kg-NMVOC/kL]
$A_{i,j}$ : Fuel temperature in car tank in prefecture $i$ in month $j$ [degree C]
$B_{i,j}$ : Temperature difference between fuel in car tank and filling fuel in prefecture $i$ in month $j$ [degree C]
$C$ : Gasoline filling speed [L/minute]
$D$ : Reid vapor pressure [kPa]

Table A 3-18 Establishing method of parameters of emission factor for loss from filling gasoline

| Parameter | | Establishing method |
|---|---|---|
| $A_{i,j}$: Fuel temperature in car tank in prefecture *i* in month *j* [degree C] | | Average temperature in prefecture *i* in month *j* ($T_{i,j}$) [degree C] + 5 [degree C] |
| $B_{i,j}$: Temperature difference between fuel in car tank and filling fuel in prefecture *i* in month *j* [degree C] | | |
| | Filling fuel temperature (Fuel temperature in underground tank) | Established depending on the average temperature in prefecture *i* in month *j* ($T_{i,j}$) [degree C] as follows;<br>$T_{i,j} < 15$ : $T_{i,j}+5$<br>$15 \leq T_{i,j} < 20$ : $T_{i,j} + 2.5$<br>$20 \leq T_{i,j} < 25$ : $T_{i,j}$<br>$25 \leq T_{i,j} < 30$ : $T_{i,j} - 2.5$<br>$30 \leq T_{i,j}$ : $T_{i,j} - 5$ |
| *C*: Gasoline filling speed [L/minute] | | 35 [L/minute] |
| *D*: Reid vapor pressure [kPa] | | June to September: 63.2 [kPa],<br>October to May: 86.0 [kPa] |

Reference: *Study on the VOC Emission Inventory*, by the Ministry of the Environment.

- ***Activity Data***

The activity data are domestic sales volume of gasoline by prefecture and by month, which are calculated by proportionally dividing the domestic monthly gasoline sales volume, provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*, by annual gasoline sales volume by prefecture, provided in the *Oil Product Sales Summary by Prefecture* (Petroleum Association of Japan).

### A3.1.1.3.h. Production of natural gas (1.B.2.b.ii)

#### *a) Category Description*

This section provides the estimation methods for NMVOC emissions occurring during production of natural gas in gas fields. As for the NMVOC emissions when lowering measuring instruments into wells at servicing, the estimation methods are provided in the section "Fugitive emissions during servicing of operating gas fields" (1.B.2.b.ii).

#### *b) Methodological Issues*

In order to keep consistency with the methods to estimate $CH_4$ and $CO_2$, the emissions from offshore and onshore are estimated separately.

- ***Estimation Method***

The NMVOC emissions are estimated by multiplying the amounts of natural gas production from offshore gas fields and onshore gas fields by the default emission factors for offshore and onshore gas fields given in the *2006 IPCC Guidelines*.

$$E = \sum_i (AD_i \times EF_i)$$

$E$ : NMVOC fugitive emissions caused by natural gas production [kt-NMVOC]
$AD_i$ : Amount of natural gas production from offshore gas fields or onshore gas fields [million $m^3$]

$EF_i$ : Emission factor for natural gas production from offshore gas fields or onshore gas fields [kt-NMVOC/million $m^3$]

- ***Emission factors***

For NMVOC emission factors of fugitive emissions from gas production, the default values for fugitive emissions of gas production from onshore and offshore gas fields (onshore: $5.5\times10^{-4}$, offshore: $9.1\times10^{-5}$ kt-NMVOC/million $m^3$), which are indicated in the *2006 IPCC Guidelines*, are used.

- ***Activity Data***

The production volume of natural gas from offshore in the *Natural Gas Data Year Book* is used for the production volume of natural gas from offshore gas fields. The production volume of natural gas from onshore gas fields is estimated by subtracting the production volume of natural gas from offshore gas fields above from the total production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

### A3.1.1.3.i. Fugitive emissions during servicing of operating gas fields (1.B.2.b.ii)

#### *a) Category Description*

This section provides the estimation methods for the NMVOC emissions which occur when lowering measuring instruments into operating wells at servicing.

#### *b) Methodological Issues*

For the fugitive emissions relating to well servicing, the estimation method of using the crude oil production amount as activity data is indicated in the *2006 IPCC Guidelines*, however, the correlation between the crude oil production amount and the emissions relating to natural gas well servicing is not clear. Therefore, the number of operation wells is used for the activity data for $CO_2$, $CH_4$ and $N_2O$ emission estimation based on IPCC, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 2000 (hereafter, *GPG (2000)*). However as for NMVOCs, the emission factor based on the number of operating wells is not indicated in the *GPG (2000)*, thus the estimation method of using the crude oil production amount is adopted based on the *2006 IPCC Guidelines*.

- ***Estimation Method***

Emission amount of NMVOCs in this category is estimated by multiplying the amount of domestic production of crude oil by the default emission factor for NMVOC.

$$E = AD \times EF$$

$E$ : NMVOC emissions during well servicing [kt-NMVOC]
$AD$ : Amount of domestic crude oil production [1000 kL]
$EF$ : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- ***Emission factors***

For NMVOC emission factor for flaring and venting during well servicing, the default value per

crude oil production amount ($1.7\times10^{-5}$ kt-NMVOC/1000 kL), which is indicated in the *2006 IPCC Guidelines*, is used. In $CO_2$, $CH_4$ and $N_2O$ emission estimation, the emissions from other than flaring and venting are also estimated for well servicing, however the emission factor, which is available for NMVOC emission estimation for well servicing, is only the default value for flaring and venting during well servicing shown in the *2006 IPCC Guidelines*, thus such emission factor is used.

- ***Activity Data***

The activity data for this category are the production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

### A3.1.1.3.j. Processing of natural gas (1.B.2.b.iii)

#### *a) Category Description*

In the distribution process to the sellers of mined natural gas, NMVOCs originated from natural gas treatment are emitted by vapor from removal device of fluid or impurities (e.g., carbon dioxide gas) contained in natural gas, or, by being released into the air in construction of pipeline relocation.

#### *b) Methodological Issues*

- ***Estimation Method***

NMVOC emissions by processing of natural gas are estimated by multiplying the domestic production volume of natural gas by the NMVOC emission factors per production volume.

$$E = AD \times EF$$

*E* : NMVOC emission amount by processing of natural gas [t-NMVOC]
*AD* : Production volume of natural gas [million $m^3$]
*EF* : Emission factor per production volume of natural gas [t-NMVOC/million $m^3$]

- ***Emission factors***

Emission factors are established using the natural gas emission amount which has been estimated in the *Study on the VOC Emission Inventory* by the Ministry of the Environment (based on the reported figures of voluntary action plan by Japan Natural Gas Association) and later-indicated activity data (domestic production volume of natural gas). Emission factors in and before FY2004 are established as indicated in the following table, using the emissions provided by Japan Natural Gas Association, since the indicated emission amounts in the *Study on the VOC Emission Inventory* are limited only to FY2000 and from FY2005 onward (same as shown in "Oil transport (1B.2.a.iii)").

Table A 3-19 Method of establishing emission factors for processing of natural gas

| Fiscal Year (FY) | Method of establishing emission factors |
|---|---|
| 1990-2004 | Established by dividing the emissions provided by Japan Natural Gas Association, by the activity data (production amount of natural gas) for FY1990-2004. |
| 2005- | Established by dividing the emissions derived from the *Study on the VOC Emission Inventory* by the activity data (production amount of natural gas) from FY2005 onward. |

- ***Activity data***

The activity data for this category are domestic production volume of natural gas provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

- ***Completeness***

The emissions from this source include the emissions from "transmission and storage of natural gas (1.B.2.b.iv)" and "venting (gas) (1.B.2.c.Venting.ii)".

### A3.1.1.3.k. Natural gas distribution (1.B.2.b.v): City gas production

#### *a) Category Description*

NMVOCs are emitted by fugitive emissions from naphtha tanks in the process of city gas production. In Japan, no emission activity in this category has been made since FY2006, because naphtha has not been used for city gas production due to the completion of shifting raw materials of city gas from low calorific gas made of naphtha to high calorific gas made of LNG in FY2005.

#### *b) Methodological Issues*

- ***Estimation Method***

NMVOC emissions from naphtha tank in city gas production are estimated by multiplying the consumption amount of gasoline used as raw material for city gas production by the NMVOC emission factor per consumption amount. The emissions in this category from FY2006 onward are reported as "NO" since no emission activity has been made during this period.

$$E = AD \times EF$$

*E* : NMVOC emission amount in city gas production [t-NMVOC]
*AD* : Consumption amount of gasoline used as raw material for city gas production [kL]
*EF* : NMVOC emission factor per consumption amount [t-NMVOC/ kL]

- ***Emission factors***

Emission factors for city gas production are established based on the emission amount from "gas production facilities" (estimated based on *Report on Voluntary Action Plan* by The Japan Gas Association) provided in the *Study on the VOC Emission Inventory* by the Ministry of the Environment and the consumption amount of crude gasoline for city gas production.

Since the emitted amount provided by the *Study on the VOC Emission Inventory* is limited to FY2000 and FY2005 onward, the emission factor for each year is established as indicated in

Table A 3-20.

Table A 3-20 Method of establishing emission factors for city gas production

| Fiscal Year (FY) | Method of establishing emission factors |
|---|---|
| FY1990-1999 | Emission factor for FY2000 is used for all fiscal years. |
| FY2000 | Established by dividing the emission amount in FY2000 provided in the *Study on the VOC Emission Inventory* by the activity data (consumption amount of crude gasoline). |
| FY2001-2003 | Established by interpolation, using the emission factors for FY2000 and FY2004. |
| FY2004 | Established by dividing the emission amount in FY2004 provided in the *Voluntary Action Plan* by the activity data (consumption amount of crude gasoline). |
| FY2005- | Established by dividing emission amount provided in the *Study on the VOC Emission Inventory* in FY2005 onward by the activity data (consumption amount of crude gasoline). |

- ***Activity data***

The activity data for this category are the consumption amount of gasoline used as raw material for city gas production provided in the *Current Survey of Production Concerning Gas Industry* (Agency for Natural Resources and Energy).

### A3.1.1.3.l. Venting (Oil) (1.B.2.c.Venting.i)

#### *a) Category Description*

This category provides the estimation method for NMVOC emissions from venting in the petroleum industry.

#### *b) Methodological Issues*

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of crude oil by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

$E$ : NMVOC emissions from venting in oil production [kt-NMVOC]
$AD$ : Amount of domestic crude oil production [1000 kL]
$EF$ : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- ***Emission factors***

For the emission factor, the NMVOC default emission factor for venting in oil production ($4.3\times10^{-4}$ kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for this category are the production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

### A3.1.1.3.m. Flaring (Oil) (1.B.2.c.Flaring.i)

#### *a) Category Description*

This category provides the estimation method for NMVOC emissions from flaring in the petroleum industry.

#### *b) Methodological Issues*

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of crude oil by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

*E* : NMVOC emissions from flaring in oil production [kt-NMVOC]
*AD* : Amount of domestic crude oil production [1000 kL]
*EF* : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- ***Emission factors***

For the emission factor, the NMVOC default emission factor for flaring in oil production ($2.1\times10^{-5}$ kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for this category are the production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

### A3.1.1.3.n. Flaring (Gas) (1.B.2.c.Flaring.ii)

#### *a) Category Description*

This category provides the estimation method for NMVOC emissions from flaring in the natural gas industry.

#### *b) Methodological Issues*

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of natural gas by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

*E* : NMVOC emissions from flaring in gas production [kt-NMVOC]
*AD* : Amount of domestic natural gas [1000 $m^3$]
*EF* : Emission factor per natural gas production [kt-NMVOC/1000 $m^3$]

- ***Emission factors***

For the emission factor, the NMVOC default emission factor for flaring in gas production ($6.2\times10^{-7}$ kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for this category are the production amount of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

### A3.1.1.3.o. Flaring (Combined) (1.B.2.c.Flaring.iii)

#### *a) Category Description*

In Japan, the statistical data are reported for two categories of oil and natural gas. Therefore, the fugitive emissions whose categories can be distinguished are reported in Flaring (Oil) (1.B.2.c.Flaring.i) or in Flaring (Gas) (1.B.2.c.Flaring.ii) respectively. In this category, $CO_2$, $CH_4$ and $N_2O$ emissions arising from exploration and test before production of oil and natural gas, which are unable to be distinguished by their categories of oil industry or natural gas industry, are reported.

#### *b) Methodological Issues*

For the fugitive emissions arising from exploration and test before production of oil and natural gas, the default emission factors, which are established using the crude oil production as activity data, are indicated in the *2006 IPCC Guidelines*. However, in case of $CO_2$, $CH_4$, and $N_2O$ emission estimation, the correlation between the emissions which accompany exploration and testing of natural gas fields, and the crude oil production amount, and the correlation between the emissions from exploration and testing and the production amount from commercial plants are not clear, thus the number of drilled and tested wells is used for the activity data based on *GPG (2000)* similar to the emissions from well servicing. Especially, as for the emissions from the exploration of wells, the number of wells is extremely small compared to the number of operating wells in Japan, thus there is a possibility of overestimation if the crude oil production amount is adopted as activity data. However, as for NMVOCs, the emission factor based on the number of operating wells is not indicated in the *GPG (2000)*, thus the estimation method of using the crude oil production amount is adopted based on the *2006 IPCC Guidelines*. Also, as for NMVOC emissions from flaring in well drilling and well testing, the default values are not prepared for oil industry and gas industry separately but the total of both values is indicated in the *2006 IPCC Guidelines*, thus the emissions are estimated together and reported in this category.

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of crude oil by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

| | |
|---|---|
| $E$ | : NMVOC emissions from flaring and venting in well drilling and well testing [kt-NMVOC] |
| $AD$ | : Amount of domestic crude oil [1000 kL] |
| $EF$ | : Emission factor per crude oil production [kt-NMVOC/1000 kL] |

- ***Emission factors***

For the emission factor, the sum of NMVOC default emission factors for flaring and venting in well drilling and well testing (well drilling: $8.7\times10^{-7}$, well testing: $1.2\times10^{-5}$ kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for this category are the production amount of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

### A3.1.2 Industrial Processes and Product Use (IPPU)

#### A3.1.2.1. Mineral Industry, Chemical Industry, Metal Production, and Other Production (2.A., 2.B., 2.C., 2.D.,: $NO_X$, $SO_X$)

***a) Category Description***

This section provides the estimation methods for emissions of precursors and other substances ($NO_X$, and $SO_X$) from the process of producing mineral products, chemical products, metal production and other production.

***b) Methodological Issues***

- ***Estimation Method***

$NO_X$ and $SO_X$ emissions from the specified sources, not included in the following facilities or industry sectors, were estimated by isolating the emissions of the IPPU sector from the data in the *General Survey of the Emissions of Air Pollutants* (MOE).

Facility: [0101– 0103: Boilers]; [0601– 0618: Metal rolling furnaces, metal furnaces, and metal forge furnaces]; [1101–1106: Drying ovens]; [1301–1304: Waste incinerators]; [2901–3202: Gas turbines, diesel engines, gas engines, and gasoline engines]

Industry sector: [A–D: Accommodation/eating establishments, health care/educational and academic institutions, public bathhouses, laundry services]; [F–L: Agriculture/fisheries, mining, construction, electricity, gas, heat distribution, building heating/other operations]

➢ ***$NO_X$***

For raw material falling under either [44: Metallurgical coal] or [45: Metallurgical coke], the following equation is used:

$$E=\Sigma\{EF_{NO_X} \times A \times (1\text{-}R)\}$$

$E$ : $NO_X$ emissions from metallurgical coal or metallurgical coke [t-$NO_X$]
$EF_{NO_X}$ : $NO_X$ emission factor by material [t- $NO_X$ /kcal]
$A$ : Energy consumed by material [kcal]

$R$ : Nitrogen removal rate [%]

For raw material falling under either [41: Iron/ironstone] or [46: Other], the following equation is used:

$$E = \Sigma \{N \times (1-R)\}$$

$E$ : $NO_X$ emissions from iron/iron ore or other material [t-$NO_X$]
$N$ : Nitrogen content in each material [t-$NO_X$]
$R$ : Nitrogen removal rate [%]

However, when the emissions from the IPPU sector calculated by the above equations exceed the emission amount listed in the *General Survey of the Emissions of Air Pollutants*, the total emissions listed in the Survey are considered to be the emissions from the IPPU sector. Materials listed in the categories [42: Sulfide minerals] and [43: Non-ferrous metal ores] are excluded from the calculation due to the lack of data.

➢ ***$SO_X$***

Emissions from the IPPU sector is calculated from the consumption and sulfur content of the materials in categories [41: Iron/ironstone] to [46: Other materials]. Energy sector emissions are estimated by subtracting IPPU sector emissions from the emissions listed in the *General Survey of the Emissions of Air Pollutants* to determine $SO_X$ emissions.

$$E = \Sigma \{S \times (1-R)\}$$

$E$ : $SO_X$ emissions [t-$SO_X$]
$S$ : Sulfur content in each material [t-$SO_X$]
$R$ : Desulfurization rate [%]

● ***Emission factors***

➢ ***$NO_X$ emission factors for metallurgical coal and coke***

$NO_X$ emission factors for the materials used in calculation of $NO_X$ emissions from metallurgical coal and coke (in the IPPU sector) were established for each facility and material type based on the *General Survey of the Emissions of Air Pollutants*.

➢ ***Nitrogen removal rate***

The nitrogen removal rate was calculated by the following equation:

$$R = RE \times (O_{removal} / O_{furnace}) \times (P / E)$$

$R$ : Nitrogen removal rate [%]
$RE$ : Nitrogen removal efficiency

$O_{removal}$ : Hours of operation of nitrogen removal unit [h/yr]
$O_{furnace}$ : Hours of operation of furnace [h/yr]
$P$ : Processing capacity of nitrogen removal unit [$m^3$/yr]
$E$ : Maximum exhaust gas emissions [$m^3$/yr]

$$RE = (V_{before} - V_{after}) / V_{SS}$$

$RE$ : Nitrogen removal efficiency
$V_{before}$ : $NO_X$ volume before treatment
$V_{after}$ : $NO_X$ volume after treatment
$V_{SS}$ : Volume of smoke and soot

The *General Survey of the Emissions of Air Pollutants* data was used for all items.

➢ ***Desulfurization rate***

The desulfurization rate was calculated by the following equation:

$$R = DE \times (O_{removal} / O_{furnace}) \times (P/E)$$

$R$ : Desulfurization rate [%]
$DE$ : Desulfurization efficiency
$O_{removal}$ : Hours of operation of desulfurization unit [h/yr]
$O_{furnace}$ : Hours of operation of furnace [h/yr]
$P$ : Processing capacity of desulfurization unit [$m^3$/yr]
$E$ : Maximum exhaust gas emissions [$m^3$/yr]

$$DE = (V_{before} - V_{after}) / V_{SS}$$

$DE$ : Desulfurization efficiency
$V_{before}$ : $SO_X$ volume before treatment
$V_{after}$ : $SO_X$ volume after treatment
$V_{SS}$ : Volume of smoke and soot

The *General Survey of the Emissions of Air Pollutants* data were used for all items.

● ***Activity data***

➢ ***Energy consumption of metallurgical coal or coke***

The activity data was calculated by multiplying the consumption of materials (under [44: Metallurgical coal] and [45: Metallurgical coke]) provided in the *General Survey of the Emissions of Air Pollutants* by the gross calorific value.

➢ ***Nitrogen content of iron/ironstone and other materials***

The activity data was calculated by multiplying the weighted average of nitrogen content, calculated from the nitrogen content and consumption of the materials (under [41: Iron/ironstone] and [46: Other raw materials]) provided in the *General Survey of the Emissions of Air Pollutants*, by the consumption amount of the materials.

➢ ***Sulfur content of various materials***

The activity data was calculated by multiplying the weighted average of sulfur content, calculated on the basis of sulfur content and consumption of the materials (under [41: Iron/ironstone] through [46: Other materials]) provided in the *General Survey of the Emissions of Air Pollutants*, by the consumption amount of the materials.

## A3.1.2.2. Non-energy products from fuels and solvent use (2.D.3.) (NMVOCs)

### A3.1.2.2.a. Use of paint

#### *a) Category Description*

NMVOCs are emitted from paint containing solvent and diluent, in the process of using paint including painting industrial products or buildings[5].

#### *b) Methodological Issues*

● ***Estimation Method***

NMVOC emissions from use of paint were estimated by multiplying the sales amount of paint

[5] The emissions in the process of manufacturing were estimated in "A3.1.2.2.n Chemicals Manufacture"

by the NMVOC emission factors per sales amount of paint.

$$E = AD \times EF$$

*E* : NMVOC emissions from use of paint [1000t -NMVOC]
*AD* : Sales amount of paint [1000t]
*EF* : Emission factors per sales amount of paint [t-NMVOC/t]

- ***Emission factors***

The annual survey on VOC emissions from use of paint by Japan Paint Manufacturers Association has been conducted since FY2000 (excluding FY2002). The NMVOC emissions per sales amount of paint which was calculated by dividing the emissions provided in the survey by the sales amount of paints are used for emission factor for use of paint.

Due to the lack of quantified data for establishing emission factors for FY1999 and before, emission factors for these periods were established by extrapolation based on the trend during FY2000-FY2010. A decreasing trend was obvious during FY2000-FY2010, and FY2010 was the target year of voluntary action plan based on the Air Pollution Control Act; it was assumed, similarly, that during FY1990-1999 emissions might have decreased because of a possible shift to aqueous paint and installation of VOC processing instruments. (Please refer to Table A 3-21)

Table A 3-21 Method of establishing NMVOC emission factors for use of paint

| Fiscal Year (FY) | Method of establishing emission factors |
|---|---|
| 1990-1999 | Established by extrapolation based on the trend in FY2000-2010 |
| 2000-2001 | Established by dividing VOC emissions from the use of paints (by Japan Paint Manufacturers Association) for FY2000 and FY2001 by the sales amount of paint in each fiscal year. |
| 2002 | Established by interpolation based on the emission factor which was calculated by dividing the emissions in FY2001 and FY2003 by the activity data in FY2001 and FY2003. |
| 2003- | Established by dividing VOC emissions from paint in FY2003 and thereafter (Japan Paint Manufacturers Association) by the sales amount of paint in each fiscal year. |

- ***Activity Data***

The sales amount of paint provided in the *Yearbook of Current Production Statistics - chemical industry* (METI) (hereafter, *Yearbook of chemical industry*) was used for activity data.

### A3.1.2.2.b. Dry-cleaning

#### *a) Category Description*

NMVOCs are emitted from dry-cleaning laundry equipment by using solvent for dry cleaning of clothes.

#### *b) Methodological Issues*

NMVOC emissions from dry-cleaning were estimated by deducting “weight as waste” (including residual weights in cartridge and distilling sludge) from “used weight of dry cleaning solvent”

$$E = AD - A - B$$

*E* : NMVOC emissions from use of dry-cleaning solvent [t -NMVOC]

*AD* : Used weight of dry-cleaning solvent (Tetrachloroethylene, Industrial gasoline No.5) [t]
*A* : Absorbed residual solvent in cartridge filter to be disposed as waste (Transferred weight of absorption solution during the changing of cartridge filters) [t]
B : Residual solvent containing distilling sludge to be disposed as waste (Transferred weight of residual solvents during the distilling of sludge) [t]

- ***Emission factors***

No emission factor was established, as all the solvents used in dry cleaning were assumed to be discharged into the atmosphere.

- ***Activity data***

***1) Used weight of dry-cleaning solvent***

Used weight of dry-cleaning solvent (tetrachloroethylene, Industrial gasoline No.5) was estimated according to Table A 3-22 and Table A 3-23, based on data in the *Study on the VOC Emission Inventory*.

Table A 3-22 Method of estimating activity data for dry-cleaning solvent (Tetrachloroethylene)

| Fiscal year (FY) | Method of estimating activity data |
|---|---|
| 1990, 1991 | Estimated by multiplying the total consumption weight of the solvent in FY1990 and FY1991 by the percentage for dry-cleaning in FY1992 which was calculated based on *Demand by end-use* by Japan Association for Hygiene of Chlorinated Solvents (hereafter, JAHCS), since the data for FY1990 and 1991 was not available. |
| 1992 | Used weight of tetrachloroethylene provided in *Demand by end-use* by JAHCS was used for activity data. |
| 1993, 1994 | Estimated by interpolating the value provided in *Demand by end-use* by JAHCS for FY1992 and FY1995. |
| 1995- | Used weight of tetrachloroethylene provided in *Demand by end-use* by JAHCS was used for activity data. |

Table A 3-23 Method of estimating activity data for dry-cleaning solvent (Industrial gasoline No.5)

| Fiscal year (FY) | Method of estimating activity data |
|---|---|
| 1990, 1991 | Estimated by multiplying the used weight of industrial gasoline No.5 in FY1992 by the installation ratio of laundry machines which use petroleum dissolution in FY1992, provided in *The survey on usage of dry-cleaning solvent* (Ministry of Health, Labour and Welfare (hereafter, MHLW) ) |
| 1992-1999 | Estimated by multiplying the shipping weight of petroleum dry-cleaning solvent in FY2000, provided in *Shipping weight of solvents* by Japan Cleaning Chemicals Association, by the used weight of industrial gasoline no.5 in FY2000 |
| 2000 | Used the result of the survey on the shipping weight of dry-cleaning solvent by petroleum solvent manufacturer, indicated in the *Study on the VOC Emission Inventory*. |
| 2001-2004 | Estimated by interpolating the values in FY2000 and FY2005. |
| 2005- | Used the result of the survey on the shipping weight of dry-cleaning solvent by petroleum solvent manufacturer, indicated in the *Study on the VOC Emission inventory*. |

***2) Weight transferred as waste***

The weight of waste transfer (including residual weights in cartridge and distilling sludge) was estimated using the equations in Table A 3-24, in accordance with the method of the *Study on the VOC Emission Inventory*; the weight was deducted from the used weight of dry-cleaning solvent. Values used for the *Study on the VOC Emission Inventory* based on hearings and other surveys

were used as parameters for estimation.

As for installed units of dry-cleaning laundry, values provided in the *Survey on usage and management of solvent for dry-cleaning* (MHLW) were used. However, the survey has been conducted biennially after FY2001; therefore, the same values as those in the previous fiscal year were used for years in which the survey was not conducted.

Table A 3-24 Method of estimation for weight of waste transfer in dry-cleaning solvent

| Type of waste | Method of estimation for weight of waste transfer in dry-cleaning solvent |
|---|---|
| Transfer weight of absorbed solvent in changing cartridge filter | Since 2L solvent per 1kg of laundry is absorbed in changing cartridge on average, the estimated annual weight is calculated according to the following formula.<br>$A = A_{unit} \times L \times D \times W_{ave.} / T \times N$<br>$A$ : Absorbed weight in cartridge [kg/year]<br>$A_{unit}$ : Absorbed VOC weight [L/time/kg] in each changing of cartridge per 1kg of loading weight by washer<br>$L$ : Standard load of washer per washing [kg]<br>$D$ : Density [kg/L]<br>$W_{ave.}$ : Annual average of operating washer [time/year]<br>$T$ : Average washer times per changing cartridge filter [time/time]<br>$N$ : Number of laundry units installed [unit] |
| Transfer weight of residual solvent in distilling sludge | Transferred weight of solvent in distilling was estimated according to the following formula.<br>$R = L \times T \times F \times N \times I$<br>$R$ : Contained residual solvent in distilling sludge [kg/year]<br>$L$ : Standard load of washer [kg/unit]<br>$T$ : Annual average of operating times of washer [time/year]<br>$F$ : Factors by type of filter [kg/kg]<br>$N$ : Unit of installation of laundry [unit]<br>$I$ : Installation rate of distilling [%] |

Reference: *Study on the VOC Emission Inventory*

### A3.1.2.2.c. Metallic cleaning

#### *a) Category Description*

NMVOCs are emitted from cleaning of metallic components by industrial cleaners in the process of manufacturing electrical/electronic products or metallic components.

#### *b) Methodological Issues*

- ***Estimation Method***

#### *1) Chlorine Cleaners*

NMVOC emissions from the use of chlorine cleaners were estimated by multiplying the used amount of chlorine cleaners by the emission rate. Since some chlorine cleaners are recycled, the emissions were adjusted for the recycling.

$$E = AD \times R \times EF$$

$E$ : NMVOC emissions from the use of chlorine cleaners [1000t -NMVOC]
$AD$ : Sales amount of chlorine cleaners [1000t]
$R$ : Adjustment rate for recycling (x 1.1)[6]

[6] JICC research at Japan Solvent Recycling Industry Association found that approximately 10 % of the sales amount of chlorine cleaners were recycled and resupplied by recycling companies. (*Studies to develop the national*

*EF* : Atmospheric emission rate by use of chlorine cleaners [%]

### *2) Non-chlorine cleaners*

NMVOC emissions from the use of non-chlorine cleaners (semi-aquatic, hydrocarbon system, alcohol system, fluorinated, and other types of cleaners) were estimated by multiplying the used weight of cleaners by the atmospheric emission rate.

$$E = AD \times EF$$

*E* : NMVOC emissions from the use of each non-chlorine cleaner [1000t -NMVOC]
*AD* : Used weight of each non-chlorine cleaner [1000t]
*EF* : Atmospheric emission rate from the use of each non-chlorine cleaner [%]

- ***Emission factors***

Emission factors provided in the *Study on the VOC Emission Inventory*, as shown in Table A 3-25, were used for chlorine cleaners and non-chlorine cleaners.

Table A 3-25 NMVOC emission factors for use of each type of cleaner

| Type of cleaner | Atmospheric emission rate | Reference |
|---|---|---|
| Chlorine cleaner | 75% | *Commission report on manual for promoting voluntary approach for emission control of VOCs in FY2005* (Japan Industrial Conference on Cleaning (hereafter, JICC)) |
| Semi-aquatic cleaner | 0.4% | The result of the survey by JICC |
| Hydrocarbon system cleaner | 31.3% | |
| Alcohol system cleaner | 60% (45% for FY2010 and thereafter) | |
| Fluorinated cleaner | 84% | |
| Other types of cleaners | 75% | |

- ***Activity Data***

### *1) Chlorine cleaners*

Activity data for chlorine cleaner was established as shown in the following

Table A 3-26 and Table A 3-27, based on the *Study on the VOC Emission Inventory* by the Ministry of the Environment and data provided by JAHCS. According to the *Study on the VOC Emission Inventory*, about 10% of the sales amount of chlorine cleaners are recycled and resupplied; therefore, this was taking into consideration, by multiplying the estimates of the amount of cleaners used by 110%, to adjust for recycling and to use as activity data.

Table A 3-26 Activity data for the use of chlorine cleaners (dichloromethane, trichloroethylene, tetrachloroethylene)

| Fiscal Year (FY) | Activity data |
|---|---|
| 1990-1994 | Estimated by multiplying the total consumption amount in each fiscal year by the proportion of metallic cleaners in FY1995 (calculated based on the *Demand by use* (JAHCS), (hereafter *Demand by use*)) since data was not available for FY1990-1994. |
| 1995- | The sales amount of dichloromethane, trichloroethylene, and tetrachloroethylene for metallic cleaning provided in the *Demand by use* was adopted for activity data. |

*emissions inventory for volatile organic compounds (VOC), FY 2011*, Ministry of the Environment)

Table A 3-27 Activity data for the use of chlorine cleaners (other types of chlorine cleaner)

| Fiscal Year (FY) | Activity data |
|---|---|
| 1990-1999 | Estimated by multiplying the total consumption amount for three major chlorine cleaners (*Demand by use*) for 2000 by the ratio in FY1990-1999 to the activity data in FY2000. |
| 2000 | The sales amount provided in the *Study on the VOC Emission Inventory* was used for activity data. (the results of research by JICC). |
| 2001-2004 | Estimated by interpolating the activity data for FY2000 and FY2005 |
| 2005- | The sales amount provided in the *Study on the VOC Emission Inventory* was used for activity data. (the results of research by JICC). |

### *2) Non-chlorine cleaner*

Activity data for non-chlorine cleaners was established as shown in Table A 3-28 based on the information provided in the *Study on the VOC Emission Inventory*.

Table A 3-28 Activity data for non-chlorine cleaner

| Fiscal year (FY) | Activity data |
|---|---|
| FY1990-1999 | Total amount of raw materials by type of cleaner was estimated by multiplying the proportion for each type of manufacturer provided in the *Study on the VOC Emission Inventory* (Table A 3-29) by the corresponding used weight of raw material; then, the activity data (the used weight) for each year was estimated by multiplying the estimated total weight by the ratio from FY2000. |
| FY2000 | Used weight of each type of cleaner in the *Study on the VOC Emission Inventory* was adopted for activity data. |
| FY2001-2004 | Estimated by interpolating the activity data for FY2000 and FY2005. |
| FY2005- | Used weight of each type of cleaner in the *Study on the VOC Emission Inventory* was adopted for activity data. As for values in the *Study on the VOC Emission Inventory*, the results of a sampling survey were used after an adjustment. The survey has not been conducting every year. Therefore, for years when the survey was not conducted, data has been supplemented by using the interpolation method. |

Table A 3-29 Proportion by type of manufacturer in VOC emissions from non-chlorine cleaner

| | Manufacture | n-Methyl-pyrrolidone admixture | Glycol ether admixture | n-Paraffin cleaner | Isoparaffin cleaner | Naphthene cleaner | Other carbon hydride cleaner | Isopropyl alcohol cleaner | Other alcohol cleaner | HFC cleaner | Other fluorine cleaner | Bromine cleaner | Other cleaner |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | Plastic Products | | | 3% | 6% | 4% | | | 12% | | | | |
| 23 | Iron and Steel | | | 3% | 0.1% | 5% | | | | 1% | 2% | | |
| 24 | Non-Ferrous Metals and Products | | | 16% | 0.05% | 7% | | | | 1% | 2% | | |
| 25 | Fabricated Metal Products | | 2% | 17% | 30% | 26% | 8% | | | | | 4% | |
| 26 | Machinery | | | 11% | 8% | 15% | 11% | | | 1% | 2% | | |
| 28 | Communications | | 19% | | | | | 1% | | | | | |
| 29 | Electric device | 70% | 49% | 17% | 15% | 7% | 13% | 25% | 28% | 28% | 38% | 30% | 100% |
| 30 | Transport | | 2% | 16% | 26% | 36% | 10% | | 12% | 7% | 19% | 18% | |
| 31 | Precision apparatus | 30% | 18% | 17% | 15% | | 18% | 74% | 46% | 61% | 37% | 48% | |
| 32 | Other | | 10% | 0.1% | | 1% | 41% | | 3% | | | | |
| | Total | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

Reference: The *Study on the VOC Emission Inventory*

### A3.1.2.2.d. Use of thinner for cleaning manufacturing equipment

#### *a) Category Description*

NMVOCs are emitted from the use of thinner for cleaning manufacturing equipment.

#### *b) Methodological Issues*

- ***Estimation Method***

NMVOC emissions from the use of thinner for cleaning manufacturing equipment were estimated by multiplying the sales volume of thinner excluding that for painting by the emission factor for NMVOC per sales volume.

$$E = AD \times EF$$

*E* : NMVOC emissions from the use of cleaning thinner [t-NMVOC]
*AD* : The sales volume of thinner excluding that for painting [kl]
*EF* : Emission factor per sales volume of cleaning thinner [t-NMVOC/ kl]

- ***Emission factors***

Emission factor was established by using the emissions from "thinner for cleaning manufacturing equipment" provided in the *Study on the VOC Emission Inventory* and later-described activity data.

Although the emission factor has a slightly decreasing trend after FY2000, the emission factor for FY2000 is applied for fiscal years FY1990 to FY1999, since there are no quantitative data for estimating emission factors in the related organization and that difficulties have been faced for implementation of technical measures for reduction of emissions from thinner cleaning ( Table A 3-30).

Table A 3-30 The Method of establishing emission factors of cleaning thinner for manufacturing equipment

| Fiscal Year (FY) | Method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was applied for all fiscal years |
| 2000 | Estimated by dividing the emissions in FY2000 provided in the *Study on the VOC Emission Inventory* by the activity data. |
| 2001-2004 | Estimated by interpolating the activity data for FY2000 and FY2005 |
| 2005- | Estimated by dividing the emissions in FY2005 and thereafter provided in the *Study on the VOC Emission Inventory* by the activity data. |

- ***Activity data***

The sales volume of thinner in FY1990 and thereafter was estimated by deducting the consumption amount of diluent thinner provided in *Summary of estimation for the current status of VOC emissions from painting* (Japan Paint Manufacturers Association) from the sales volume of thinner provided in the *Yearbook of chemical industry*.

Since data on the consumption amount of diluent thinner in and before FY2004 was unidentified, it was estimated (Table A3-31).

Table A 3-31 Method of estimating activity data for the use of cleaning thinner for manufacturing equipment

| Fiscal Year (FY) | Activity data |
|---|---|
| 1990-2004 | The consumption amount of diluent thinner in and before FY2004, which was estimated by multiplying the proportion of the amount of diluent thinner to the sales volume of thinner in FY2005 by the sales volume of thinner in and before FY2004, and, deducting the amount from the total sales volume of thinner, was adopted for activity data. |
| 2005- | Estimated by deducting the consumption amount of diluent thinner for painting provided in *Summary of estimation for the current status of VOC emissions from painting* (Japan Paint Manufacturers Association) from the sales amount of thinner provided in the *Yearbook of chemical industry* |

### A3.1.2.2.e. Use of printing ink solvents

#### *a) Category Description*

VOCs are emitted from printing ink solvent or other types of diluent in the process of printing. Ink included in stationaries, solvent for cleaning of printing machine (estimated as "A3.1.2.2.d thinner for cleaning manufacturing equipment"), and emissions at the stage of production of printing ink (estimated as "A3.1.2.2.n Chemicals Manufacture") were excluded from emissions in this category.

#### *b) Methodological Issues*

- ***Estimation Method***

VOC emissions were estimated by multiplying the used weight of VOCs in the process of printing, which was provided in the *Study on the VOC Emission Inventory*, by the atmospheric emission rate.

$$E = AD \times EF$$

*E* : NMVOC emissions from the use of printing ink solvents [t-NMVOC]
*AD* : Used weight of VOCs in the process of printing [t]
*EF* : Atmospheric emission rate per used weight of VOCs [%]

- ***Emission factors***

Atmospheric emission rate by type of ink, provided in the *Study on the VOC Emission Inventory* was adopted for emission factor. As for printing ink other than planographic and photogravure ink, the same atmospheric emission rate was adopted for the emission factor for FY2000 and thereafter; in a similar way, the atmospheric emission rate in FY2000 was adopted for and before FY1999.

As for emissions from planographic ink and photogravure ink, the atmospheric emission rate for FY1990-1999 was estimated by extrapolation, using the trend in FY2000-2010: the decreasing trend after FY2000 suggested that some measures aimed at reducing emissions might have been implemented during this period. (Table A 3-32) However, as for photogravure ink, the emission factor was established by interpolating between of the FY1983 value from the *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (Institute of Behavioral Science, 1984) and the FY2000 value, since the atmospheric emission rate in FY1990 would surpass 100% by a simple extrapolating calculation.

Table A 3-32 The method of establishing emission factor for the use of printing ink solvent (Planographic ink, photogravure ink)

| Fiscal Year (FY) | The method of establishing of emission factor | |
|---|---|---|
| | Planographic ink | Photogravure ink |
| 1990-1999 | Estimated by extrapolation, using the trend in FY2000-2010 | Interpolated between the 1983 value from the *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (Institute of Behavioral Science, 1984) and the 2000 value. |
| 2000 | Established based on the *Study on the VOC Emission Inventory* in FY2000 | |
| 2001-2004 | Established by interpolating the figures in FY2000 and FY2005 | |
| 2005- | Emission factors in each fiscal year provided in the *Study on the VOC Emission Inventory*. | |

Note: The same emission factor was applied for resin anastatic ink, metallic printing ink, news ink, and other inks for all time-series.

- ***Activity data***

The used amount of VOCs, provided in the *Study on the VOC Emission Inventory* (estimated based on the results of the survey by Japan Printing Ink Makers Association and voluntary action plan of Japan Federation of Printing Industries) was used for activity data and was estimated as shown in Table A 3-33.

Table A 3-33 Method of estimating activity data

| Fiscal Year (FY) | Activity data |
|---|---|
| 1990-1999 | Estimated by multiplying the ratio of sales amount of print ink for each product type in each year to that in FY2000, provided in the *Yearbook of Chemical Industry*, by the activity data of FY2000. |
| 2000 | Used amount of VOCs in the process of printing, provided in the *Study on the VOC Emission Inventory*, was used. |
| 2001-2004 | Estimated by interpolating the activity data of FY2000 and 2005. |
| 2005- | Used amount of VOCs in the process of printing, provided in the *Study on the VOC Emission Inventory*, was used. |

### A3.1.2.2.f. Use of adhesive agent for laminate

#### *a) Category Description*

VOC are emitted from lamination, caused by solvent contained in adhesive agents for bonding base material and laminate. VOC emissions from producing adhesive agents for laminate are estimated in “A3.1.2.2.n Chemicals Manufacture”.

#### *b) Methodological Issues*

- ***Estimation Method***

NMVOC emissions from polyethylene laminate were estimated by multiplying the sales amount of film for laminate, which was adopted for activity data, by the NMVOC emission factor per sales amount of film for laminate.

$$E = AD \times EF$$

*E* : NMVOC emissions from lamination [t-NMVOC]
*AD* : Sales amount of film for laminate [t]
*EF* : Emission factor per sales amount of film for laminate [t-NMVOC/ t]

- ***Emission factors***

Emission factor was established by dividing VOC emissions, which was estimated based on

reported values in voluntary action plan in the *Study on the VOC emission inventory*, by the sales amount of film for laminating. For fiscal years which were not subject to voluntary action plan, emission factor was established as shown in the following Table A 3-34 .

Table A 3-34 Method of establishing emission factor for lamination

| Fiscal Year | Method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor in FY2000 was adopted for each fiscal year. |
| 2000 | Established by dividing VOC emissions from the use of adhesive agent for laminate (estimated by voluntary action plan) by the sales amount of film for laminating by the Japan Polyethylene Products Industrial Federation). |
| 2001-2004 | Established by interpolating the emission factors for FY2000 and FY2005. |
| 2005- | Established by dividing VOC emissions from the use of adhesive agent for laminate (estimated figures by the Japan Polyethylene Products Industrial Federation) by the sales amount of film for laminate. |

- ***Activity data***

The sales amount of film for laminate provided in the *Yearbook of Current Production Statistics - paper, printing, plastics products and rubber products* (METI), (hereafter, *Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics*) was used for activity data.

### A3.1.2.2.g. Use of solvent-type adhesives

#### *a) Category Description*

VOCs are emitted from the use of solvent-type adhesive.

#### *b) Methodological issues*

- ***Estimation Method***

As for VOC emissions from the use of solvent-type adhesive, the atmospheric emission rate was regarded as 100%; the total amount was used for estimating emissions.

$$E = AD$$

*E* : NMVOC emissions from the use of adhesive [t-NMVOC]
*AD* : The used amount of VOCs from the use of adhesive [t]

- ***Emission factors***

No emission factors were established since it was assumed that the total amount of the solvent used for adhesive were emitted into the air.

- ***Activity Data***

Activity data for FY2001-2004 was estimated by interpolating the *Study on the VOC Emission Inventory*. Activity data for and before FY2000 was estimated by multiplying the used amount of VOCs in FY2000 by the ratio of the shipping weight of each type of adhesive in the *Current Survey Report on Adhesives* (Japan Adhesive Industry Association) to the 2000 level (Table A 3-35).

Table A 3-35 Method of establishing activity data for the use of adhesive

| Fiscal year | Activity data |
|---|---|
| 1990-1999 | Estimated by multiplying the used amount of VOCs in FY2000 by the ratio of the total of shipping weight of each type of adhesive in each year to the 2000 level. |
| 2000 | Used amount of VOC emissions provided in the *Study on the VOC Emission Inventory* (estimated by the Committee for the VOC Emission Inventory) |
| 2001-2004 | Estimated by interpolation, using activity data for FY2000 and FY2005 |
| 2005- | Used amount of VOCs provided in the VOC Emission Inventory (estimated by the Committee for the VOC Emission Inventory) |

### A3.1.2.2.h. Use of gum solvents

#### *a) Category Description*

VOCs are emitted from gum solvent in the manufacturing of gum products.

#### *b) Methodological Issues*

- ***Estimation Method***

NMVOC emissions from gum solvents for gum production were estimated by multiplying the consumption of volatile oil for solvent use for gum production by the NMVOC emission factor per consumption of volatile oil for solvent use, which was estimated based on the *Study on the VOC Emission Inventory*.

$$E = AD \times EF$$

*E* : NMVOC emissions from gum production [t-NMVOC]
*AD* : Consumption of volatile oil for solvent use for gum production [t]
*EF* : Emission factor per consumption of volatile oil for solvent use [t-NMVOC/ t]

- ***Emission Factors***

VOC emissions per consumption of volatile oil for solvent use, which was calculated by dividing emissions based on reported values in the voluntary action plan by the Japan Rubber Manufacturers Association in the *Study on the VOC Emission inventory*, by the consumption of volatile oil for solvent use, were adopted as emission factors for gum production.

Table A 3-36 Method of establishing NMVOC emission factor for gum production

| Fiscal Year | Method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was applied. |
| 2000 | Established by dividing VOC emissions from volatile oil for solvent use (estimated values based on the report in the voluntary action plan by the Japan Rubber Manufacturers Association) by the consumption of volatile oil for solvent use. |
| 2001-2004 | Median value of FY2000 and FY2005 was used. |
| 2005- | Established by dividing VOC emissions from volatile oil for solvent use (estimated values based on the report in the voluntary action plan by the Japan Rubber Manufacturers Association) by the consumption of volatile oil for solvent use. |

- ***Activity data***

Consumption of volatile oil for solvent use, which was obtained from the *Yearbook of Rubber Products Statistics* by the Ministry of Economy, Trade and Industry and the survey results by the Japan Rubber Manufacturers Association, was applied for activity data. The consumption was converted from volume to mass using the solvent density. As for FY2006-2010, the activity data

was adjusted using interpolation since the business entities surveyed for this period was possibly different from before/after this period.

### A3.1.2.2.i. Use of adhesive solvents and detachment solvents

#### *a) Category Description*

NMVOCs are emitted from the use of adhesive solvent and detachment solvent in manufacturing adhesive tape or adhesive label. This source category does not deal with the NMVOC emissions in manufacturing adhesive solvent and detachment solvent since the emissions are included in "A3.1.2.2.n Chemicals Manufacture".

#### *b) Methodological Issues*

- ***Estimation Method***

The shipping amount of adhesive tape was used for activity data. NMVOC emissions from the use of adhesive solvent and detachment solvent were estimated by multiplying the activity data by the emission factor per shipping amount.

$$E = AD \times EF$$

*E* : NMVOC emissions from the use of adhesive and detachment solvent [t-NMVOC]
*AD* : Shipping amount of adhesive tape [Million $m^2$]
*EF* : Emission factor per shipping amount of adhesive tape [t-NMVOC/million $m^2$]

- ***Emission factors***

Emission factors per adhesive for use of solvent and detachment solvent were established by dividing emissions, which were based on the reported values in voluntary action plan by four business associations including Japan Paper Association, by the shipping amount of adhesive tape.

Table A 3-37 NMVOC emission factors for the use of adhesive and detachment solvent

| Fiscal year | Method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was applied. |
| 2000 | Established by dividing VOC emissions (estimated based on the reported figure by four business associations including Japan Paper Association) by the shipping amount of adhesive tape. |
| 2001-2004 | Established by interpolating between the FY2000 and FY2005 EFs |
| 2005- | Established by dividing VOC emissions (estimated based on the reported figure by four business association including Japan Paper Association) by the shipping amount of adhesive tape |

- ***Activity data***

The shipping amount provided by Japan Adhesive Tape Manufacturers Association was adopted for activity data.

### A3.1.2.2.j. Use of repellents and air fresheners

#### *a) Category Description*

NMVOCs are emitted from the sublimation of chemical agents during the use of repellents or air fresheners such as at home. The major substance in the emissions is p-dichlorobenzene.

#### *b) Methodological Issues*

- ***Estimation Method***

Repellents and air fresheners are mainly used in general households; it is considered that the total amount of them are released into the atmosphere. Therefore, the atmospheric emission rate was regarded as 100% and the amount of p-dichlorobenzene contained in repellents or air fresheners was applied for VOC emissions.

- ***Emission factors***

It was assumed that the total amount of p-dichlorobenzene contained in repellent and air fresheners was released into the atmosphere. Therefore, no emission factor has been established.

- ***Activity data***

Total amount of p-dichlorobenzene shipped as repellent and air fresheners, which was provided by Japan Moth Repellent Association and indicated in *Estimation Methods for Releases from Sources not Required to Report under PRTR* (METI and MOE) was applied for activity data.

The shipping amount provided by Japan Moth Repellent Association was not available for and before FY2000; therefore, for this period, the shipping amount was estimated by multiplying the amount in FY 2001 by the growth rate of market size from FY2001. For FY1990 and 1991, it was estimated by extrapolation.

Table A 3-38 Method of estimating activity data for repellents and air fresheners

| Fiscal year | Activity data |
|---|---|
| 1990-1991 | Estimated by extrapolation from the shipping volume in FY1992-2010 |
| 1992-2000 | Estimated by multiplying the shipping volume in FY2001 by the growth rate of market size of p-dichlorobenzene from FY2001. |
| 2001- | The total amount of p-dichlorobenzene shipped as repellent and air freshener, which was provided by Japan Moth Repellent Association and indicated in *Estimation Methods for Releases from Sources not Required to Report under PRTR* (METI and MOE) was applied for activity data. |

### A3.1.2.2.k. Use of aerosols inhalers

#### *a) Category Description*

NMVOCs are emitted from inhalers by the use of aerosols products including pesticide, lacquer, and hair spray. NMVOC emissions from content fluid including paint solvent are estimated in other categories such as the use of paint or cosmetic products. Therefore, to avoid double counting, only NMVOC emissions from liquefied gas in inhalers are included in this category. As for inhalers for aerosols products, propane (LPG) and dimethyl ether (DME) are mainly used.

### *b) Methodological Issues*

- ***Estimation Method***

The emissions were estimated based on the estimation method provided in the *Research Report on VOC emissions from private sector* by the Institute of Behavioral Science (hereafter, Survey by Tokyo Metropolitan Government*)*, in March in 2010. The emissions were estimated as shown in the following equation, by multiplying the production amount for each type of product, by the emission factors for LPG and DME.

$$E = \sum (AD_i \times EF_{LPG,DME})$$

| | |
|---|---|
| $E$ | : NMVOC emissions from the use of aerosols products [g] |
| $AD_i$ | : Production capacity of aerosols product *i* [cc] |
| $EF_{LPG,\ DME}$ | : LPG and DME emission factor [g/cc] |

- ***Emission factors***

Based on each parameter which was used by the Survey by Tokyo Metropolitan Government, the LPG and DME emission amount per aerosols production capacity was applied using the following equation.

$$EF_{LPG,DME} = R_{LPG,DME} \times R_P \times C_{LPG,DME} \times d_{LPG,DME}$$

| | |
|---|---|
| $EF_{LPG,\ DME}$ | : LPG and DME emission factor per aerosols production capacity [g/cc] |
| $R_{LPG,\ DME}$ | : Percentage of LPG and DME aerosols products [%] |
| $R_P$ | : Percentage of aerosols propellant in can [%] |
| $C_{LPG}$, $C_{DME}$ | : Percentage of LPG and DME in propellant [%] |
| $d_{LPG}$, $d_{DME}$ | : Specific gravity of LPG and DME [g/cc] |

Emission factors for LPG and DME by aerosols products were shown in Table A 3-39.

Table A 3-39 Emission factors for aerosols products (g/cc)

| Type of products | | LPG | DME |
|---|---|---|---|
| Pesticide | For fly and mosquito | 0.223 | 0.0296 |
| | Other pesticides | 0.223 | 0.0296 |
| Paint | Paint | 0.227 | 0.0151 |
| Household product | Room air freshener | 0.236 | - |
| | Cleaner | 0.236 | - |
| | Wax and polish | 0.236 | - |
| | Laundry articles | 0.236 | - |
| | Other household products | 0.236 | - |
| Body care products | Hair spray | 0.202 | 0.0269 |
| | Other hair care products | - | 0.269 |
| | Shaving cream | 0.202 | 0.0269 |
| | Perfume and cologne | 0.112 | 0.134 |
| | Pharmaceutical products | 0.176 | 0.0905 |
| | Deodorizing and antiperspirant agents | 0.225 | - |
| | Other body care products | 0.112 | 0.134 |
| Car-related items | Anti-fog | 0.213 | - |
| | Other car-related products | 0.213 | - |
| Others | Handy extinguisher | - | - |
| | Others | 0.221 | - |

Reference: *Survey by Tokyo Metropolitan Government*

### *1) Percentage of aerosol products which used LPG and DME as propellent*

As for the percentage of aerosols products which used LPG and DME as propellant, it was calculated by deducting the percentages indicated in Table A 3-40 (established by Tokyo Metropolitan Government research) from 100% for each product and was adapted to each use. As for paint and pharmaceutical products, 100% was applied since no data was available. (Table A 3-41)

Table A 3-40 Percentage of aerosols products which used compressed gas as propellant aerosols

| Product | Percentage |
|---|---|
| Pesticide | 1.8% |
| Household product | 6.2% |
| Cosmetic items | 10.8% |
| Industrial goods | 2.3% |
| Car-related items | 15.3% |
| Others | 12.5% |

Reference: *Survey by Tokyo Metropolitan Government*

Table A 3-41 Percentage of aerosol products which used LPG and DME as propellant

| Type of product | | Percentage |
|---|---|---|
| Pesticide | For fly and mosquito | 98.2% |
| | Other pesticides | 98.2% |
| Paint | Paint[1)] | 100.0% |
| Household product | Room air freshener | 93.8% |
| | Cleaner | 93.8% |
| | Wax and polish | 93.8% |
| | Laundry articles | 93.8% |
| | Other household products | 93.8% |
| Body care products | Hair spray | 89.2% |
| | Other hair care products | 89.2% |
| | Shaving cream | 89.2% |
| | Perfume and cologne | 89.2% |
| | Pharmaceutical products[1)] | 100.0% |
| | Deodorizing and antiperspirant agents | 89.2% |
| | Other body care products | 89.2% |
| Car-related items | Anti-fog | 84.7% |
| | Other car-related products | 84.7% |
| Others | Handy extinguisher | 87.5% |
| | Others | 87.5% |

Note: Based on the *Survey by Tokyo Metropolitan Government*

1) As for paint and pharmaceutical products, 100% was applied since no data was available.

### *2) Percentage of propellant gas contained in aerosols cans*

According to the Survey by Tokyo Metropolitan Government, the percentage of propellant gas contained in aerosols cans was estimated to be 45%.

### *3) Percentage of LPG and DME in propellant gas*

According to the Survey by Tokyo Metropolitan Government, the percentage of LPG and DME in propellant gas was estimated as shown in Table A 3-42.

Table A 3-42 Percentage of LPG and DME in propellant

| Type of product | | LPG | DME |
|---|---|---|---|
| Pesticide | For fly and mosquito | 90% | 10% |
| | Other pesticides | 90% | 10% |
| Paint | Paint | 90% | 5% |
| Household products | Room air freshener | 100% | 0% |
| | Cleaner | 100% | 0% |
| | Wax and polish | 100% | 0% |
| | Laundry articles | 100% | 0% |
| | Other household products | 100% | 0% |
| Body care products | Hair spray | 90% | 10% |
| | Other hair care products | 0% | 100% |
| | Shaving cream | 90% | 10% |
| | Perfume and cologne | 50% | 50% |
| | Pharmaceutical products | 70% | 30% |
| | Deodorizing and antiperspirant agents | 100% | 0% |
| | Other body care products | 50% | 50% |
| Car-related products | Anti-fog | 100% | 0% |
| | Other car-related products | 100% | 0% |
| Others | Handy extinguisher | 0% | 0% |
| | Others | 100% | 0% |

Reference: *Survey by Tokyo Metropolitan Government*

### *4) Specific gravity of LPG and DME*

Based on the Survey by Tokyo Metropolitan Government, specific gravity of LPG and DME was established as 0.56 and 0.67, respectively.

- ***Activity data***

Following the Survey by Tokyo Metropolitan Government, production volume of aerosols products was adopted as activity data; it was estimated by multiplying the production volume of aerosols products for each type of container and capacity, by the average capacity per a can for each type of container and capacity, which converts it to capacity base.

$$AD_i = \sum (N_{i,k} \times P_{ave,k})$$

$AD_i$ : Production capacity of aerosols product *i* [cc]
$N_{i,k}$ : Production amount of aerosols Product *i*, Container capacity *k* [can]
$P_{ave,k}$ : Average capacity of aerosol cans with container capacity *k* [cc/can]

As for “Production volume for each type of container and capacity”, the results of the *Survey of Production Amounts of Aerosols* which has been annually conducted by the Aerosols Industry Association of Japan were used. As for “average capacity”, the values were set by the type of container and capacity which was provided in the Survey by Tokyo Metropolitan Government, based on the hearing survey of the Aerosols Industry Association of Japan (shown in Table A 3-43, Table A 3-44, and Table A 3-45).

Table A 3-43 Average capacity by capacity class (tinplate container)

| Capacity class [cc] | 100- | 150- | 180- | 220- | 280- | 420- |
|---|---|---|---|---|---|---|
| Average capacity[cc] | 125 | 165 | 200 | 250 | 350 | 420 |

Table A 3-44 Average capacity by capacity class (aluminum container)

| Capacity class [cc] | -49 | 50- | 100- | 150- | 200- | 300- |
|---|---|---|---|---|---|---|
| Average capacity[cc] | 25 | 75 | 125 | 175 | 250 | 300 |

Table A 3-45 Average capacity by capacity class (synthetic resin container)

| Capacity class [cc] | * |
|---|---|
| Average capacity[cc] | 210 |

Note: * Same for all capacity classes
Reference: *Survey by Tokyo Metropolitan Government*

### A3.1.2.2.l. Use of cosmetic products

#### *a) Category Description*

VOCs contained in various types of cosmetic products are emitted to the atmosphere by the use of cosmetics.

#### *b) Methodological Issues*

- ***Estimation Method***

Following the methodology of the *Survey by Tokyo metropolitan government*, VOC emissions were estimated by multiplying the sales amount of cosmetic products for each type by the VOC content rate for each type of cosmetic product, by the atmospheric emission rate for each type of cosmetic product.

$$E = \sum_i (AD_i \times C_i \times EF_i)$$

$E$ : NMVOC emissions from the use of cosmetic product [t-NMVOC]
$AD_i$ : Sales amount of cosmetic items $i$ [t]
$C_i$ : VOC content in cosmetic products $i$ [%]
$EF_i$ : Atmospheric emission rate of cosmetic products $i$ [%]

- ***Emission factors***

The VOC content rate of products was classified according to the *Yearbook of chemical industry* from the VOC content rate which was provided in the Survey by Tokyo Metropolitan Government based on some reports. (Table A3-46)

The smaller classified categories in the Survey by Tokyo Metropolitan Government than those in *Yearbook of chemical industry* were integrated by weighted average using shipping amount allocated ratio provided in *Cosmetic Products Marketing Directory* (Fuji Keizai CO., Ltd.), to make them correspond to the categories in the *Yearbook of chemical industry*.

Table A 3-46 VOC content rate and atmospheric emission rate based on classification in *Yearbook of Chemical Industry*

| Cosmetic products | | VOC content rate | Atmospheric emission rate |
|---|---|---|---|
| Skin care | Massage and cold cream | 7.5% | 100% |
| | Moisturizing cream | 7.5% | 100% |
| | Cleansing foam | 10.0% | 0% |
| | Cleansing cream | 10.0% | 0% |
| | Lotion | 10.0% | 100% |
| | Milk | 6.0% | 100% |
| | Beauty essence | 8.5% | 100% |
| | Facial mask[1)] | 4.4% | 100% |
| | Other skincare products | 7.5% | 100% |
| Makeup | Foundation[1)] | 2.6% | 100% |
| | Face powder | 0.0% | 100% |
| | Eye makeup | 4.0% | 100% |
| | Eyebrow and eyelash cosmetics | 0.0% | 100% |
| | Cheek rouge | 0.0% | 100% |
| | Lip rouge | 0.0% | 100% |
| | Nail cosmetics (including nail-polish remover) [1)] | 76.8% | 100% |
| Fragrance | Perfume and cologne | 7.5% | 100% |
| Body care | Lip balm | 10.0% | 100% |
| | Sunscreen and cosmetics for sun-burn | 83.5% | 100% |
| Hair care in bath | Shampoo | 1.5% | 0% |
| | Rinse | 1.5% | 0% |
| | Hair conditioner | 1.5% | 0% |
| Hair making | Pomade, hair oil, hair dress, perfume oil[1)] Hairdressing[1)], Setting lotion[1)] | 10.6% | 100% |
| | Hair spray | 27.5% | 100% |
| | Other items for hair (including permanent wave lotion) | 1.5% | 100% |
| Hair color | Hair color (Including hair bleach) [1)] | 22.1% | 100% |
| For men | Products for shaving or bath | 25.0% | 100% |
| | Skin care products | 7.5% | 100% |
| | Hair tonic (including hair growing agents) | 42.5% | 100% |

Note: 1) Integrated categories by weighted average

Reference: Survey by Tokyo Metropolitan Government

The atmospheric emission rate, as well as VOC content in the category were reset, so that they correspond to the categories in the *Yearbook of chemical industry*. Assuming that cosmetic products were used in a normal way, atmospheric emission rate of solid products and liquid products were set at either 0% or 100% (Table A 3-47 and Table A 3-48).

Table A 3-47 Atmospheric emission rate by the way of usage, provided in the Survey by Tokyo Metropolitan Government

| State of matter | Usage and process | Atmospheric emission rate |
|---|---|---|
| Solid | To use in water or wash away | 0% |
| | To leave it and volatilize component | 100% |
| Liquid | To use in water or wash away in a short time | 0% |
| | To leave it for a long time and dry it | 100% |
| | To volatilize component | 100% |
| | To spray mist (only undiluted solution is used for estimation. Propellant solvent is separately estimated.) | 100% |

Reference: *Survey by Tokyo Metropolitan Government*

Table A 3-48 Atmospheric emission rate based on the Survey by Tokyo Metropolitan Government

| Cosmetic products | | | Atmospheric emission rate |
|---|---|---|---|
| Skin care | Massage and Cold cream *1 | | 100% |
| | Remover | | 0% |
| | Facial-wash | Facial-wash | 0% |
| | | Cleansing | 0% |
| | Lotion | Lotion | 100% |
| | Milk | Milk | 100% |
| | Beauty essence | Beauty essence | 100% |
| | Facial mask | Wash-off facial mask | 0% |
| | | Peel-off pack | 100% |
| | | Sheet pack | 100% |
| | Face cream | (*Classified into *1) | - |
| | Others | Spot care | 100% |
| Makeup | Base | Makeup base | 100% |
| | Foundation, concealer | Foundation, etc. | 100% |
| | Face powder | Face powder | 100% |
| | Eye color | Eye shadow | 100% |
| | Eye liner | Eye liner | 100% |
| | Eyelash liner | Eyelash liner | 100% |
| | Eyebrow | Eyebrow | 100% |
| | Cheek rouge | Cheek rouge | 100% |
| | Lip color | Lip color | 100% |
| | Nail color | Nail enamel | 100% |
| | | Nail care (including remover) | 100% |
| Body care | Body cream, lotion | Body cream, lotion, etc. | 100% |
| | Lip cream | Lip cream | 100% |
| | Hand cream | Hand cream | 100% |
| | UV care product | Suntan, sunscreen | 100% |
| | Unwanted hair treatment agent | Hair removal, depilatory | 100% |
| | Anhidrotic deodorant *2 | Deodorant (for foot, for underarm) | 100% |
| Fragrance | Perfume *3 | Parfum, Eau de Parfum | 0% |
| | Eau de toilette *3 | | 100% |
| | Cologne *3 | | 0% |
| Hair care in bath | Shampoo | Shampoo | 0% |
| | Rinse, Hair conditioner | Rinse, Hair conditioner | 0% |
| | Hair treatment, pack | Hair treatment | 0% |
| Hair make | Blow styling agent, Hair spray, Hair gross | Hair styling agent | 100% |
| | Hair tonic for female | (*Classified into *6) | - |
| | Hair growing agent for female | (*Classified into *7) | - |
| | Permanent wave lotion | Cold wave treating agent | 100% |
| Hair color | Hair coloring agent for black hair, Hair coloring agent for white hair*4 | Hair coloring agent for white hair | 100% |
| | | Hair coloring agent for black hair | 100% |
| | | Hair manicure for white hair | 100% |
| | | Hair manicure for black hair | 100% |
| | | Other types of hair color (including spray) | 100% |
| | | Bleach (decoloring) | 100% |
| For men | Pre-shaving agent, shaving agent | Shaving agent | 100% |
| | Face wash, pack | Skin care products | 0% |
| | Skin lotion | | 100% |
| | Skin cream and milk | | 0% |
| | Make-up items | | 0% |
| | Hair tonic for men *6 | Hair tonic | 100% |
| | Hair growing agent *7 | Hair growing agent, tonic | 100% |
| | Blow styling agent | (* classified into *4) | - |
| | Hair spray, hair gloss | | 0% |
| | Hair coloring agent for black hair | (*classified into *5) | - |
| | Hair coloring agent for white hair | (*classified into *5) | - |
| | Anhidrotic deodorant | (*classified into *2) | - |
| | Fragrance | (*classified into *3) | - |

Reference: *Research report on VOC emissions from public sector* (March, 2010, The Institute of Behavioral Science)

- ***Activity data***

Sales amount of cosmetic products by types provided in the *Yearbook of chemical industry* is used for activity data. However, since import goods are not included in the *Yearbook of chemical industry* there might be a wide gap between reported sales amount and actual consumption amount. Therefore, as for "perfume and cologne", since the percentage of import excess was especially high, correction measures were conducted.

Table A 3-49 Cosmetic products provided in Yearbook of chemical industry

| | |
|---|---|
| Skin care | Massage and cold cream |
| | Moisturizing cream |
| | Cleansing foam |
| | Cleansing cream |
| | Lotion |
| | Milk |
| | Beauty essence |
| | Facial mask |
| | Other skincare products |
| Makeup | Foundation |
| | Face powder |
| | Eye makeup |
| | Eyebrow and eyelash cosmetics |
| | Cheek rouge |
| | Lip rouge |
| | Nail cosmetics (including nail-polish remover) |
| Fragrance | Perfume and cologne |
| Body care | Lip balm |
| | Sunscreen and cosmetics for sun-burn |
| Hair care in bath | Shampoo |
| | Rinse |
| | Hair conditioner |
| Hair making | Pomade, hair oil, hair dress, perfume oil |
| | Hairdressing |
| | Setting lotion |
| | Hair spray |
| | Other items for hair (including permanent wave lotion) |
| Hair color | Hair color (including hair bleach) |
| For men | Products for shaving or bath |
| | Skin care products |
| | Hair tonic (including hair growing agents) |

### A3.1.2.2.m. Use of products for car washing and repair

#### *a) Category Description*

VOC components contained in various products for car washing and repairing including wax and cleaner are emitted into the air.

#### *b) Methodological Issues*

- ***Estimation Method***

Following the methodology of the Survey by Tokyo Metropolitan Government, the VOC amount used was estimated by multiplying the production amount of car repairing and washing products for each type of product, by the VOC content by type of product. The whole amount of VOCs contained in car repairing and washing products is assumed to be emitted into the atmosphere by the use of the products. The used amount of VOCs was applied for VOC emissions from this

source category.

$$E = \sum_i (AD_i \times C_i)$$

$E$ : NMVOC emissions by the use of car washing and repairing products [t-NMVOC]
$AD_i$ : The production amount of $i$ [t]
$C_i$ : VOC content rate of car washing and repairing products $i$ [%]

- ***Emission factors***

VOC content rate was newly established based on various statistical data and existing VOC content provided in the Survey by Tokyo Metropolitan Government; as for some whose minimum value and maximum value was indicated, the median value was calculated. (Table A 3-50 )

Table A 3-50 VOC content rate for car washing and repairing products

| Product | | VOC | VOC content rate |
|---|---|---|---|
| Wax for cars, coating material | | Hydrocarbon compounds including kerosene | 50.0% |
| Products for car window | Window washer fluid | Methanol | 25.0% |
| | Water repellent product | Ethanol | 49.0% |
| | | Isopropyl alcohol | 42.0% |
| | Oil film remover | Ethanol | 6.5% |
| | | Isopropyl alcohol | 12.5% |
| | | Diethanolamine | 5.0% |
| | | Petroleum solvent | 30.0% |
| | Frost remover | Ethylene glycol | 25.0% |
| | | Isopropyl alcohol | 25.0% |
| Car cleaner | | Ethylene glycol | 10.0% |
| Paint for car, repairing agent | Paint | | - |
| | Adhesive | | - |
| Air fresher and air freshener for cars | Air fresher | Aroma chemical (liquid) | 1.5% |
| | | Ethanol | 2.3% |
| | | Methanol | 3.5% |
| | | Aroma chemical (gel) | 3.5% |
| | Air freshener | Ethanol | 50.0% |

Reference: *Survey by Tokyo Metropolitan Government*

- ***Activity data***

Production weight by type of chemical product for car indicated in *Research report on the current status of auto chemical manufacturing* (Japan Auto Chemical Industry Association) was used for activity data. Activity data in FY2006 and thereafter was estimated by multiplying the consumption of car washing and repairing products per vehicle by the number of registered vehicles provided in *Statistical Yearbook of Motor Vehicle Transport* (Ministry of Land, Infrastructure, Transport and Tourism).Consumption of car washing and repairing products per vehicle was estimated by dividing the production weight for each type of chemical product for car of FY2003 to FY2005 by the number of registered vehicles of each fiscal year, and multiplying the average weight of the three years[7] by the growth rate of travel distance per vehicle from FY2005. The average value was used to reflect the trend of travel distance per vehicle because the consumption of wax and coating material for cars has been showing a downward trend since FY1990 and according to Auto-parts & Accessories Retail Association, recently,

[7] Three-year average was used since the FY2005 value drastically increased from the previous year.

consumption per vehicle has been decreasing due to a decline in the rate of utilization of cars, miniaturization of cars, and the prevalence of car washing machines. The consumption of other products for cars was also estimated based on the growth rate of travel distance per vehicle.

Table A 3-51 Method of establishing activity data for car washing and repairing products

| Fiscal Year | Activity data |
|---|---|
| 1990 | The value for FY1991 was used. |
| 1991-1996 | Production weight of chemical products for car by type provided in *Research report on the current status of auto chemical manufacturing* (Japan Auto Chemical Industry Association) was used. |
| 1997, 1998 | Estimated by interpolation, using activity data in FY1996 and FY1999. |
| 1999-2005 | Production weight of products for cars by type provided in *Research report on the current status of auto chemical manufacturing* was used. |
| 2006- | Estimated by multiplying the consumption of car washing and repairing products per vehicle by the number of registered vehicles (*Statistical Yearbook of Motor Vehicle Transport* (Ministry of Land, Infrastructure, Transport and Tourism)). Consumption of car washing and repairing products per vehicle was estimated by dividing the production weight of products for cars of FY2003 to FY2005 by type by the number of registered vehicles of each fiscal year, provided in *Statistical Yearbook of Motor Vehicle Transport* and multiplying the average weight of three years by the growth rate of travel distance per vehicle from FY2005 to each year. |

### A3.1.2.2.n. Chemicals Manufacture

#### *a) Category Description*

This source category provides the methods for estimating NMVOC emissions from highly-volatile substances in manufacturing facilities to polymerize or synthesize chemical products, fugitive emissions by storage or shipping of chemical products, and emissions from solvent in chemical reaction by polymerizing or component extraction.

#### *b) Methodological Issues*

- ***Estimation Method***

NMVOC emissions from chemicals manufacture were estimated by multiplying source-specific activity data (production amount of paint, production amount of print ink, shipping amount of solvent-type adhesive, amount of VOC of surface finishing equipment, shipping value of chemical industry-related products and production amount of film soft chemical products for wrapping) by each NMVOC emission factor defined by dividing source-specific VOC emissions in the *Study on the VOC Emission Inventory* by activity data.

$$E = AD \times EF$$

*E* : NMVOC emissions by chemical manufacture [t-NMVOC]
*AD* : Activity data by source
*EF* : Emission factor per activity data[t-NMVOC/ t]

The emissions estimated by the equation above include the emissions from chemical tankers estimated in A3.1.1.3.c Oil transport (1.B.2.a.iii): Navigation. Therefore, the emissions from chemical tankers were subtracted from the total emissions in this category.

- ***Emission factors***

Emission factor was established by dividing emissions from emission activities indicated in the *Study on the VOC Emission Inventory* by each activity data shown in Table A 3-58. From FY1990

to FY1999 and FY2001 to FY2004, the emission factor was established as shown in Table A 3-52 - Table A 3-57.

Table A 3-52 Method of establishing NMVOC emission factors for chemical manufacture (paint manufacturing)

| Fiscal Year (FY) | Method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was used for all fiscal years. |
| 2000 | Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Paint Manufacturers Association) by the production amount of paint. |
| 2001-2004 | Average value of FY2000 and 2005 was used. |
| 2005- | Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Paint Manufacturers Association) by the production amount of paint. |

Table A 3-53 Method of establishing NMVOC emission factors for chemical manufacture (print ink manufacturing)

| Fiscal Year (FY) | Method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was used for all fiscal years. |
| 2000 | Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Printing Ink Makers Association) by the production amount of print ink. |
| 2001-2004 | Average value of FY2000 and 2005 was used. |
| 2005- | Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Printing Ink Makers Association) by the production amount of print ink. |

Table A 3-54 Method of establishing NMVOC emission factors for chemical manufacture (solvent-type adhesive manufacturing)

| Fiscal Year (FY) | Method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was used for all fiscal years. |
| 2000 | Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Adhesive Industry Association) by the shipping amount of solvent-type adhesive. |
| 2001-2004 | Average value of FY2000 and 2005 was used. |
| 2005- | Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Adhesive Industry Association) by the shipping amount of solvent-type adhesive. |

Table A 3-55 Method of establishing NMVOC emission factors for chemical manufacture (manufacturing of surface finishing equipment)

| Fiscal Year (FY) | Method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was used for all fiscal years. |
| 2000 | Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Surface Finishing Suppliers Association) by the used amount of VOCs by manufacturing of surface finishing equipment. |
| 2001-2004 | Average value of FY2000 and 2005 was used. |
| 2005- | Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Surface Finishing Suppliers Association) by the used amount of VOCs by manufacturing of surface finishing equipment. |

Table A 3-56 Method of establishing NMVOC emission factors for chemical manufacture (manufacturing of various chemical products)

| Fiscal Year (FY) | Method of establishing emission factor |
|---|---|
| 1990-1994 | Since no aggressive actions to reduce emissions have been taken, the emission factor for FY1995 was used for all fiscal years. |
| 1995-1999 | Since voluntary actions started in FY1995, it is considered that emissions have been on a downward trend since then. Therefore, emissions were estimated by extrapolation, using the trend for 2000-2010[1)]. |
| 2000 | Established by dividing VOC emissions from chemical industry (estimated figure based on voluntary action plan by Japan Chemical Industry Association) by shipping value of chemical industry-related products. |
| 2001-2004 | Estimated by interpolation, using emission factors in FY2000 and 2005. |
| 2005- | Established by dividing VOC emissions from chemical industry (estimated figure based on voluntary action plan by Japan Chemical Industry Association) by the shipping value of chemical industry-related products. |

1) In the case that emission factor for FY1990-1999 is established by extrapolation, it should be established based on the trend for and before FY2010, which is the target year of the voluntary action plans for VOC emission reduction.

Table A 3-57 Method of establishing emission factors for chemical manufacture (cellophane manufacturing)

| Fiscal Year (FY) | Method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was applied for all fiscal years. |
| 2000 | Established by dividing VOC emissions from cellophane manufacturing (emissions reported to the PRTR) by the production amount of film soft chemical products for wrapping |
| 2001-2004 | Average value of FY2000 and 2005 was used. |
| 2005- | Established by dividing VOC emissions from cellophane manufacturing (emissions reported to the PRTR) by the production amount of film soft chemical products for wrapping. |

- ***Activity data***

The following data indicated in Table A 3-58 was used for activity data, since it is considered to be correlated to each emission activity. As for “Manufacturing of various chemical products”, the total shipping value for all various chemical products was used for activity data due to difficulty in selecting specific chemical products from many chemical products provided in voluntary action plan by Japan Chemical Industry Association. Since the total shipping value is available only for calendar year, the value was converted from calendar year to fiscal year using the following equation.

$$S_{FYi} = S_{CYi} \times 0.75 + S_{CY(i+1)} \times 0.25$$

$S$ : Shipping value
$FY_i$ : Fiscal year $i$
$CY_i$ : Calendar year $i$

Table A 3-58 Activity data for chemical manufacture

| Emission source | Activity data | Reference |
|---|---|---|
| Paint manufacturing | The production amount of paint | *Yearbook of chemical industry* (METI) |
| Print ink manufacturing | The production amount of print ink | *Yearbook of chemical industry* (METI) |
| Solvent-type adhesive manufacturing | The shipping amount of solvent-type adhesive | *Current Survey Report on Adhesive*(Japan Adhesive Industry Association) |
| Manufacturing of surface finishing equipment | Used amount of VOCs by manufacturing surface finishing equipment<br>Note: For FY1990-1999, the value for FY2000 was applied. For FY2001-2004, the average of the values for FY2000 and 2005 was used. | *VOC voluntary action plan and achievement report* (METI) |
| Manufacturing of various chemical products | Total shipping value of various chemical products reported in PRTR in voluntary action plan. (“Chemical industry” and “Manufacturing plastic products (not specified elsewhere)”) | *Census of manufactures*(METI) |
| Cellophane manufacturing | The production amount of film-soft chemical products for wrapping. | *Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics* (METI) |

### A3.1.2.2.o. Use of removers

#### *a) Category Description*

Dichloroethane is used to remove paint before re-painting and is emitted during use.

#### *b) Methodological issues*

- ***Estimation Method***

It is difficult to take measures to reduce emissions such as through local venting during the use of removers. Therefore, the total amount of Dichloroethane used for removers was used for estimating emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The Dichloroethane used for removers was established based on the data provided by the JAHCS data as follows:

Table A 3-59 The method of establishing activity data for the use of removers

| Fiscal year | Method of establishing activity data |
|---|---|
| 1990-1994 | Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of remover-use to the total consumption of FY1995. |
| 1995- | The Dichloroethane used for removers in *Consumption by End-Use* by the JAHCS. |

### A3.1.2.2.p. Use of reagents

#### *a) Category Description*

NMVOCs are included in reagents that are used to induce chemical reactions during chemical experiments and component analyses, etc, and are emitted during use.

### b) Methodological issues

- ***Estimation Method***

Following the estimation method in the VOC emission inventory, the amount of reagents used by substance is multiplied by the emission rate by substance, to estimate emissions.

$$E = AD \times EF$$

*E* : NMVOC emissions from the use of reagents [t-NMVOC]
*AD* : Amount of reagents used [t]
*EF* : Emission rate during reagent use [t-NMVOC/ t]

- ***Emission factors***

Following the VOC emission inventory, the EF for reagent use as described in the *Report on the Promotion of Chemical Substance Safety Measures (The Survey on Methods for Emission Estimation for Below-threshold Entities and Methods for Emission Estimation for Ozone-depleting Substances and Low-content Substances)* is used. The EFs up to 1999 and 2001- 2004 are established as described in the following Table.

Table A 3-60 The method of establishing emission factors for reagent use

| Fiscal Year (FY) | The method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was applied. |
| 2000 | EF for reagent use as described in the *Report on the Promotion of Chemical Substance Safety Measures (The Survey on Methods for Emission Estimation for Below-threshold Entities and Methods for Emission Estimation for Ozone-depleting Substances and Low-content Substances)* |
| 2001-2004 | Estimated by interpolating between 2000 and 2005 EFs. |
| 2005- | EF for reagent use as described in the *Report on the Promotion of Chemical Substance Safety Measures (The Survey on Methods for Emission Estimation for Below-threshold Entities and Methods for Emission Estimation for Ozone-depleting Substances and Low-content Substances)* |

- ***Activity Data***

The Dichloroethane/Trichloroethylene used for reagents was established based on the *Study on the VOC Emission inventory* by the Ministry of the Environment and the data provided by the JAHCS data as follows:

Table A 3-61 The method of establishing activity data for the use of reagents

| Fiscal year | Method of establishing activity data |
|---|---|
| 1990-1994 | Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of reagent-use to the total consumption of FY1995. (calculated from the *Consumption by End-Use* by the JAHCS). |
| 1995- | The Dichloroethane/Trichloroethylene used for reagents in *Consumption by End-Use* by the JAHCS. |

For other reagents, Dichloroethane used for reagents in *Consumption by End-Use* by the JAHCS is multiplied by the ratio of reported substances in the *Study on the VOC Emission inventory* (from the environmental ordinance of Tokyo) that are used as reagents to the amount of Dichloroethane used as reagents, to estimate emissions.

### A3.1.2.2.q. Use of blowing agents

#### *a) Category Description*

Dichloroethane is used as an auxiliary blowing agent for flexible polyurethane foams of polyurethane and is emitted during use.

#### *b) Methodological issues*

- ***Estimation Method***

The total amount of Dichloroethane used for blowing agents was used for estimating emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The Dichloroethane used for blowing agents production was established based on the data provided by JAHCS as follows:

Table A 3-62 The method of establishing activity data for the use of blowing agents production

| Fiscal year | Method of establishing activity data |
|---|---|
| 1990-1994 | Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of blow agent-use to the total consumption of FY1995. |
| 1995- | The Dichloroethane used for blowing agents in *Consumption by End-Use* by JAHCS. |

### A3.1.2.2.r. Use of Fishing Net Antifouling Agents

#### *a) Category Description*

Solvents are used to dilute fishing net antifouling agents which are applied to nets used in fish farms or stationary nets. The nets are first immersed in the chemicals and then dried off before use. Solvents are emitted into the atmosphere at this stage.

#### *b) Methodological issues*

- ***Estimation Method***

Total amount of xylene used (sea aquaculture and stationary nets) from the 'Total amounts used for fishing net antifouling agents in sea aquaculture, etc' (surveyed by the Fisheries Agency), in the ‘emissions from fishing net antifouling agents’, from the Emissions from Sources not Required to Report under PRTR, was used for emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

Activity data is established as shown in the below Table, based on *Emissions from Sources not Required to Report under PRTR* and data provided by the Fisheries Agency.

Table A 3-63 The method of establishing activity data for the use of Fishing Net Antifouling Agents

| Fiscal year | Method of establishing activity data |
|---|---|
| 1990-1997 | Xylene used for fishing net antifouling agents for sea aquaculture and stationary nets in FY1998 is used, since no data exist for xylene used for fishing net antifouling agents. |
| 1998-2001 | Data provided by the Fisheries Agency is used. |
| 2002- | Total amount of xylene used (sea aquaculture and stationary nets) from the 'Total amounts used for fishing net antifouling agents in sea aquaculture, etc' (surveyed by the Fisheries Agency), in the 'emissions from fishing net antifouling agents', from the Emissions from So*urces not Required to Report under PRTR*, was used. |

### A3.1.2.2.s. Use of converting solvents

#### *a) Category Description*

The solvents used at the drying stage of the converting processing facilities, the drying and baking (wrinkle-resistant processing) stage during finishing, and the drying stage of printing, are emitted into the atmosphere.

#### *b) Methodological issues*

- ***Estimation Method***

Emissions were estimated by multiplying the product quantity in the dyeing and finishing processes, by the emission factor per product quantity.

- ***Emission factors***

Emission factors were established by dividing emissions based on the reported values in the Voluntary Action Plan of the Japan Textile Finishers' Association in the VOC emission inventory, by product quantity totals in the dyeing and finishing processes (excluding wool fabrics).

Table A 3-64 The method of establishing emission factors for the use of converting solvents

| Fiscal Year (FY) | The method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was applied. |
| 2000 | Emission factors were established by dividing VOC emissions from the use of converting solvents (estimated values based on the reported values in the Voluntary Action Plan of the Japan Textile Finishers' Association), by product quantity in the dyeing and finishing processes (excluding wool fabrics). |
| 2001-2004 | Estimated by interpolating between FY2000 and FY2005 EFs. |
| 2005- | Emission factors were established by dividing VOC emissions from the use of converting solvents (estimated values based on the reported values in the Voluntary Action Plan of the Japan Textile Finishers' Association), by product quantity in the dyeing and finishing processes (excluding wool fabrics). |

- ***Activity Data***

Product quantity in the dyeing and finishing processes (excluding wool fabrics) in the *Yearbook of Current Production Statistics - Textiles and Consumer Goods Statistics* (METI) is used. As for wool fabrics, converting solvents are not used in the production process and is therefore excluded from the activity data.

### A3.1.2.2.t. Use of coating solvents

#### *a) Category Description*

Emissions occur from solvents used when coating plastic films for special functions (such as antistatic agents, abrasion and scratch resistants, anti-fogging agents, electromagnetic shielding, conductivity imparting agents, UV absorbers)

#### *b) Methodological issues*

- ***Estimation Method***

Emissions were estimated by multiplying the film sales amount by the emission factor per sales amount.

- ***Emission factors***

Emission factors were established by dividing emissions based on the reported values in the Voluntary Action Plan of the Japan Polyethylene Products Industrial Federation in the VOC emission inventory by film sales amounts.

Table A 3-65 The method of establishing emission factors for the use of coating solvents

| Fiscal Year (FY) | The method of establishing emission factor |
|---|---|
| 1990-2004 | The EF for FY2005 is applied. |
| 2005- | Emission factors were established by dividing VOC emissions from the use of coating solvents (estimated values based on the reported values in the Voluntary Action Plan of Japan Polyethylene Products Industrial Federation) by film sales amounts. |

- ***Activity Data***

The film sales amounts in the *Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics* are used.

### A3.1.2.2.u. Use of Synthetic leather solvents

#### *a) Category Description*

N, N-dimethylformamide is used to dissolve polyurethane when manufacturing synthetic leather and is emitted in the process of use.

#### *b) Methodological issues*

- ***Estimation Method***

The sum of the atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry reported under the PRTR and the emissions similar as the above but from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR , are used as emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The sum of the atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry under the PRTR and the emissions similar as the above but from below-

threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR, are used as emissions.

Table A 3-66 The method of establishing activity data for the use of synthetic leather solvents

<table>
<tr><th rowspan="2">Fiscal year</th><th colspan="2">Method of establishing activity data</th></tr>
<tr><th>Emissions under the PRTR</th><th>Emissions from sources not required to report under the PRTR</th></tr>
<tr><td>1990-2000</td><td colspan="2">Estimated by multiplying FY2001 atmospheric emissions by the ratio to the FY2001 data for consumption amounts of other resin for synthetic leather in the Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics.</td></tr>
<tr><td>2001-2012</td><td rowspan="2">The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry, reported under the PRTR is used as emissions.</td><td>Estimated by multiplying FY2001 to FY2012 emissions reported under the PRTR, by the ratio of FY2017[8] emissions from sources not required to report under PRTR to the FY2017 emissions reported under the PRTR.</td></tr>
<tr><td>2013-</td><td>The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR is used.</td></tr>
</table>

### A3.1.2.2.v. Use of fumigants

#### *a) Category Description*

Methyl bromide is emitted from the use of fumigants on croplands and in warehouses, etc.

#### *b) Methodological issues*

- ***Estimation Method***

Emissions were estimated by multiplying the amount of methyl bromide used for fumigants by the emission factor per use amount.

- ***Emission factors***

An emission factor (64%) based on the *Survey of Actual Use of Methyl Bromide* (National Institute for Environmental Studies, 1998) is applied to all years.

- ***Activity Data***

The activity data was established as follows, based on the amount of methyl bromide used for fumigants provided in the domestic shipment amounts by use from the Methyl Bromide Association. As for the Soil and Quarantine categories, it is assumed that 100% is used as fumigants. As for the Other category, although it includes uses for industrial raw material, details are unknown and is therefore assumed that 50% is used as fumigants.

[8] The value of the year with the highest ratio was used to avoid underestimation.

Table A 3-67 The method of establishing activity data for the use of fumigants

| Fiscal year | Method of establishing activity data |
|---|---|
| 1990-1999 | Amount of methyl bromide provided in the domestic shipment amounts by use (Surveyed by the Agricultural Safety Management Section, Food Safety and Consumer Affairs Bureau, MAFF) The Other category is estimated using this data. |
| 2000 | Amount of methyl bromide used for fumigants provided in the domestic shipment amounts by use from the Methyl Bromide Association |
| 2001-2004 | Amount of methyl bromide provided in the domestic shipment amounts by use (Surveyed by the Agricultural Safety Management Section, Food Safety and Consumer Affairs Bureau, MAFF) The Other category is estimated using this data. |
| 2005- | Amount of methyl bromide used for fumigants provided in the domestic shipment amounts by use from the Methyl Bromide Association |

### A3.1.2.2.w. Use of Dampening Solutions

#### *a) Category Description*

Isopropyl alcohol, included in etch solutions that are added to dampening solutions used in offset printing, is emitted into the atmosphere as a VOC.

#### *b) Methodological Issues*

- ***Estimation Method***

Emissions were estimated by multiplying the sales amount of planographic printing ink by the NMVOC emissions per sales amount of planographic printing ink.

$$E = AD \times EF$$

*E* : NMVOC emissions from the use of dampening solutions [t-NMVOC]
*AD* : Sales amount of planographic printing ink [t]
*EF* : NMVOC emissions per sales amount of planographic printing ink [t-NMVOC/t]

- ***Emission factors***

The emission factors were established as follows, based on the reported values in the voluntary action plan of the Japan Federation of Printing Industries.

Table A 3-68 The method of establishing emission factors for the use of dampening solutions

| Fiscal year | Method of establishing emission factor |
|---|---|
| 1990-1999 | Emission factor for FY2000 was applied. |
| 2000 | Emission factors were established by dividing VOC emissions from the use of dampening solutions (estimated values based on the reported values in the voluntary action plan of the Japan Federation of Printing Industries) by sales amounts of planographic printing ink. |
| 2001-2003 | Estimated by interpolating between FY2000 and FY2004 EFs. |
| 2004- | Emission factors were established by dividing VOC emissions from the use of dampening solutions (estimated values based on the reported values in the voluntary action plan of the Japan Federation of Printing Industries) by sales amounts of planographic printing ink. |

- ***Activity data***

The sales amounts of planographic printing ink in the *Yearbook of Chemical Industry* (METI) are used.

### A3.1.2.3. Others – Food and beverage industry (2.H.2.) (NMVOCs)

### A3.1.2.3.a. Foods (fermentation)

#### *a) Category Description*

NMVOCs are released as a fugitive emission in alcohol in the process of manufacturing foods or beverages. For the estimation of NMVOC emissions from this source category, alcohol which is generated by bread making and alcoholic brewing is included in the calculation; it is considered to be of biogenic-origin.

#### *b) Methodological Issues*

- ***Estimation Method***

NMVOC emissions from manufacturing foods or beverages were estimated by multiplying the production amount of bread and alcohol drinks, by the NMVOC emission factor per production amount of bread and alcoholic drinks.

➢ ***Calculation of NMVOC emissions from bread making***

$$E = AD \times EF$$

*E* : NMVOC emissions from bread making [t -NMVOC]
*AD* : Production amount of bread [1000 t]
*EF* : Emission factor per production amount of bread [kg-NMVOC/t]

➢ ***Calculation of NMVOC emissions from alcohol brewing***

$$E = AD \times ABV \times EF$$

*E* : NMVOC emissions from alcohol brewing [t -NMVOC]
*AD* : Production volume of alcoholic drinks [1000 kl]
*ABV*: Ethyl alcohol content rate [%] (only for Shochu (Japanese distilled spirit), whiskey, spirits, and liqueur)
*EF* : Emission factor per production amount of alcoholic drinks [kg-NMVOC/kl]

- ***Emission factors***

Emission factor (4.5kg/t) for bread making, provided in the European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*, was used as the emission factor for bread making.

As for emission factor for brewing alcoholic drinks, the ethyl alcohol content provided in European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009* was also used (TableA3-69). The ethyl alcohol contents of the alcoholic drinks were only established for Shochu, whiskey, sprites and liqueurs. The ethyl alcohol contents of Shochu and whiskey were established based on the European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009* (TableA3-70). The ethyl alcohol content provided in the *VOC Emission Inventory* was used for spirits and liquor. (TableA3-71 and TableA3-72).

Table A 3-69 Emission factors for brewing alcoholic drinks

| Alcoholic drinks | Emission factor | Unit |
|---|---|---|
| Sake | 0.08 | kg/100L- volume of brewed alcoholic drinks |
| Sake compound | 0.08 | kg/100L- volume of brewed alcoholic drinks |
| Shochu (Japanese distilled spirit) | 0.4 | kg/100L- volume of brewed ethyl alcohol |
| Beer | 0.035 | kg/100L- volume of brewed alcoholic drinks |
| Fruit wine | 0.08 | kg/100L- volume of brewed alcoholic drinks brewed volume |
| Whiskey | 15 | kg/100L- volume of brewed ethyl alcohol |
| Spirits | 0.4 | kg/100L- volume of ethyl alcohol |
| Liqueurs | 0.4 | kg/100L- volume of brewed ethyl alcohol |
| Other liquors (including low-malt beer) | 0.035 | kg/100L-volume of brewed alcoholic drinks |

Note: *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*, established by using the *Study on the VOC Emission Inventory*

Table A 3-70 Ethyl alcohol content for alcoholic drinks (shochu, whiskey)

| Alcoholic drinks | Ethyl alcohol content |
|---|---|
| Shochu (Japanese distilled spirit) | 25% |
| Whiskey | 40% |

Note: Based on *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*

Table A 3-71 Methods of establishing ethyl alcohol content of spirits and liquor

| Fiscal year (FY) | Methods of establishing ethyl alcohol content of spirits and liquor |
|---|---|
| 1990-1999 | The value of ethyl alcohol content for FY2000 provided in the VOC Emission Inventory was used. |
| 2000 | The value of ethyl alcohol content provided in the VOC Emission Inventory was used. |
| 2001-2004 | Estimated by interpolating between the ethyl alcohol contents for FY2000 and FY2005. |
| 2005- | The value of ethyl alcohol content for each year provided in the VOC Emission Inventory was used. |

Table A 3-72 Ethyl alcohol content for alcoholic drinks (spirits, liquor)

| Item | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spirits | 25.9% | 25.9% | 25.9% | 12.7% | 10.6% | 10.3% | 10.1% | 10.1% | 10.0% | 9.8% | 9.7% | 9.7% | 9.8% | 9.8% |
| Liqueurs | 11.7% | 11.7% | 11.7% | 8.5% | 7.2% | 7.0% | 6.9% | 6.8% | 6.7% | 6.8% | 6.7% | 6.5% | 6.4% | 6.4% |

- ***Activity data***

For bread, the production amount of various kinds of bread, provided in *Yearbook of rice and wheat processed food production statistics* (Ministry of Agriculture, Forestry and Fisheries of Japan), was used for activity data.

For alcoholic drinks, the volume of production of brewed alcoholic drinks, provided in Table of volume of production of brewed alcoholic drinks and volume of stock (The National Tax Administration Agency) was used for activity data.

### A3.1.3 Agriculture

#### A3.1.3.1. Field burning of agricultural residues (3.F: CO, NOx)

***a) Methodological Issues***

- ***Estimation Method***

CO and NOx emissions were calculated by using the method indicated in the *2006 IPCC Guidelines*, which is the same method as that for $CH_4$ and $N_2O$ estimation.

$$E = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

$E$ : CO and NOx emissions from field burning of agriculture residues [t-CO or t-$NO_X$]
$A$ : Area burnt [ha]
$M_B$ : Mass of fuel available for combustion [t/ha]
$C_f$ : Combustion factor
$G_{ef}$ : Emission factor [g-CO/kg or g-$NO_X$/kg]

- ***Emission factors***

CO : 92 g-CO/kg (dry matter) (default value in the *2006 IPCC Guidelines*)
NOx :2.5 g-$NO_X$/kg (dry matter) (default value in the *2006 IPCC Guidelines*)

- ***Activity data***

Activity data are the same as those used for $CH_4$ and $N_2O$ estimation described in "5.7. Field Burning of Agricultural Residues (3.F.)".

### A3.1.4 Land Use, Land-Use Change and Forestry

***a) Methodological Issues***

***1)* Biomass burning in Forest land (4(V))**

- ***Estimation Method***

For CO and $NO_X$ emissions due to biomass burning from forest fires, the Tier 1 method is used.

➢ ***CO***

$$bbGHG_f = L_{forest\ fires} \times ER$$

➢ ***$NO_X$***

$$bbGHG_f = L_{forest\ fires} \times ER \times NC_{ratio}$$

$bbGHG_f$ : CO and $NO_X$ emissions due to forest biomass burning
$L_{forest\ fires}$ : Carbon released due to forest fires [tC/yr]
$ER$ : Emission ratio (CO: 0.06, $NO_X$: 0.121)
$NC_{ratio}$ : NC ratio

- ***Emission Factor***

➢ ***Emission ratio***

The following values are applied to emission ratios for CO and $NO_X$ due to biomass burning.

CO: 0.06, $NO_X$: 0.121
(default value stated in the GPG-LULUCF, Table 3A.1.15)

➢ ***NC ratio***

The following values are applied to NC ratio of $NO_X$.

NC ratio: 0.01 (default value stated in the GPG-LULUCF p.3.50)

- ***Activity data***

For activity data in Forest land, carbon released by forest fire is used. For detailed information, see the description on the activity data in section 6.16 in Chapter 6.

### *2)* From burning of pruned branches from orchard trees (4(V))

- ***Estimation Method***

For CO and NOx emissions due to biomass burning of pruned branches from orchard trees, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* is applied. The estimation equation is as follows:

$$L_{fire} = M_B \times C_f \times G_{ef} \times 10^{-6}$$

$L_{fire}$ : CO and NOx emissions from fire [kt]
$W_B$ : Amount burnt [t-d.m.]
$C_f$ : Combustion factor
$G_{ef}$ : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor, a general value (0.9) which has been used generally in field burning of crop residues in agriculture in Japan is applied. The default emission factors (Agricultural residue value) described in the *2006 IPCC Guidelines* are used.

Table A 3-73 Emission factors [t/kt-d.m.]

| Category | CO | NOx |
|---|---|---|
| Agricultural residue | 92 | 2.5 |

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity Data (Amount burned)***

For activity in orchard land, see the description on the activity data in section 6.16 in Chapter 6.

### *3)* Biomass burning in grassland (4(V))

- ***Estimation Method***

For CO and NOx emissions due to biomass burning of grassland, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* is applied. The estimation equation is as follows:

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-6}$$

$L_{fire}$ : CO and NOx Emissions from fire [kt]
$M_B$ : Amount burnt [t-d.m.]
$C_f$ : Combustion factor
$G_{ef}$ : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor, value of 0.9 is applied according to expert judgment that considering survey data on burning of grassland in Japan. The default emission factors (Savanna and grassland) described in the *2006 IPCC Guidelines* are used.

Table A 3-74 Emission factors [t/kt-d.m.]

| Category | CO | NOx |
|---|---|---|
| Savanna and grassland | 65 | 3.9 |

Note: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity Data (Amount burned)***

For activity data in grassland, see the description on the activity data in section 6.16 in Chapter 6.

## A3.1.5 Waste

### A3.1.5.1. Incineration and Open Burning of Waste (5.C.)

### A3.1.5.1.a. Municipal Solid Waste Incineration (5.C.1.–)

- ***Estimation Method***

The $NO_X$, CO, NMVOCs, and $SO_X$ emissions from the specified sources were calculated by multiplying the incineration amount of MSW in each incinerator type (Continuous Incinerators, Semi-continuous Incinerators, Batch type Incinerators, Gasification melting furnaces) by Japan's country-specific emission factors. These emissions are categorized following the methods given in chapter 7 based on incinerations either with or without energy recovery. The former emissions are reported in the Energy sector, while the latter are reported in the Waste sector.

- ***Emission factors***

➢ ***$NO_X$, $SO_X$***

For incinerators, emission factors were established for each incinerator type by using the emission amount and amount of treated waste identified in the *General Survey of the Emissions of Air Pollutants*. (The categories of incinerator types included: [1301: Waste incinerator (municipal solid waste; continuous system)] and [1302: Waste incinerator (municipal solid waste; batch system)]). The incineration material was [53: Municipal solid waste].) It is noted that while the *General Survey of the Emissions of Air Pollutants* classified the incinerators into two classes (Continuous and Batch), this report classifies incinerators into three classes ("Continuous", "Semi-continuous", and "Batch type") by dividing the Continuous system and assigning those which operated for less than 3,000 hours to the "Semi-continuous" class.

For gasification melting furnaces, the value for Continuous Incinerators with a similar incineration method was used.

Table A 3-75 $NO_X$ and $SO_X$ emission factors for municipal waste incineration by facility type

| Furnace type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOx | | | | | | | | | | | | | | | |
| Continuous incinerator | kg-NOx/t | 1.238 | 1.213 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 |
| Semi-continuous incinerator | kg-NOx/t | 1.055 | 1.226 | 1.226 | 1.226 | 1.226 | 1.226 | 1.226 | 1.226 | 1.226 | 1.226 | 1.226 | 1.226 | 1.226 | 1.226 |
| Batch type incinerator | kg-NOx/t | 1.137 | 1.918 | 1.850 | 1.850 | 1.850 | 1.850 | 1.850 | 1.850 | 1.850 | 1.850 | 1.850 | 1.850 | 1.850 | 1.850 |
| Gasification melting furnace | kg-NOx/t | 1.238 | 1.213 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 | 1.127 |
| SOx | | | | | | | | | | | | | | | |
| Continuous incinerator | kg-$SO_x$/t | 0.555 | 0.539 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 |
| Semi-continuous incinerator | kg-SOx/t | 0.627 | 1.141 | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 | 0.712 |
| Batch type incinerator | kg-SOx/t | 1.073 | 1.625 | 1.714 | 1.714 | 1.714 | 1.714 | 1.714 | 1.714 | 1.714 | 1.714 | 1.714 | 1.714 | 1.714 | 1.714 |
| Gasification melting furnace | kg-SOx/t | 0.555 | 0.539 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 | 0.361 |

Note: The data for 2000 were used for 2001 and subsequent years.
Reference: *General Survey of the Emissions of Air Pollutants* (Ministry of the Environment)

➢ ***CO***

For incinerators, the emission factors were established for each incinerator class based on the emission factors for individual facilities summarized in the *Report on Emission Factor Results for Combustion Facilities* (Japan Society for Atmospheric Environment, 1997) as well as other reports. It is noted that while the Japan Society for Atmospheric Environment report subdivided the facilities by furnace type (e.g., stoker, fluidized bed, etc.), this report determined the emission factors for three classes of "Continuous", "Semi-continuous" and "Batch type" by taking the average weighted by incinerated amount for each furnace.

For gasification melting furnaces, the value for continuous stoker furnaces with a similar incineration method was used.

Table A 3-76 CO emission factors for municipal waste incineration by facility type

| Furnace type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Continuous incinerator | g-CO/t | 557 | 557 | 555 | 554 | 554 | 554 | 553 | 553 | 553 | 553 | 553 | 553 | 554 | 554 |
| Semi-continuous incinerator | g-CO/t | 548 | 548 | 567 | 591 | 605 | 611 | 609 | 613 | 609 | 614 | 607 | 600 | 603 | 603 |
| Batch type incinerator | g-CO/t | 8,237 | 8,237 | 8,298 | 8,341 | 8,351 | 8,270 | 8,272 | 8,270 | 8,274 | 8,274 | 8,279 | 8,281 | 8,239 | 8,239 |
| Gasification melting furnace | g-CO/t | 567 | 567 | 567 | 567 | 567 | 567 | 567 | 567 | 567 | 567 | 567 | 567 | 567 | 567 |

Reference: *Report on Emission Factor Results for Combustion Facilities* (Japan Society for Atmospheric Environment, 1997), and others.

➢ ***NMVOCs***

For both incinerators and gasification melting furnaces, NMVOC emission factors were established by multiplying the $CH_4$ emission factors for each furnace type of each fuel type by "NMVOC/$CH_4$", the emission ratio for fuel type. The ratio was determined by using the reference material by Japan Environmental Sanitation Center and Institute of Behavioral Science, which estimated $CH_4$ and NMVOC emissions per unit calorific value.

Table A 3-77 NMVOC emission factors for municipal waste incineration by facility type

| Furnace type | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Continuous incinerator | g-NMVOC/t | 0.9 | 0.9 | 0.9 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Semi-continuous incinerator | g-NMVOC/t | 7.8 | 7.8 | 8.5 | 2.2 | 2.3 | 2.4 | 2.3 | 2.4 | 2.3 | 2.4 | 2.3 | 2.3 | 2.3 | 2.3 |
| Batch type incinerator | g-NMVOC/t | 9.1 | 9.1 | 9.5 | 1.5 | 1.5 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 |
| Gasification melting furnace | g-NMVOC/t | - | - | 0.6 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |

Reference: *Report on Screening Survey Regarding Measures to Counter Global Warming (Atmospheric Management)* (Japan Environmental Sanitation Center, 1989), *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (Institute of Behavioral Science, 1984)

● ***Activity data***

For incinerators, the activity data used was the incineration amount for each facility type as calculated by multiplying the incineration amount of municipal waste by the incineration rate for each facility type. The incineration amount data were extracted from the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes* (the Volume on Cyclical Use) by the Ministry of the Environment. The incineration rate was calculated in the *Waste Treatment in Japan* published by the Ministry of the Environment.

For gasification melting furnaces, the activity data used was the amount incinerated in gasification melting furnaces, calculated from data in the Ministry of the Environment's "*Waste Treatment in Japan*."

### A3.1.5.1.b. Industrial Wastes Incineration (5.C.1.–)

- ***Estimation Method***

$NO_X$, CO, NMVOCs, and $SO_X$ emissions from the specified sources were calculated by multiplying the incineration amount of industrial waste for each waste type by Japan's country-specific emission factors. These emissions are categorized following the methods given in chapter 7 based on incinerations either with or without energy recovery. The former emissions are reported in the Energy sector, while the latter are reported in the Waste sector.

- ***Emission factors***

➢ ***$NO_X$, $SO_X$***

An emission factor was established for each type of industrial solid waste using the emission amount and amount of treated industrial solid waste identified by the *General Survey of the Emissions of Air Pollutants*. The categories of incinerator types included: [1303: Waste incinerator (industrial solid waste; continuous system)] and [1304: Waste incinerator (industrial solid waste; batch system)]. The incinerator fuel covered the categories [23: Fuel Wood] and [54: Industrial solid waste]). The six types of industrial waste were "Waste paper or waste wood", "Sludge", "Waste oil", "Waste plastics", "Waste textiles", and "Animal/plant residue, livestock carcasses". Category [23: Sawn Timber] was used for "Waste paper or waste wood", "Waste textiles", and "Animal/plant residues, livestock carcasses", while category [54: Industrial waste] was used for "Sludge", "Waste oil", and "Waste plastics". However, no emission factor was set for the mixed burning of multiple waste types.

Table A 3-78 $NO_X$ and $SO_X$ emission factors for industrial waste by facility type

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOx | | | | | | | | | | | | | | | |
| "Fuel Wood 23" | kg-NOx/t | 1.545 | 1.312 | 5.828 | 5.828 | 5.828 | 5.828 | 5.828 | 5.828 | 5.828 | 5.828 | 5.828 | 5.828 | 5.828 | 5.828 |
| "Industrial Waste 54" | kg-NOx/t | 0.999 | 1.158 | 1.415 | 1.415 | 1.415 | 1.415 | 1.415 | 1.415 | 1.415 | 1.415 | 1.415 | 1.415 | 1.415 | 1.415 |
| SOx | | | | | | | | | | | | | | | |
| "Fuel Wood 23" | kg-SOx/t | 1.528 | 1.274 | 2.118 | 2.118 | 2.118 | 2.118 | 2.118 | 2.118 | 2.118 | 2.118 | 2.118 | 2.118 | 2.118 | 2.118 |
| "Industrial Waste 54" | kg-SOx/t | 1.179 | 1.882 | 1.352 | 1.352 | 1.352 | 1.352 | 1.352 | 1.352 | 1.352 | 1.352 | 1.352 | 1.352 | 1.352 | 1.352 |

Note: The data for 2000 were used for 2001 and subsequent years.
Reference: *General Survey of the Emissions of Air Pollutants* (Ministry of the Environment)

➢ ***CO***

Based on the emission factors for individual facilities summarized in the *Report on Emission Factor Results for Combustion Facilities* (Japan Society for Atmospheric Environment, 1997) as well as other reports, an emission factor was established for each type of industrial solid waste. The six types of industrial waste were "Waste paper or waste wood", "Sludge", "Waste oil", "Waste plastics", "Waste textiles", and "Animal/plant residues, livestock carcasses". The emission factor for "wood waste" was used for "Waste textiles" and "Animal/plant residues, livestock carcasses", for which there are no measurements. No emission factor was set for the mixed burning of multiple waste types.

Table A 3-79 CO emission factors for industrial waste incinerators by operation type

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paper/cardboard, wood | g-CO/t | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 |
| Waste oil | g-CO/t | 127 | 127 | 127 | 127 | 127 | 127 | 127 | 127 | 127 | 127 | 127 | 127 | 127 | 127 |
| Plastics | g-CO/t | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 | 1,790 |
| Sludge | g-CO/t | 2,285 | 2,285 | 2,285 | 2,285 | 2,285 | 2,285 | 2,285 | 2,285 | 2,285 | 2,285 | 2,285 | 2,285 | 2,285 | 2,285 |
| Textile | g-CO/t | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 |
| Animal and vegetable residues/ animal carcasses | g-CO/t | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 | 1,334 |

Reference: *Report on Emission Factor Results for Combustion Facilities* (Japan Society for Atmospheric Environment, 1997) and others

➢ ***NMVOCs***

NMVOC emission factors were established by multiplying the $CH_4$ emission factors for each furnace type of each fuel type by "NMVOC/$CH_4$", the emission ratio for fuel type. The ratio was determined by using the reference materials by Japan Environmental Sanitation Center and Institute of Behavioral Science, which estimated $CH_4$ and NMVOC emissions per unit calorific value.

Table A 3-80 NMVOC emission factors for industrial waste incineration by facility type

| Item | Unit | 1990 | 1995 | 2000 | 2005 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paper/cardboard, wood | g-NMVOC/t | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 |
| Waste oil | g-NMVOC/t | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 |
| Plastics | g-NMVOC/t | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 | 3.40 |
| Sludge | g-NMVOC/t | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 |
| Textile | g-NMVOC/t | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 |
| Animal and vegetable residues/ animal carcasses | g-NMVOC/t | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 |

Reference: *Report on Screening Survey Regarding Measures to Counter Global Warming (Atmospheric Management)* (Japan Environmental Sanitation Center, 1989), *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (Institute of Behavioral Science, 1984)

- ***Activity data***

The activity data used the incineration amount data for each type of waste extracted from the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes* (the Volume on Cyclical Use) and the *Waste Treatment in Japan* published by the Ministry of the Environment.

### A3.1.5.1.c. Open Burning of Industrial Waste (5.C.2.–)

- ***Estimation Method***

$NO_X$, CO, NMVOCs, and $SO_X$ emissions from the specified sources were calculated by multiplying the amount of industrial waste burned in the open air for each waste type by Japan's country-specific emission factors.

- ***Emission factors***

As no knowledge is obtained for making it possible to set emission factors specific to open burning of waste in Japan, the country-specific emission factors for industrial waste incineration were substituted. For detail, the $NO_X$, CO, NMVOC and $SO_X$ emission factors for plastics incineration as for plastics burned in the open air, and those for wood incineration as for other waste burned in the open air were adopted respectively. See also section "A3.1.5.1.b. Industrial Wastes Incineration (5.C.1.–)".

- ***Activity data***

The amount of industrial waste burned in the open air obtained from the "*Report on Survey of Organizations in Industrial Waste Administration*, Ministry of the Environment" was used as the activity data in and after FY1996. As for the past activity data from FY1990 to 1995 for which the survey data is not available, the data of FY1996 was uniformly used as a substitute since there are no other appropriate way to estimate.

### A3.1.5.1.d. Incineration in Conjunction with Use of Waste as Fuel and Raw Material (1.A.-)

- ***Estimation Method***

CO and NMVOC emissions from this source were estimated by multiplying the amounts of fuel/raw material burned for each waste type by a Japan-specific emission factor. These emissions are reported in Energy sector (1.A.) following the methodologies given in chapter 7 (Waste).

- ***Emission Factors***

➢ ***CO***

The CO emission factors were established by converting the emission factors (energy unit basis) by furnace type, which are used for estimating emissions from 1A Stationary Sources, to weight-based emission factors by multiplying the calorific values in the *General Energy Statistics*.

Table A 3-81 CO emission factors from incineration in conjunction with use of waste as fuel and raw material

| Application | Units | Waste oil | RDF | RPF | Waste tires (FY2004 and before) | Waste tires (FY2005 and after) | Plastics | Plastics (Liquefaction) | Wood |
|---|---|---|---|---|---|---|---|---|---|
| Simple incineration | kg-CO/t | 0.13 | 1.79 | 1.79 | 1.79 | 1.79 | - | - | - |
| Boilers | kg-CO/t | 0.052 | 0.24 | 0.39 | 0.28 | 0.44 | 0.39 | 0.034 | 3.64 |
| Cement kilns | kg-CO/t | - | 19.8 | 32.2 | 23.0 | 36.5 | 32.2 | - | - |
| Other furnaces | kg-CO/t | 0.052 | 0.24 | 0.39 | 0.28 | 0.44 | - | - | - |
| Pyrolysis furnaces | kg-CO/t | - | - | - | 0.021 | 0.033 | - | - | - |
| Gasification | kg-CO/t | - | - | - | 0.015 | 0.024 | - | - | - |

➢ ***NMVOCs***

Just as for the incineration of municipal solid waste and industrial waste, emission factors were determined from documents with estimates of emissions of $CH_4$ and NMVOCs per unit calorific values.

Table A 3-82 NMVOC emissions factors from incineration in conjunction with use of waste as fuel and raw material

| Application | Units | Waste oil | RDF | RPF | Waste tires (FY2004 and before) | Waste tires (FY2005 and after) | Plastics | Plastics (Liquefaction) | Wood |
|---|---|---|---|---|---|---|---|---|---|
| Boilers | kg-NMVOC/t | 0.015 | 0.00027 | 0.00043 | 0.00031 | 0.00049 | 0.00043 | 0.010 | 0.12 |
| Cement kilns | kg-NMVOC/t | - | - | 0.043 | 0.031 | 0.049 | 0.043 | - | - |
| Pyrolysis furnaces | kg-NMVOC/t | - | - | - | 0.0051 | 0.0080 | - | - | - |
| Gasification | kg-NMVOC/t | - | - | - | 0.0187 | 0.0297 | - | - | - |

- ***Activity data***

Same activity data that were used when estimating $CH_4$ emissions for the use of waste as fuel and raw material were used.

## A3.1.6 Other sectors

### A3.1.6.1. Smoking (6.–: CO)

- ***Estimation Method***

CO emissions were calculated by multiplying the amount of cigarette sales by Japan's country-specific emission factor.

$$E_{CO} = S \times EF$$

$E_{CO}$ : CO emissions from smoking
$S$ : Cigarette sales
$EF$ : Emission factor [g-CO/cigarette]

- ***Emission factors***

The emission factor (0.055 [g-CO/cigarette]) was provided by Japan Tobacco Inc.

- ***Activity data***

The amount of cigarette sales published on Tobacco Institute of Japan website (http://www.tioj.or.jp/) was used for activity data.

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# Annex 4. The National Energy Balance for the Most Recent Inventory Year

## A4.1. Discrepancies between the figures reported in the CRF tables and the IEA statistics

In the report of the individual review of the greenhouse gas inventory of Japan submitted in 2006 (FCCC/ARR/2006/JPN), which was conducted from January to February 2007, the ERT (Expert Review Team) recommended that in the next NIR submission Japan provide a clear explanation for the discrepancies found between the data in the CRF tables and the IEA statistics. In response to this recommendation, Japan has provided the detailed information on the Annex of the NIR regarding the discrepancies of the FY2005 data between the CRF tables and the IEA statistics. Also, in the individual review report of the GHG inventory of Japan submitted in 2010 (FCCC/ARR/2010/JPN), the updating of this information with the latest available inventory year data was recommended by the ERT. In response to this recommendation, the detailed information regarding the discrepancies of the reported value between the CRF and the IEA statistics is hereby updated with the FY2016 actual data. The IEA statistical data used in the explanation were extracted from the *World Energy Statistics*, 2019 Edition, OECD/IEA (online version).

In summary, these discrepancies occurred; because (a) the CRF tables and the IEA statistics treat international aviation and marine bunker fuels (bonded exports) differently, and (b) fuel oil A is classified in a different way. The figures for imports and exports of fuels reported in the CRF tables include the bonded exports, whereas the figures for imports and exports of fuels in the IEA statistics do not. With respect to fuel oil A, Japan includes it under “heavy fuel oil” in its energy balances but reports it to the IEA under gas/diesel oil according to the classifications used in Europe and the United States.

According to Japanese definition, fuel oil A has a flash point of more than 60 °C, kinematic viscosity of below 20 $mm^2/s$, carbon residue content of below 4% and sulfur content of below 2.0 %. Fuel oil B has a flash point of more than 60 °C, kinematic viscosity of below 50 $mm^2/s$, carbon residue content of below 8% and sulfur content of below 3.0 %. Fuel oil B is rarely used nowadays in Japan, for this reason, fuel oil B is treated as “fuel oil B/C” together with fuel oil C in Japanese statistics. Fuel oil C has a flash point of more than 70 °C, kinematic viscosity of less than 1,000 $mm^2/s$ and sulfur content of less than 3.5%.

In addition, the preliminary figures of reporting year ($y$) based on the *General Energy Statistics* are used for reporting to the IEA in fall of the next fiscal year ($y$+1), which starts in April and ends in March; on the other hand, the final figures based on the *General Energy Statistics* are used for reporting to the UNFCCC since the final figures are available in the CRF submission period in spring of the next year ($y$+2). Therefore, there are discrepancies of the reported values between the IEA statistics (preliminary figures) and the CRF tables (final figures) at the time of review under the UNFCCC in summer of the next year ($y$+2). The preliminary figures reported to the IEA are updated to the final figures in fall of the next year ($y$+2) and are published in the IEA statistics in summer of the year after next ($y$+3); the discrepancies between the data in the CRF tables and the IEA statistics are dissolved at the time, except for discrepancies resulted from the definitions or different estimation methods mentioned below.

Further explanations are provided below for each of the discrepancies noted by the ERT.

### *a) Differences in exports of jet kerosene and residual fuel oil*

<ERT findings on FCCC/ARR/2006/JPN>

Exports of liquid fuels are between 40 and 70 per cent lower in the IEA data; the differences are due in particular to differences in the figures for jet kerosene and residual fuel oil, with the largest errors occurring in recent years.

<Explanation 1: Exports of jet kerosene>

The figures for jet kerosene exports reported in the CRF tables are different from those in the IEA statistics because the CRF figures include bonded exports whereas the export figures in the IEA statistics do not. The IEA statistics accounted the consumption of jet kerosene by international aviation bunkers as an aggregate of the bonded exports and imports. (See Chapter 3, for bonded exports and imports.)

Table A 4-1 Exports of jet kerosene in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Exports: $9,878.62\times10^3$ kL<br><br><Breakdown><br>Exports excluding bonded exports:<br>$2,643.66\times10^3$ kL<br>Bonded exports: $7,234.96\times10^3$ kL | Exports: $2,071\times10^3$ t<br>[ $2,643.66\times10^3$ kL (exports excluding bonded exports)<br>× 0.7834 t/kL (density) = $2,071\times10^3$ t ]<br><br><Remarks><br>International aviation: $6,652\times10^3$ t<br>[ $7,234.96\times10^3$ kL (bonded exports)<br>+ $1,256.10\times10^3$ kL (bonded imports)<br>= $8,491.06\times10^3$ kL;<br>$8,491.06\times10^3$ kL × 0.7834 t/kL (density)<br>= $6,652\times10^3$ t ] |

<Explanation 2: Exports of residual fuel oil>

The figures for exports of residual fuel oil reported in the CRF tables are different from those in the IEA statistics because the CRF figures for residual fuel oil include the bonded exports, whereas the export figures for fuel oil in the IEA statistics do not. The bonded exports portion of the fuel oil was reported in the IEA statistics as an aggregate of the bonded exports and imports of fuel oil under international marine bunkers. (See Chapter 3, for bonded exports and imports.)

Further, the figures for exports of residual fuel oil reported in the CRF include fuel oil A, whereas the figures reported under fuel oil in the IEA statistics do not. The IEA reports fuel oil A together with gas oil under gas/diesel oil in its statistics. Because fuel oil A, which is treated as a fuel oil that is distinguished from diesel oil in Japan, is grouped together with diesel oil in Europe and the United States, the fuel oil A data have been included in the diesel oil data in Japan's report to the IEA.

Table A 4-2 Exports of residual fuel oil in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Exports: 8,338.08×$10^3$ kL<br>[ 1,243.78×$10^3$ kL (fuel oil A)<br>+ 7,094.30×$10^3$ kL (fuel oils B and C)<br>= 8,338.08×$10^3$ kL]<br><br><Breakdown><br>Exports of fuel oil A: 1,243.78×$10^3$ kL<br>Exports excluding bonded exports: 1,075.53×$10^3$ kL<br>Bonded exports: 168.25×$10^3$ kL<br>Exports of fuel oils B and C: 7,094.30×$10^3$ kL<br>Exports excluding bonded exports: 2678.80×$10^3$ kL<br>Bonded exports: 4,415.51×$10^3$ kL | Exports: 2,411×$10^3$ t<br>[ 2,679×$10^3$ kL (exports of fuel oils B and C excluding bonded exports)<br>× 0.9 t/kL (density) = 2,411×$10^3$ t ]<br><br><Remarks><br>International marine bunkers: 3,983×$10^3$ t<br>[ 4,415.51×$10^3$ kL (bonded exports of fuel oils B and C)<br>+ 10.06×$10^3$ kL (bonded imports of fuel oils B and C)<br>= 4,425.57×$10^3$ kL;<br>4,425.57×$10^3$ kL × 0.9 t/kL (density)<br>= 3,983×$10^3$ t ] |

***b) Differences in imports of jet kerosene and gas/diesel oil***

<ERT findings on FCCC/ARR/2006/JPN>

Imports of jet kerosene have been reported to the IEA, but are shown as zero in the CRFs for the years 1990–1997, while imports of gas/diesel oil are systematically about 80 per cent lower in the CRF tables than in the IEA figures.

<Explanation 1: Imports of jet kerosene>

The figures for jet kerosene imports reported in the CRF tables are different from those in the IEA statistics because the CRF figures are the sums of imports including bonded imports and bonded exports while the IEA statistics figures are the imports including bonded imports. (See Chapter 3, for bonded exports and imports.)

Table A 4-3 Imports of jet kerosene in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Imports: 8,846.11×$10^3$ kL<br><br><Breakdown><br>Imports excluding bonded imports: 355.05×$10^3$ kL<br>Bonded imports: 1,256.10×$10^3$ kL<br>Bonded exports: 7,234.96×$10^3$ kL | Imports: 1,262×$10^3$ t<br>[ 355.05×$10^3$ kL (imports excluding bonded imports)<br>+ 1,256.10×$10^3$ kL (bonded imports)<br>= 1,611.14×$10^3$ kL.<br>1,611.14×$10^3$ kL (imports including bonded imports) × 0.7834 t/kL (density)<br>= 1,262×$10^3$ t ] |

<Explanation 2: Imports of gas/diesel oil>

The figures for imports of gas/diesel oil reported in the CRF tables are different from those in the IEA statistics, because the CRF figures are the sums of imports (including bonded imports) and bonded exports of diesel oil, which excludes fuel oil A, while the figures for imports of gas/diesel oil in the IEA statistics are the aggregate of imports of diesel oil and fuel oil A, both of which included the bonded imports.

Table A 4-4 Imports of gas/diesel oil in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Imports: $542.74\times10^3$ kL<br><br><Breakdown><br>Imports excluding bonded imports: $510.96\times10^3$ kL<br>Bonded imports: $18.42\times10^3$ kL<br>Bonded exports: $13.36\times10^3$ kL | Imports: $516\times10^3$ t<br>[ $510.96\times10^3$ kL (imports of gas/diesel oil excluding bonded imports)<br>+ $18.42\times10^3$ kL (bonded imports of gas/diesel oil)<br>+ $83.06\times10^3$ kL (imports of fuel oil A excluding bonded imports)<br>+ 0 kL (bonded imports of fuel oil A)<br>= $612.44\times10^3$ kL;<br>$612.44\times10^3$ kL × 0.843 t/kL (density) = $516\times10^3$ t ] |

### *c) Differences in imports of coking coal*

<ERT findings on FCCC/ARR/2006/JPN>

Furthermore, the figures for imports of coking coal are systematically lower in the CRF tables than those in the IEA statistics, with the largest discrepancy occurring in 1999.

<Explanation: Imports of coking coal>

The imported amounts of coking coal in the CRF and the IEA statistics in physical units are basically the same.

Table A 4-5 Imports of coking coal in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Imports: $47{,}347.40\times10^3$ t<br><br><Remarks><br>The simple sum of coking coal and pulverized coal injection (PCI) coal is reported in the CRF.<br>Coking coal: $47{,}347.40\times10^3$ t<br>PCI coal: $0\times10^3$ t | Imports: $47{,}347.40\times10^3$ t |

### *d) Differences in stock changes in liquid and gaseous fuels*

<ERT findings on FCCC/ARR/2006/JPN>

In addition, the data on stock changes are not consistent for liquid and gaseous fuels.

It should be noted that the plus-minus signs of stock changes in the CRF differ from those of the IEA. The changes in the CRF are defined as plus for stock increase and as minus for stock release, while the changes in the IEA are defined as minus for stock increase and as plus for stock release.

<Explanation 1: Changes in crude oil stock>

The difference between the CRF table and the IEA statistics with respect to changes in crude oil stock occurred because the figures reported in the CRF were calculated using the stock of crude oil after customs clearance (or more precisely, after inspection in the presence of customs officers). The stock changes reported in the IEA statistics were calculated based on stock that included crude oil carried by oil tankers in Japanese territorial waters but which was yet to clear customs as well as the crude oil in

the national stockpile. This discrepancy arose because the UNFCCC and the IEA had different objectives.

Table A 4-6 Changes in crude oil stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: -327.54×$10^3$ kL | Stock changes: 896×$10^3$ t |

<Explanation 2: Changes in NGL stock>

Stock changes concerning NGL in FY2017 were reported as 0 in the CRF and the IEA Statistics.

The NGL stock changes reported in the IEA statistics were 0 because the NGL stock figure in the Monthly Oil Statistics (MOS) of the IEA was 0. This discrepancy resulted from the direction given by the IEA that the figures in the IEA statistics must be consistent with the MOS figures. Furthermore, the figures for "stock changes" required by the CRF tables are not included in the MOS. On the other hand, the MOS requires figures for opening stock and closing stock, but Japan does not collect such statistical data for NGL. As a result, Japan reported 0 values to the IEA for both opening stock and closing stock data for the MOS.

Due to lack of statistical data for stock changes in NGL, the estimated value calculated as a difference between supply and consumption amount is reported as stock change in the CRF tables. The estimated value is 0 in FY2017.

<Explanation 3: Changes in gasoline stock>

The figures for stock of gasoline reported in the CRF tables are changes of gasoline stock only, whereas the values relating to the stock of gasoline in the IEA statistics are changes of gasoline stock plus national stockpile minus other gasoline stock. Other gasoline stock is reported as stock change of white spirit in the IEA statistics.

Table A 4-7 Changes in gasoline stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: -104.78×$10^3$ kL | Stock changes in motor gasoline: 77×$10^3$ t<br><br><Remarks><br>The values relating to the stock of motor gasoline in the IEA statistics are changes of gasoline stock plus national stockpile minus other gasoline stock. |

<Explanation 4: Changes in jet kerosene stock>

The figures for changes in jet kerosene stock reported in the CRF tables are basically the same as the figures in the IEA statistics.

Table A 4-8 Changes in jet kerosene stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: $79\times10^3$ kL (final figure) | Stock changes: $-61\times10^3$ t (preliminary figures)<br>[ $-79\times10^3$ kL × 0.7834 t/kL (density) = $-61\times10^3$ t ]<br><br><Remarks><br>The difference is calculated from the amount which is rounded off to whole after multiplying the stock volume at the end of fiscal year by density. Therefore, it sometimes slightly differs from the result which is obtained by multiplying the total changes by density. |

<Explanation 5: Changes in kerosene stock>

The figures reported in the CRF tables are changes in kerosene stock only, while the figures in the IEA statistics are the sum of the changes in kerosene stock and national stockpile of kerosene.

Table A 4-9 Changes in kerosene stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: $474.88\times10^3$ kL | Stock changes: $-386\times10^3$ t<br><br><Remarks><br>The difference is calculated from the amount which is rounded off to whole after multiplying the stock volume at the end of fiscal year by density. Therefore, it sometimes slightly differs from the result which is obtained by multiplying the total changes by density. |

<Explanation 6: Changes in gas/diesel oil stock>

The figures for gas/diesel stock reported in the CRF tables did not include stock changes in fuel oil A, while the figures in the IEA statistics included stock changes in fuel oil A and change of national stockpile of gas/diesel oil and fuel oil A.

Table A 4-10 Changes in gas/diesel oil stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: $-98.66\times10^3$ kL | Stock changes: $-136\times10^3$ t<br><br><Remarks 1><br>The figures for changes of gas/diesel oil stock reported to the IEA were the difference between the stock at the beginning of the current fiscal year and the stock at the beginning of the next fiscal year. The figures for changes of gas/diesel oil stock reported in the CRF tables were the difference between the stock at the end of the previous fiscal year and the stock at the end of the current fiscal year. Therefore, the figures in the IEA statistics sometimes slightly differ from the figures in the CRF tables even for the stock changes of gas/diesel oil only.<br><br><Remarks 2><br>The difference is calculated from the amount which is rounded off to whole after multiplying the stock volume at the end of fiscal year by density. Therefore, it sometimes slightly differs from the |

| | |
|---|---|
| | result which is obtained by multiplying the total changes by density. |

<Explanation 7: Changes in residual fuel oil stock>

The figures for residual fuel oil stock reported in the CRF tables were different from those in the IEA statistics because the CRF figures included changes in fuel oil A stock, whereas stock change data under fuel oil in the IEA statistics did not include fuel oil A. (See the explanation for the gas/diesel oil data above.)

Table A 4-11 Changes in residual fuel oil stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: $-163.07\times10^3$ kL<br><br><Breakdown><br>Stock changes in fuel oil A: $-63.17\times10^3$ kL<br>Stock changes in fuel oil C: $-99.9\times10^3$ kL | Stock changes: $90\times10^3$ t<br><br><Remarks><br>The figures for residual fuel oil stock in the IEA statistics were those reported to MOQ of IEA. The values reported to MOQ are as follows:<br>Stock of fuel oil C at the end of March 2017:<br>$1{,}308.76\times10^3$ kL×0.90 t/kL (density)<br>$= 1{,}178\times10^3$ t<br>Stock of fuel oil C at the end of March 2018:<br>$1{,}208.86\times10^3$ kL×0.90 t/kL (density)<br>$= 1{,}088\times10^3$ t<br>Stock changes:<br>$1{,}178\times10^3$ t – $1{,}088\times10^3$ t = $90\times10^3$ t<br><br>The stock changes of fuel oil C in volume unit are 1,308.76 – 1,208.86 = $99.9\times10^3$ kL. The plus-minus signs in the IEA statistics differ from those of the CRF. |

<Explanation 8: Changes in LPG stock>

The figures for changes in LPG stock reported in the CRF tables differ from those reported in IEA statistics, because the LPG stock in IEA includes the national stock.

Table A 4-12 Changes in LPG stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: $-77.9\times10^3$ t | Stock changes: $29\times10^3$ t |

<Explanation 9: Changes in naphtha stock>

The figures for changes in naphtha stock reported in the CRF tables are the same as the figures in the IEA statistics.

Table A 4-13 Changes in naphtha stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: $264.78\times10^3$ kL (final figure) | Stock changes: $-195\times10^3$ t (preliminary figures)<br>[ $-264.78\times10^3$ kL × 0.737 t/kL (density)<br>= $-195\times10^3$ t] |

<Explanation 10: Changes in bitumen stock>

The figures for changes in bitumen stock reported in the CRF tables were slightly different from the figures reported under bitumen in the IEA statistics because the bitumen data in the CRF tables included asphalt and other heavy oil and paraffin products. The IEA statistics reported figures for only asphalt under bitumen, and the figures for other heavy oil and paraffin products reported in the CRF tables under bitumen were included in the figures reported under paraffin waxes in the IEA statistics.

Table A 4-14 Changes in bitumen stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: $30.95\times10^3$ t<br><br><Breakdown><br>Asphalt: $30.19\times10^3$ t<br>Stock at the end of March 2017: $193.11\times10^3$ t<br>Stock at the end of March 2018: $223.29\times10^3$ t<br>Grease: $1.40\times10^3$ t<br>Paraffin: $-0.63\times10^3$ t | Stock changes in bitumen: $-30\times10^3$ t<br><br><Breakdown><br>Asphalt: $-30\times10^3$ t<br>Stock at the end of March 2017: $193.11\times10^3$ t<br>Stock at the end of March 2018: $223.29\times10^3$ t<br><br><Remarks><br>The figures for grease and paraffin were reported under bitumen in the CRF tables, while they were reported under paraffin waxes in the IEA statistics. |

<Explanation 11: Changes in lubricants stock>

The figures for changes in lubricants stock reported in the CRF tables are basically the same as the figures in the IEA statistics.

Table A 4-15 Changes in lubricants stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: $3.01\times10^3$ kL<br>(final figure) | Stock changes: $-3\times10^3$ t (preliminary figures)<br>[ $3.01\times10^3$ kL × 0.891 t/kL (density) = $-3\times10^3$ t]<br><br><Remarks><br>The plus-minus signs in the IEA statistics differ from those of the CRF. |

<Explanation 12: Changes in petroleum coke stock>

The figures for changes in petroleum coke stock reported in the CRF tables are the same as the figures in the IEA statistics.

Table A 4-16 Changes in petroleum coke stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: $-0.64\times10^3$ t | Stock changes: $1\times10^3$ t |

<Explanation 13: Changes in refinery feedstock stock>

The figures for changes in refinery feedstock stock reported in the CRF were different from those in the IEA statistics because the IEA statistics included the figures for stock changes in slack wax and slack coke in addition to the semi-refined products reported in the CRF tables.

The changes in slack wax and coke stocks were not reported in the CRF tables because the both items were solids used as raw materials for the production of paraffin and petroleum coke, and unlikely to be returned to oil refining processes. In addition, shipments of paraffin and petroleum coke produced using slack wax and slack coke were separately accounted for.

Table A 4-17 Changes in refinery feedstock stock in FY2017 (reference)

| CRF Table 1.A(b) | | IEA statistics | |
|---|---|---|---|
| Stock changes: $-591.97\times10^3$ kL | | Stock changes: $506\times10^3$ t | |
| <Breakdown> | | <Breakdown> | |
| Slack gasoline: | $-89.92\times10^3$ kL | Slack gasoline: | $90\times10^3$ kL |
| Slack kerosene: | $-68.67\times10^3$ kL | Slack kerosene: | $69\times10^3$ kL |
| Slack diesel oil or gas oil: | $-45.81\times10^3$ kL | Slack diesel oil or gas oil: | $46\times10^3$ kL |
| Slack fuel oil: | $-338.32\times10^3$ kL | Slack fuel oil: | $338\times10^3$ kL |
| Slack lubricant: | $-49.25\times10^3$ kL | Slack lubricant: | $49\times10^3$ kL |
| | | Slack wax: | $-4\times10^3$ kL |
| | | Slack coke: | $0\times10^3$ kL |
| | | Each of the above figures is multiplied by its density for conversion to mass for reporting purposes. | |

<Explanation 14: Changes in natural gas stock>

The figures for changes in natural gas stock (imported liquefied natural gas (LNG) and domestic natural gas) reported in the CRF tables were different from those in the IEA statistics because of the differences in the methods used for estimation of changes in the imported LNG stock and the treatment of changes in city gas stock.

The source figures for the domestic natural gas stock were the same for reporting of the CRF and the IEA statistics because the statistical data existed in Japan.

The estimation method for imported LNG were different between the CRF tables and the IEA statistics. The figures for stock changes reported to the CRF tables were the difference between the stock of imported LNG at the end of the previous fiscal year and the stock at the end of the current fiscal year, both from national statistics. The figures for stock changes reported to the IEA were the difference between the stock of imported LNG at the end of the previous fiscal year and the stock at the end of the current fiscal year, with the former calculated as one-half of the LNG import in March of the previous year, and the latter as one-half of the LNG import in March of the current year. One reason for reporting

the estimated data to IEA is that the national statistics did not catch stocks of LNG in the past and the stock data have been estimated in this way since then.

The figures for stock of natural gas reported in the CRF tables include the city gas stock, whereas the figures for stock of natural gas in the IEA statistics do not.

Table A 4-18 Changes in natural gas stock in FY2017 (reference)

| CRF Table 1.A(b) | IEA statistics |
|---|---|
| Stock changes: -8,114 TJ (GCV)<br><br><Breakdown><br>Stock changes in LNG: -5,693 TJ<br>Stock changes in domestic natural gas: 107 TJ<br>Stock changes in city gas: -2,529 TJ | Stock changes: 5,576 TJ (GCV)<br><br><Breakdown><br>Stock changes in LNG: 5,683 TJ<br>Stock changes in domestic natural gas: -107 TJ |

## A4.2. General Energy Statistics

### A4.2.1 General Energy Statistics Overview

The data given in the *General Energy Statistics* compiled by the Agency for Natural Resources and Energy were used for the activity data of fuel combustion in energy sector.

The *General Energy Statistics* (Energy Balance Table) provides a comprehensive overview of domestic energy supply and demand to grasp what are converted from energy sources, such as coal, oil, natural gas and others, provided in Japan and what are consumed in what sectors. The supply/conversion and consumption data in *General Energy Statistics* use official statistics and are structured with the minimum of estimation and adjustment. (Kainou, 2012)

*General Energy Statistics* (Energy Balance Table) indicates an overview of domestic energy supply and demand, shows the main energy sources used in Japan as "Columns" and the supply, conversion and consumption sectors as "Rows", in a matrix. Specifically, columns comprise 13 major categories (coal [$0100[1]], coal products [$0200], crude oil [$0300], oil products [$0400], natural gas [$0500], city gas [$0600], renewable energy (excl. hydro) [$0700], hydraulic power generation (excl. pumped) [$0800], pumped storage [$0900], effective recovery use of wasted energy [$1000], nuclear power generation [$1100], electricity [$1200], and heat [$1300]) and the necessary sub-categories and a more detailed breakdown of the sub-categories. The *General Energy Statistics* supply and demand sectors (rows) comprise 3 major sectors — primary energy supply [#01], energy transformation & own use [#08], and final energy consumption [#19] — plus the necessary sub-categories and a more detailed breakdown of the sub-categories. (Refer to the following *General Energy Statistics* simplified table.)

The *General Energy Statistics* (complete Energy Balance Tables) for the years since FY1990 is available on the following internet site:

**http://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2**

The following is the energy balance simplified table (Table A 4-19 –Table A 4-22).

[1] Code number of the *General Energy Statistics* (Energy Balance Table)

# Table A 4-19 Energy balance simplified table (General Energy Statistics, FY1990, 1995)

| *1990FY* | *Row $* | *$0100* | *$0200* | *$0300* | *$0400* | *$0500* | *$0600* | *$0700* | *$0800* | *$0900* | *$1000* | *$1100* | *$1200* | *$1300* | *$1400* | *$1401* | *$1402* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ** | | Coal | Coal Products | Crude Oil | Oil Products | Natural Gas | City Gas | Renewable (excl. hydro) | Hydraulic Power Generation (excl. pumped) | Pumped Storage | Effective Recovery Use of Wasted Energy | Nuclear Power Generation | Electricity | Heat | Total | Energy Use Total | Non-Energy Use Total |
| **Line #** | | | | | | | | | | | | | | | | | |
| #01 | Primary Energy Supply | 3,357,112 | -39,341 | 8,981,710 | 2,026,426 | 2,056,326 | 0 | 265,253 | 818,519 | 0 | 317,978 | 1,883,500 | 0 | 0 | 19,667,485 | 18,065,096 | 1,602,388 |
| #02 | Indigenously Produced | 193,762 | 0 | 24,484 | 0 | 89,203 | 0 | 264,134 | 818,519 | 0 | 317,978 | 1,883,500 | 0 | 0 | 3,591,581 | 0 | 0 |
| #03 | Import | 3,161,715 | 15,352 | 9,139,187 | 2,341,168 | 1,967,475 | 0 | 1,119 | 0 | 0 | 0 | 0 | 0 | 0 | 16,626,016 | 0 | 0 |
| #04 | Total Primary Energy Supply | 3,355,476 | 15,352 | 9,163,671 | 2,341,168 | 2,056,678 | 0 | 265,254 | 818,519 | 0 | 317,978 | 1,883,500 | 0 | 0 | 20,217,596 | 18,615,208 | 1,602,388 |
| #05 | Export | -53 | -56,644 | 0 | -292,955 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | -349,653 | 0 | 0 |
| #06 | Stockpile Change / Supply (+: withdrawal/-: build-up) | 1,689 | 1,951 | -181,961 | -21,786 | -352 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -200,458 | 0 | 0 |
| #07 | Domestic Primary Energy Supply (Supply) | 3,357,112 | -39,341 | 8,981,710 | 2,026,426 | 2,056,326 | 0 | 265,253 | 818,519 | 0 | 317,978 | 1,883,500 | 0 | 0 | 19,667,485 | 18,065,096 | 1,602,388 |
| | (Demand) | | | | | | | | | | | | | | 19,784,409 | 18,182,020 | 1,602,388 |
| #08 | Energy Transformation & Own Use | -3,151,561 | 1,278,447 | -8,961,984 | 5,499,143 | -1,980,245 | 510,901 | -210,804 | -818,519 | 0 | -317,978 | -1,883,500 | 2,785,371 | 1,017,851 | -6,232,880 | -6,170,658 | -62,222 |
| #09 | Manufacture of Coal Products (+: output/-: input) | -2,142,047 | 1,934,969 | 0 | -27,085 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -234,162 | -234,162 | 0 |
| #10 | Oil Products (+: output/-: input) | 0 | 0 | -8,073,053 | 8,125,199 | 5,121 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -94,149 | -36,882 | 0 | -36,882 |
| #11 | Gas Conversion and Production (+: output/-: input) | 0 | -19,178 | 0 | -161,220 | -503,899 | 683,704 | -101 | 0 | 0 | -445 | 0 | 0 | 0 | -1,139 | -1,139 | 0 |
| #12 | Power Generation | -673,045 | -209,619 | -874,209 | -1,052,475 | -1,529,799 | -65 | -13,827 | -752,524 | 0 | 0 | -1,882,503 | 2,679,366 | 0 | -4,308,700 | -4,308,700 | 0 |
| #13 | Auto Power Generation | -162,252 | -132,541 | 0 | -432,338 | -4,367 | -27,139 | -87,643 | -65,995 | 0 | -170,247 | -997 | 407,088 | 0 | -676,431 | -676,431 | 0 |
| #14 | Auto Steam Generation | -147,046 | -135,509 | 0 | -640,435 | -4,241 | -61,907 | -109,183 | 0 | 0 | -145,775 | 0 | 0 | 1,106,351 | -137,745 | -137,745 | 0 |
| #15 | District Heat Supply | -824 | 0 | 0 | -2,592 | 0 | -6,169 | -37 | 0 | 0 | -1,511 | 0 | -1,229 | 8,445 | -3,916 | -3,916 | 0 |
| #16 | Own Use and Loss | -3,015 | -161,697 | -1,017 | -319,060 | -238 | -20,889 | 0 | 0 | 0 | 0 | 0 | -299,854 | -2,796 | -808,566 | -808,566 | 0 |
| #17 | Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up) | -20,454 | -858 | -13,705 | 1,607 | 542 | 0 | -13 | 0 | 0 | 0 | 0 | 0 | 0 | -32,881 | 0 | -32,881 |
| #18 | Statistical Discrepancy (+: excess/-: shortage) | -195,600 | 12,361 | 19,725 | 610,760 | 18,443 | 967 | 7,398 | 0 | 0 | 0 | 0 | 32,051 | -3,906 | 502,201 | 428,368 | 73,832 |
| #19 | Final Energy Consumption | 401,151 | 1,226,745 | 0 | 7,525,569 | 57,638 | 510,901 | 54,449 | 0 | 0 | 0 | 0 | 2,753,319 | 1,021,756 | 13,551,529 | 12,011,363 | 1,540,166 |
| #20 | Industry | 401,119 | 1,223,865 | 0 | 3,918,348 | 57,638 | 167,823 | 7,398 | 0 | 0 | 0 | 0 | 2,036,799 | 1,020,472 | 8,833,463 | 7,334,048 | 1,499,414 |
| #21 | Agriculture, Fishery, Mining and Construction | 133 | 5,090 | 0 | 676,135 | 1,753 | 2,182 | 0 | 0 | 0 | 0 | 0 | 82,174 | 2,276 | 769,744 | 538,526 | 231,218 |
| #22 | Manufacturing | 400,852 | 1,218,775 | 0 | 2,186,936 | 55,885 | 100,469 | 0 | 0 | 0 | 0 | 0 | 1,453,695 | 935,052 | 6,351,664 | 5,157,299 | 1,194,364 |
| #23 | Food, Beverages, Tobacco and Feed | 48 | 0 | 0 | 52,839 | 0 | 8,102 | 0 | 0 | 0 | 0 | 0 | 55,667 | 49,454 | 166,110 | 166,110 | 0 |
| #24 | Textile Mill Products | 544 | 0 | 0 | 50,419 | 0 | 4,699 | 0 | 0 | 0 | 0 | 0 | 70,615 | 92,180 | 218,458 | 218,458 | 0 |
| #25 | Pulp, Paper and Paper Products | 126 | 0 | 0 | 31,978 | 2 | 4,731 | 0 | 0 | 0 | 0 | 0 | 130,637 | 274,119 | 441,594 | 441,594 | 0 |
| #26 | Chemical and Allied Products, Oil and Coal Products | 6,633 | 46,779 | 0 | 1,458,711 | 25,021 | 9,582 | 0 | 0 | 0 | 0 | 0 | 209,979 | 234,151 | 1,990,856 | 809,905 | 1,180,951 |
| #27 | Ceramic, Stone and Clay Products | 236,521 | 37,016 | 0 | 202,373 | 854 | 13,546 | 0 | 0 | 0 | 0 | 0 | 110,399 | 42,437 | 643,147 | 630,418 | 12,728 |
| #28 | Iron and Steel | 140,959 | 1,109,711 | 0 | 126,609 | 24,987 | 11,084 | 0 | 0 | 0 | 0 | 0 | 271,771 | 110,581 | 1,795,703 | 1,795,017 | 685 |
| #29 | Non-Ferrous Metals | 15,811 | 11,378 | 0 | 56,323 | 322 | 9,162 | 0 | 0 | 0 | 0 | 0 | 61,575 | 17,411 | 171,982 | 171,982 | 0 |
| #30 | Machinery | 15 | 13,891 | 0 | 170,765 | 4,698 | 33,072 | 0 | 0 | 0 | 0 | 0 | 395,851 | 76,719 | 695,011 | 695,011 | 0 |
| #31 | Miscellaneous | 194 | 0 | 0 | 36,918 | 0 | 6,489 | 0 | 0 | 0 | 0 | 0 | 147,202 | 38,000 | 228,803 | 228,803 | 0 |
| #32 | Commercial Industry | 133 | 0 | 0 | 1,055,278 | 0 | 65,172 | 7,398 | 0 | 0 | 0 | 0 | 500,931 | 83,144 | 1,712,055 | 1,638,223 | 73,832 |
| #33 | Residential | 0 | 2,880 | 0 | 606,330 | 0 | 343,074 | 47,051 | 0 | 0 | 0 | 0 | 656,006 | 1,284 | 1,656,625 | 1,656,625 | 0 |
| #34 | Transportation | 33 | 0 | 0 | 3,000,891 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 60,514 | 0 | 3,061,441 | 3,020,689 | 40,752 |
| #35 | Passenger | 33 | 0 | 0 | 1,513,029 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 56,610 | 0 | 1,569,672 | 1,537,748 | 31,923 |
| #36 | Freight | 0 | 0 | 0 | 1,487,862 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3,905 | 0 | 1,491,770 | 1,482,941 | 8,829 |
| #37 | Non-energy and Feedstock Use | 6,063 | 26,437 | 0 | 1,493,632 | 13,997 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,540,166 | 0 | 1,540,166 |

| *1995FY* | *Row $* | *$0100* | *$0200* | *$0300* | *$0400* | *$0500* | *$0600* | *$0700* | *$0800* | *$0900* | *$1000* | *$1100* | *$1200* | *$1300* | *$1400* | *$1401* | *$1402* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ** | | Coal | Coal Products | Crude Oil | Oil Products | Natural Gas | City Gas | Renewable (excl. hydro) | Hydraulic Power Generation (excl. pumped) | Pumped Storage | Effective Recovery Use of Wasted Energy | Nuclear Power Generation | Electricity | Heat | Total | Energy Use Total | Non-Energy Use Total |
| **Line #** | | | | | | | | | | | | | | | | | |
| #01 | Primary Energy Supply | 3,725,382 | -91,908 | 10,166,812 | 1,642,489 | 2,477,257 | 0 | 270,876 | 728,509 | 0 | 380,411 | 2,693,458 | 0 | 0 | 21,993,285 | 20,191,531 | 1,801,754 |
| #02 | Indigenously Produced | 153,374 | 0 | 32,455 | 0 | 95,250 | 0 | 268,391 | 728,509 | 0 | 380,411 | 2,693,458 | 0 | 0 | 4,351,848 | 0 | 0 |
| #03 | Import | 3,575,648 | 18,016 | 10,171,504 | 2,226,378 | 2,382,172 | 0 | 2,491 | 0 | 0 | 0 | 0 | 0 | 0 | 18,376,210 | 0 | 0 |
| #04 | Total Primary Energy Supply | 3,729,022 | 18,016 | 10,203,959 | 2,226,378 | 2,477,422 | 0 | 270,882 | 728,509 | 0 | 380,411 | 2,693,458 | 0 | 0 | 22,728,057 | 20,926,303 | 1,801,754 |
| #05 | Export | -75 | -103,811 | 0 | -717,045 | 0 | 0 | -6 | 0 | 0 | 0 | 0 | 0 | 0 | -820,938 | 0 | 0 |
| #06 | Stockpile Change / Supply (+: withdrawal/-: build-up) | -3,565 | -6,113 | -37,147 | 133,156 | -165 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 86,166 | 0 | 0 |
| #07 | Domestic Primary Energy Supply (Supply) | 3,725,382 | -91,908 | 10,166,812 | 1,642,489 | 2,477,257 | 0 | 270,876 | 728,509 | 0 | 380,411 | 2,693,458 | 0 | 0 | 21,993,285 | 20,191,531 | 1,801,754 |
| | (Demand) | | | | | | | | | | | | | | 21,958,385 | 20,156,631 | 1,801,754 |
| #08 | Energy Transformation & Own Use | -3,316,691 | 1,148,397 | -10,063,320 | 6,946,884 | -2,418,050 | 685,997 | -224,089 | -728,509 | 0 | -380,411 | -2,693,458 | 3,146,437 | 1,055,422 | -6,841,391 | -6,776,339 | -65,052 |
| #09 | Manufacture of Coal Products (+: output/-: input) | -1,899,695 | 1,792,057 | 0 | -24,231 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -131,869 | -131,869 | 0 |
| #10 | Oil Products (+: output/-: input) | 0 | 0 | -9,375,750 | 9,417,456 | 5,773 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -103,260 | -55,781 | 0 | -55,781 |
| #11 | Gas Conversion and Production (+: output/-: input) | 0 | -12,205 | 0 | -180,538 | -723,679 | 915,060 | -37 | 0 | 0 | 0 | 0 | 0 | 0 | -1,400 | -1,400 | 0 |
| #12 | Power Generation | -1,072,304 | -219,914 | -669,401 | -835,632 | -1,750,119 | -663 | -27,002 | -667,399 | 0 | 0 | -2,691,935 | 3,054,038 | 0 | -4,880,332 | -4,880,332 | 0 |
| #13 | Auto Power Generation | -182,384 | -138,015 | -539 | -439,103 | -5,482 | -45,424 | -97,713 | -61,110 | 0 | -202,462 | -1,523 | 440,632 | 0 | -733,124 | -733,124 | 0 |
| #14 | Auto Steam Generation | -160,158 | -127,828 | -669 | -672,325 | -4,887 | -98,261 | -99,257 | 0 | 0 | -174,443 | 0 | 0 | 1,145,849 | -191,980 | -191,980 | 0 |
| #15 | District Heat Supply | -638 | 0 | 0 | -1,601 | 0 | -11,101 | -99 | 0 | 0 | -3,505 | 0 | -2,548 | 15,985 | -3,507 | -3,507 | 0 |
| #16 | Own Use and Loss | -2,978 | -139,799 | -1,058 | -322,242 | -86 | -19,128 | 0 | 0 | 0 | 0 | 0 | -345,686 | -3,152 | -834,129 | -834,129 | 0 |
| #17 | Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up) | 3,103 | -7,537 | -15,903 | -3,893 | 5,944 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | -18,265 | 0 | -18,265 |
| #18 | Statistical Discrepancy (+: excess/-: shortage) | -45,916 | 425 | 103,492 | 597,548 | 991 | 1,724 | 6,146 | 0 | 0 | 0 | 0 | 8,298 | -32,390 | 640,318 | 561,034 | 79,283 |
| #19 | Final Energy Consumption | 454,606 | 1,056,064 | 0 | 8,589,373 | 58,216 | 685,997 | 46,786 | 0 | 0 | 0 | 0 | 3,138,139 | 1,087,812 | 15,116,994 | 13,380,291 | 1,736,703 |
| #20 | Industry | 454,575 | 1,054,427 | 0 | 4,287,233 | 58,216 | 286,618 | 6,182 | 0 | 0 | 0 | 0 | 2,252,156 | 1,086,444 | 9,485,851 | 7,781,649 | 1,704,203 |
| #21 | Agriculture, Fishery, Mining and Construction | 82 | 1,590 | 0 | 632,231 | 1,571 | 2,963 | 0 | 0 | 0 | 0 | 0 | 80,014 | 1,944 | 720,394 | 511,426 | 208,969 |
| #22 | Manufacturing | 454,325 | 1,052,837 | 0 | 2,523,618 | 56,645 | 160,422 | 36 | 0 | 0 | 0 | 0 | 1,407,034 | 969,692 | 6,624,609 | 5,208,658 | 1,415,951 |
| #23 | Food, Beverages, Tobacco and Feed | 82 | 0 | 0 | 63,040 | 0 | 14,756 | 0 | 0 | 0 | 0 | 0 | 65,040 | 70,106 | 213,026 | 213,026 | 0 |
| #24 | Textile Mill Products | 823 | 0 | 0 | 46,240 | 14 | 6,320 | 0 | 0 | 0 | 0 | 0 | 64,732 | 92,448 | 210,577 | 210,577 | 0 |
| #25 | Pulp, Paper and Paper Products | 0 | 0 | 0 | 35,616 | 5 | 10,330 | 36 | 0 | 0 | 0 | 0 | 132,158 | 274,405 | 452,551 | 452,551 | 0 |
| #26 | Chemical and Allied Products, Oil and Coal Products | 6,103 | 31,971 | 0 | 1,779,418 | 21,427 | 16,674 | 0 | 0 | 0 | 0 | 0 | 210,028 | 248,201 | 2,313,821 | 913,726 | 1,400,096 |
| #27 | Ceramic, Stone and Clay Products | 236,215 | 34,354 | 0 | 216,059 | 1,758 | 15,743 | 0 | 0 | 0 | 0 | 0 | 104,388 | 43,204 | 651,722 | 636,075 | 15,647 |
| #28 | Iron and Steel | 200,658 | 962,201 | 0 | 123,530 | 26,217 | 23,652 | 0 | 0 | 0 | 0 | 0 | 257,705 | 112,652 | 1,706,614 | 1,706,406 | 208 |
| #29 | Non-Ferrous Metals | 10,236 | 9,869 | 0 | 54,931 | 96 | 10,237 | 0 | 0 | 0 | 0 | 0 | 51,308 | 14,066 | 150,743 | 150,743 | 0 |
| #30 | Machinery | 4 | 14,444 | 0 | 166,021 | 7,128 | 54,690 | 0 | 0 | 0 | 0 | 0 | 393,794 | 73,276 | 709,357 | 709,357 | 0 |
| #31 | Miscellaneous | 203 | 0 | 0 | 38,762 | 0 | 8,020 | 0 | 0 | 0 | 0 | 0 | 127,879 | 41,334 | 216,198 | 216,198 | 0 |
| #32 | Commercial Industry | 168 | 0 | 0 | 1,131,385 | 0 | 123,233 | 6,146 | 0 | 0 | 0 | 0 | 765,108 | 114,808 | 2,140,848 | 2,061,565 | 79,283 |
| #33 | Residential | 0 | 1,637 | 0 | 706,407 | 0 | 399,238 | 40,605 | 0 | 0 | 0 | 0 | 818,465 | 1,368 | 1,967,719 | 1,967,719 | 0 |
| #34 | Transportation | 31 | 0 | 0 | 3,595,734 | 0 | 141 | 0 | 0 | 0 | 0 | 0 | 67,518 | 0 | 3,663,424 | 3,630,924 | 32,500 |
| #35 | Passenger | 31 | 0 | 0 | 1,949,500 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 63,676 | 0 | 2,013,227 | 1,988,259 | 24,968 |
| #36 | Freight | 0 | 0 | 0 | 1,646,234 | 0 | 121 | 0 | 0 | 0 | 0 | 0 | 3,842 | 0 | 1,650,197 | 1,642,665 | 7,532 |
| #37 | Non-energy and Feedstock Use | 5,446 | 26,024 | 0 | 1,693,199 | 12,033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,736,703 | 0 | 1,736,703 |

# Table A 4-20 Energy balance simplified table (General Energy Statistics, FY2000, 2005)

| *2000FY* | *Row $* | *$0100* | *$0200* | *$0300* | *$0400* | *$0500* | *$0600* | *$0700* | *$0800* | *$0900* | *$1000* | *$1100* | *$1200* | *$1300* | *$1400* | *$1401* | *$1402* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ** | | Coal | Coal Products | Crude Oil | Oil Products | Natural Gas | City Gas | Renewable (excl. hydro) | Hydraulic Power Generation (excl. pumped) | Pumped Storage | Effective Recovery Use of Wasted Energy | Nuclear Power Generation | Electricity | Heat | Total | Energy Use Total | Non-Energy Use Total |
| **Line #** | | | | | | | | | | | | | | | | | |
| #01 | Primary Energy Supply | 4,202,973 | -3,821 | 9,634,832 | 1,528,928 | 3,058,878 | 0 | 273,741 | 745,903 | 0 | 409,621 | 2,858,092 | 0 | 0 | 22,709,148 | 20,834,599 | 1,874,549 |
| #02 | Indigenously Produced | 66,683 | 0 | 28,034 | 0 | 106,340 | 0 | 269,008 | 745,903 | 0 | 409,621 | 2,858,092 | 0 | 0 | 4,483,681 | 0 | 0 |
| #03 | Import | 4,139,375 | 76,219 | 9,733,303 | 2,252,207 | 2,952,403 | 0 | 4,746 | 0 | 0 | 0 | 0 | 0 | 0 | 19,158,252 | 0 | 0 |
| #04 | Total Primary Energy Supply | 4,206,057 | 76,219 | 9,761,337 | 2,252,207 | 3,058,742 | 0 | 273,754 | 745,903 | 0 | 409,621 | 2,858,092 | 0 | 0 | 23,641,932 | 21,767,383 | 1,874,549 |
| #05 | Export | -112 | -78,077 | 0 | -617,396 | 0 | 0 | -13 | 0 | 0 | 0 | 0 | 0 | 0 | -695,597 | 0 | 0 |
| #06 | Stockpile Change / Supply (+: withdrawal/-: build-up) | -2,972 | -1,963 | -126,505 | -105,883 | 136 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -237,187 | 0 | 0 |
| #07 | Domestic Primary Energy Supply (Supply) | 4,202,973 | -3,821 | 9,634,832 | 1,528,928 | 3,058,878 | 0 | 273,741 | 745,903 | 0 | 409,621 | 2,858,092 | 0 | 0 | 22,709,148 | 20,834,599 | 1,874,549 |
| | (Demand) | | | | | | | | | | | | | | 22,728,662 | 20,854,113 | 1,874,549 |
| #08 | Energy Transformation & Own Use | -3,705,208 | 1,114,629 | -9,622,842 | 7,212,868 | -3,022,830 | 806,834 | -223,793 | -745,903 | 0 | -403,364 | -2,858,092 | 3,414,136 | 1,158,623 | -6,874,942 | -6,769,391 | -105,551 |
| #09 | Manufacture of Coal Products (+: output/-: input) | -1,738,478 | 1,664,686 | 0 | -33,697 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -107,489 | -107,489 | 0 |
| #10 | Oil Products (+: output/-: input) | 0 | 0 | -9,331,059 | 9,412,940 | 6,972 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -137,327 | -48,474 | 0 | -48,474 |
| #11 | Gas Conversion and Production (+: output/-: input) | 0 | -9,573 | 0 | -150,046 | -925,341 | 1,084,614 | -31 | 0 | 0 | 0 | 0 | 0 | 0 | -377 | -377 | 0 |
| #12 | Power Generation | -1,513,154 | -219,155 | -301,245 | -544,697 | -2,130,517 | -1,632 | -27,668 | -679,439 | 0 | 0 | -2,851,772 | 3,320,803 | 0 | -4,948,477 | -4,948,477 | 0 |
| #13 | Auto Power Generation | -222,305 | -114,011 | -83 | -431,572 | -9,034 | -71,592 | -99,374 | -66,464 | 0 | -178,038 | -6,320 | 457,666 | 0 | -741,126 | -741,126 | 0 |
| #14 | Auto Steam Generation | -198,902 | -69,828 | -135 | -673,602 | -7,845 | -128,034 | -96,581 | 0 | 0 | -220,572 | 0 | 0 | 1,276,604 | -118,895 | -118,895 | 0 |
| #15 | District Heat Supply | -708 | 0 | 0 | -1,692 | 0 | -14,515 | -116 | 0 | 0 | -4,755 | 0 | -3,940 | 22,910 | -2,817 | -2,817 | 0 |
| #16 | Own Use and Loss | -4,240 | -132,502 | -518 | -335,337 | -519 | -13,139 | 0 | 0 | 0 | 0 | 0 | -360,392 | -3,564 | -850,210 | -850,210 | 0 |
| #17 | Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up) | -27,422 | -4,989 | 10,199 | 3,549 | -5,414 | 0 | -22 | 0 | 0 | 1 | 0 | 0 | 0 | -24,098 | 0 | -24,098 |
| #18 | Statistical Discrepancy (+: excess/-: shortage) | 75,778 | 60,164 | 11,990 | 579,916 | -14,343 | 1,900 | 4,904 | 0 | 0 | 0 | 0 | -87,507 | -65,597 | 567,206 | 492,144 | 75,062 |
| #19 | Final Energy Consumption | 421,987 | 1,050,644 | 0 | 8,741,796 | 50,391 | 806,834 | 49,948 | 0 | 0 | 6,256 | 0 | 3,501,643 | 1,224,220 | 15,853,720 | 14,084,722 | 1,768,998 |
| #20 | Industry | 421,941 | 1,050,644 | 0 | 4,217,503 | 50,391 | 386,796 | 17,046 | 0 | 0 | 6,256 | 0 | 2,534,187 | 1,222,914 | 9,907,679 | 8,172,843 | 1,734,835 |
| #21 | Agriculture, Fishery, Mining and Construction | 47 | 1,744 | 0 | 553,302 | 1,930 | 2,959 | 0 | 0 | 0 | 0 | 0 | 75,110 | 1,530 | 636,622 | 470,277 | 166,345 |
| #22 | Manufacturing | 421,754 | 1,048,900 | 0 | 2,490,337 | 48,461 | 178,337 | 12,142 | 0 | 0 | 6,256 | 0 | 1,442,530 | 1,076,657 | 6,725,374 | 5,231,946 | 1,493,428 |
| #23 | Food, Beverages, Tobacco and Feed | 34 | 0 | 0 | 66,924 | 0 | 21,171 | 0 | 0 | 0 | 0 | 0 | 76,030 | 79,504 | 243,663 | 243,663 | 0 |
| #24 | Textile Mill Products | 257 | 0 | 0 | 34,638 | 1 | 5,858 | 0 | 0 | 0 | 0 | 0 | 56,856 | 79,810 | 177,420 | 177,420 | 0 |
| #25 | Pulp, Paper and Paper Products | 0 | 0 | 0 | 26,149 | 71 | 8,250 | 12,142 | 0 | 0 | 0 | 0 | 140,751 | 287,154 | 474,517 | 474,517 | 0 |
| #26 | Chemical and Allied Products, Oil and Coal Products | 556 | 36,239 | 0 | 1,872,199 | 23,397 | 22,408 | 0 | 0 | 0 | 0 | 0 | 212,850 | 352,672 | 2,520,320 | 1,028,207 | 1,492,113 |
| #27 | Ceramic, Stone and Clay Products | 185,818 | 24,256 | 0 | 171,471 | 1,681 | 19,036 | 0 | 0 | 0 | 6,235 | 0 | 96,439 | 33,996 | 538,932 | 537,768 | 1,164 |
| #28 | Iron and Steel | 230,744 | 973,938 | 0 | 109,345 | 22,154 | 36,208 | 0 | 0 | 0 | 0 | 0 | 261,843 | 109,404 | 1,743,636 | 1,743,484 | 152 |
| #29 | Non-Ferrous Metals | 4,209 | 10,185 | 0 | 49,559 | 238 | 14,836 | 0 | 0 | 0 | 19 | 0 | 57,029 | 23,072 | 159,147 | 159,147 | 0 |
| #30 | Machinery | 0 | 4,282 | 0 | 123,449 | 919 | 37,437 | 0 | 0 | 0 | 2 | 0 | 389,555 | 65,343 | 620,985 | 620,985 | 0 |
| #31 | Miscellaneous | 137 | 0 | 0 | 36,602 | 0 | 13,133 | 0 | 0 | 0 | 0 | 0 | 151,177 | 45,703 | 246,753 | 246,753 | 0 |
| #32 | Commercial Industry | 140 | 0 | 0 | 1,173,863 | 0 | 205,500 | 4,904 | 0 | 0 | 0 | 0 | 1,016,548 | 144,727 | 2,545,682 | 2,470,621 | 75,062 |
| #33 | Residential | 0 | 0 | 0 | 768,778 | 0 | 418,897 | 32,902 | 0 | 0 | 0 | 0 | 900,592 | 1,306 | 2,122,475 | 2,122,475 | 0 |
| #34 | Transportation | 46 | 0 | 0 | 3,755,515 | 0 | 1,141 | 0 | 0 | 0 | 0 | 0 | 66,864 | 0 | 3,823,565 | 3,789,403 | 34,162 |
| #35 | Passenger | 46 | 0 | 0 | 2,188,610 | 0 | 172 | 0 | 0 | 0 | 0 | 0 | 63,385 | 0 | 2,252,212 | 2,226,404 | 25,808 |
| #36 | Freight | 0 | 0 | 0 | 1,566,905 | 0 | 969 | 0 | 0 | 0 | 0 | 0 | 3,479 | 0 | 1,571,353 | 1,562,999 | 8,354 |
| #37 | Non-energy and Feedstock Use | 19 | 19,641 | 0 | 1,740,814 | 8,523 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,768,998 | 0 | 1,768,998 |

| *2005FY* | *Row $* | *$0100* | *$0200* | *$0300* | *$0400* | *$0500* | *$0600* | *$0700* | *$0800* | *$0900* | *$1000* | *$1100* | *$1200* | *$1300* | *$1400* | *$1401* | *$1402* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ** | | Coal | Coal Products | Crude Oil | Oil Products | Natural Gas | City Gas | Renewable (excl. hydro) | Hydraulic Power Generation (excl. pumped) | Pumped Storage | Effective Recovery Use of Wasted Energy | Nuclear Power Generation | Electricity | Heat | Total | Energy Use Total | Non-Energy Use Total |
| **Line #** | | | | | | | | | | | | | | | | | |
| #01 | Primary Energy Supply | 4,765,771 | 15,795 | 9,517,554 | 1,173,834 | 3,291,376 | 0 | 381,401 | 671,487 | 0 | 428,091 | 2,660,242 | 0 | 0 | 22,905,552 | 20,957,622 | 1,947,930 |
| #02 | Indigenously Produced | 28,110 | 0 | 33,051 | 0 | 134,612 | 0 | 375,991 | 671,487 | 0 | 428,091 | 2,660,242 | 0 | 0 | 4,331,584 | 0 | 0 |
| #03 | Import | 4,737,747 | 81,303 | 9,473,040 | 2,127,563 | 3,156,903 | 0 | 5,461 | 0 | 0 | 0 | 0 | 0 | 0 | 19,582,017 | 0 | 0 |
| #04 | Total Primary Energy Supply | 4,765,856 | 81,303 | 9,506,092 | 2,127,563 | 3,291,515 | 0 | 381,452 | 671,487 | 0 | 428,091 | 2,660,242 | 0 | 0 | 23,913,601 | 21,965,671 | 1,947,930 |
| #05 | Export | -85 | -49,279 | -4 | -880,259 | 0 | 0 | -51 | 0 | 0 | 0 | 0 | 0 | 0 | -929,678 | 0 | 0 |
| #06 | Stockpile Change / Supply (+: withdrawal/-: build-up) | 0 | -16,228 | 11,466 | -73,470 | -138 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -78,371 | 0 | 0 |
| #07 | Domestic Primary Energy Supply (Supply) | 4,765,771 | 15,795 | 9,517,554 | 1,173,834 | 3,291,376 | 0 | 381,401 | 671,487 | 0 | 428,091 | 2,660,242 | 0 | 0 | 22,905,552 | 20,957,622 | 1,947,930 |
| | (Demand) | | | | | | | | | | | | | | 22,954,739 | 21,006,810 | 1,947,930 |
| #08 | Energy Transformation & Own Use | -4,310,565 | 1,121,057 | -9,510,672 | 7,253,280 | -3,227,280 | 966,321 | -354,038 | -671,487 | 0 | -421,786 | -2,660,242 | 3,561,818 | 1,200,062 | -7,053,534 | -6,930,734 | -122,800 |
| #09 | Manufacture of Coal Products (+: output/-: input) | -1,730,636 | 1,633,464 | 0 | -18,801 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -115,974 | -115,974 | 0 |
| #10 | Oil Products (+: output/-: input) | 0 | 0 | -9,209,723 | 9,278,313 | 8,203 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -139,784 | -62,992 | 0 | -62,992 |
| #11 | Gas Conversion and Production (+: output/-: input) | 0 | -1,994 | 0 | -99,300 | -1,315,246 | 1,414,464 | -46 | 0 | 0 | 0 | 0 | 0 | 0 | -2,121 | -2,121 | 0 |
| #12 | Power Generation | -2,146,038 | -189,378 | -301,537 | -546,895 | -1,910,075 | -58,869 | -52,804 | -614,127 | 0 | 0 | -2,660,242 | 3,440,790 | 0 | -5,039,177 | -5,039,177 | 0 |
| #13 | Auto Power Generation | -250,929 | -106,559 | -20 | -400,673 | -16,206 | -115,803 | -132,042 | -57,360 | 0 | -178,129 | 0 | 502,571 | 0 | -755,149 | -755,149 | 0 |
| #14 | Auto Steam Generation | -215,125 | -66,543 | -37 | -573,353 | -12,856 | -183,042 | -168,956 | 0 | 0 | -238,466 | 0 | 0 | 1,317,977 | -140,401 | -140,401 | 0 |
| #15 | District Heat Supply | -633 | 0 | 0 | -1,023 | 0 | -18,102 | -146 | 0 | 0 | -5,124 | 0 | -4,129 | 25,433 | -3,724 | -3,724 | 0 |
| #16 | Own Use and Loss | -6,994 | -129,554 | -91 | -331,117 | -16,279 | -9,176 | 0 | 0 | 0 | 0 | 0 | -377,413 | -3,563 | -874,188 | -874,188 | 0 |
| #17 | Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up) | 39,791 | -18,378 | 736 | 86 | -27,972 | 0 | -44 | 0 | 0 | -68 | 0 | 0 | 0 | -5,850 | 0 | -5,850 |
| #18 | Statistical Discrepancy (+: excess/-: shortage) | 33,648 | 93,718 | 6,882 | 689,356 | -566 | 2,003 | 4,315 | 0 | 0 | 0 | 0 | -127,635 | -55,234 | 646,487 | 579,348 | 67,138 |
| #19 | Final Energy Consumption | 421,558 | 1,043,135 | 0 | 8,427,113 | 64,662 | 966,321 | 27,363 | 0 | 0 | 6,305 | 0 | 3,689,453 | 1,255,296 | 15,901,205 | 14,076,076 | 1,825,130 |
| #20 | Industry | 421,521 | 1,043,135 | 0 | 4,159,284 | 64,662 | 526,270 | 4,340 | 0 | 0 | 6,305 | 0 | 2,624,656 | 1,253,971 | 10,104,143 | 8,314,686 | 1,789,456 |
| #21 | Agriculture, Fishery, Mining and Construction | 34 | 524 | 0 | 478,484 | 2,758 | 3,115 | 0 | 0 | 0 | 0 | 0 | 61,043 | 1,350 | 547,307 | 430,354 | 116,954 |
| #22 | Manufacturing | 421,249 | 1,042,611 | 0 | 2,438,710 | 61,905 | 259,987 | 25 | 0 | 0 | 6,305 | 0 | 1,416,208 | 1,115,783 | 6,762,781 | 5,157,417 | 1,605,364 |
| #23 | Food, Beverages, Tobacco and Feed | 39 | 0 | 0 | 62,531 | 0 | 32,399 | 0 | 0 | 0 | 0 | 0 | 88,576 | 88,379 | 271,924 | 271,924 | 0 |
| #24 | Textile Mill Products | 231 | 0 | 0 | 26,523 | 0 | 6,957 | 0 | 0 | 0 | 0 | 0 | 45,914 | 64,926 | 144,552 | 144,552 | 0 |
| #25 | Pulp, Paper and Paper Products | 506 | 0 | 0 | 23,807 | 119 | 10,603 | 25 | 0 | 0 | 0 | 0 | 134,446 | 282,635 | 452,140 | 452,140 | 0 |
| #26 | Chemical and Allied Products, Oil and Coal Products | 971 | 39,347 | 0 | 1,936,945 | 31,470 | 31,462 | 0 | 0 | 0 | 0 | 0 | 211,498 | 392,864 | 2,644,558 | 1,039,730 | 1,604,828 |
| #27 | Ceramic, Stone and Clay Products | 163,358 | 21,640 | 0 | 132,734 | 2,541 | 22,808 | 0 | 0 | 0 | 6,300 | 0 | 80,925 | 29,084 | 459,392 | 458,984 | 408 |
| #28 | Iron and Steel | 252,942 | 968,364 | 0 | 93,221 | 25,126 | 54,384 | 0 | 0 | 0 | 0 | 0 | 263,947 | 113,867 | 1,771,850 | 1,771,721 | 129 |
| #29 | Non-Ferrous Metals | 2,993 | 9,518 | 0 | 41,559 | 315 | 19,808 | 0 | 0 | 0 | 0 | 0 | 54,707 | 26,351 | 155,251 | 155,251 | 0 |
| #30 | Machinery | 1 | 3,742 | 0 | 90,268 | 2,334 | 63,972 | 0 | 0 | 0 | 5 | 0 | 394,832 | 65,339 | 620,494 | 620,494 | 0 |
| #31 | Miscellaneous | 206 | 0 | 0 | 31,121 | 0 | 17,593 | 0 | 0 | 0 | 0 | 0 | 141,362 | 52,339 | 242,621 | 242,621 | 0 |
| #32 | Commercial Industry | 238 | 0 | 0 | 1,242,090 | 0 | 263,168 | 4,315 | 0 | 0 | 0 | 0 | 1,147,405 | 136,838 | 2,794,055 | 2,726,916 | 67,138 |
| #33 | Residential | 0 | 0 | 0 | 729,070 | 0 | 436,076 | 23,023 | 0 | 0 | 0 | 0 | 996,765 | 1,326 | 2,186,261 | 2,186,261 | 0 |
| #34 | Transportation | 37 | 0 | 0 | 3,538,759 | 0 | 3,974 | 0 | 0 | 0 | 0 | 0 | 68,031 | 0 | 3,610,802 | 3,575,128 | 35,674 |
| #35 | Passenger | 37 | 0 | 0 | 2,078,473 | 0 | 591 | 0 | 0 | 0 | 0 | 0 | 64,483 | 0 | 2,143,584 | 2,116,934 | 26,651 |
| #36 | Freight | 0 | 0 | 0 | 1,460,286 | 0 | 3,383 | 0 | 0 | 0 | 0 | 0 | 3,548 | 0 | 1,467,218 | 1,458,195 | 9,023 |
| #37 | Non-energy and Feedstock Use | 32 | 18,343 | 0 | 1,790,501 | 16,254 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,825,130 | 0 | 1,825,130 |

## Table A 4-21 Energy balance simplified table (General Energy Statistics, FY2010, 2015)

| *2010FY* | *Row $* | *$0100* | *$0200* | *$0300* | *$0400* | *$0500* | *$0600* | *$0700* | *$0800* | *$0900* | *$1000* | *$1100* | *$1200* | *$1300* | *$1400* | *$1401* | *$1402* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ** | | Coal | Coal Products | Crude Oil | Oil Products | Natural Gas | City Gas | Renewable (excl. hydro) | Hydraulic Power Generation (excl. pumped) | Pumped Storage | Effective Recovery Use of Wasted Energy | Nuclear Power Generation | Electricity | Heat | Total | Energy Use Total | Non-Energy Use Total |
| **Line #** | | | | | | | | | | | | | | | | | |
| #01 | Primary Energy Supply | 4,983,144 | 14,115 | 8,127,286 | 730,774 | 3,994,127 | 1,105 | 436,721 | 715,871 | 0 | 529,798 | 2,462,243 | 0 | 0 | 21,995,185 | 20,126,923 | 1,868,262 |
| #02 | Indigenously Produced | 25,764 | 0 | 30,637 | 0 | 149,324 | 0 | 421,916 | 715,871 | 0 | 529,798 | 2,462,243 | 0 | 0 | 4,335,554 | 0 | 0 |
| #03 | Import | 4,957,466 | 29,909 | 8,140,499 | 1,946,768 | 3,844,997 | 0 | 14,857 | 0 | 0 | 0 | 0 | 0 | 0 | 18,934,496 | 0 | 0 |
| #04 | Total Primary Energy Supply | 4,983,230 | 29,909 | 8,171,136 | 1,946,768 | 3,994,321 | 0 | 436,773 | 715,871 | 0 | 529,798 | 2,462,243 | 0 | 0 | 23,270,050 | 21,401,788 | 1,868,262 |
| #05 | Export | -87 | -19,695 | 0 | -1,187,778 | 0 | 0 | -51 | 0 | 0 | 0 | 0 | 0 | 0 | -1,207,611 | 0 | 0 |
| #06 | Stockpile Change / Supply (+: withdrawal/-: build-up) | 0 | 3,901 | -43,851 | -28,216 | -194 | 1,105 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -67,255 | 0 | 0 |
| #07 | Domestic Primary Energy Supply (Supply) | 4,983,144 | 14,115 | 8,127,286 | 730,774 | 3,994,127 | 1,105 | 436,721 | 715,871 | 0 | 529,798 | 2,462,243 | 0 | 0 | 21,995,185 | 20,126,923 | 1,868,262 |
| | (Demand) | | | | | | | | | | | | | | 21,931,268 | 20,063,006 | 1,868,262 |
| #08 | Energy Transformation & Own Use | -4,523,260 | 1,090,966 | -8,133,969 | 6,531,651 | -3,960,650 | 1,087,983 | -415,373 | -715,871 | 0 | -522,602 | -2,462,243 | 3,799,612 | 1,004,032 | -7,219,724 | -7,082,491 | -137,233 |
| #09 | Manufacture of Coal Products (+: output/-: input) | -1,704,578 | 1,611,327 | 0 | -20,407 | 0 | 0 | 0 | 0 | 0 | -87 | 0 | 0 | 0 | -113,745 | -113,745 | 0 |
| #10 | Oil Products (+: output/-: input) | 0 | 0 | -7,949,128 | 8,038,382 | 5,579 | 0 | -8,588 | 0 | 0 | 0 | 0 | 0 | -146,978 | -60,732 | 0 | -60,732 |
| #11 | Gas Conversion and Production (+: output/-: input) | 0 | 0 | 0 | -73,311 | -1,646,183 | 1,719,690 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 196 | 196 | 0 |
| #12 | Power Generation | -2,087,400 | -207,076 | -189,297 | -374,290 | -2,342,899 | -59,859 | -49,589 | -574,862 | 0 | -5,678 | -2,462,243 | 3,474,987 | 0 | -4,878,205 | -4,878,205 | 0 |
| #13 | Auto Power Generation | -440,814 | -104,816 | -46 | -309,431 | -149,028 | -133,885 | -172,142 | -141,010 | 0 | -282,311 | 0 | 704,858 | 0 | -1,028,624 | -1,028,624 | 0 |
| #14 | Auto Steam Generation | -240,628 | -76,411 | -90 | -379,511 | -27,268 | -168,223 | -184,754 | 0 | 0 | -229,472 | 0 | 0 | 1,131,316 | -175,042 | -175,042 | 0 |
| #15 | District Heat Supply | 0 | 0 | 0 | -822 | 0 | -17,003 | -331 | 0 | 0 | -4,068 | 0 | -4,126 | 24,925 | -1,425 | -1,425 | 0 |
| #16 | Own Use and Loss | -20,471 | -134,613 | -62 | -293,998 | -4,773 | -50,390 | 0 | 0 | 0 | 0 | 0 | -376,108 | -5,231 | -885,645 | -885,645 | 0 |
| #17 | Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up) | -29,368 | 2,555 | 4,654 | -9,526 | 1,573 | 0 | 278 | 0 | 0 | -987 | 0 | 0 | 0 | -30,821 | 0 | -30,821 |
| #18 | Statistical Discrepancy (+: excess/-: shortage) | 68,210 | 49,980 | -6,683 | 305,495 | -34,148 | 108,373 | 4,483 | 0 | 0 | 0 | 0 | 72,105 | -85,415 | 482,400 | 424,308 | 58,092 |
| #19 | Final Energy Consumption | 391,674 | 1,055,101 | 0 | 7,262,558 | 67,624 | 1,089,087 | 21,349 | 0 | 0 | 7,196 | 0 | 3,727,507 | 1,089,447 | 14,711,544 | 12,980,516 | 1,731,028 |
| #20 | Industry | 391,630 | 1,055,101 | 0 | 3,299,700 | 67,624 | 657,370 | 4,832 | 0 | 0 | 7,196 | 0 | 2,584,207 | 1,088,165 | 9,155,827 | 7,460,274 | 1,695,552 |
| #21 | Agriculture, Fishery, Mining and Construction | 87 | 140 | 0 | 395,747 | 5,064 | 2,672 | 0 | 0 | 0 | 0 | 0 | 45,685 | 1,392 | 450,789 | 371,050 | 79,738 |
| #22 | Manufacturing | 391,306 | 1,052,992 | 0 | 2,193,545 | 62,560 | 281,280 | 350 | 0 | 0 | 7,196 | 0 | 1,328,271 | 976,583 | 6,294,085 | 4,736,363 | 1,557,722 |
| #23 | Food, Beverages, Tobacco and Feed | 28 | 91 | 0 | 50,351 | 0 | 39,753 | 0 | 0 | 0 | 0 | 0 | 91,017 | 99,108 | 280,349 | 280,349 | 0 |
| #24 | Textile Mill Products | 153 | 0 | 0 | 13,555 | 0 | 7,678 | 0 | 0 | 0 | 0 | 0 | 35,646 | 49,765 | 106,797 | 106,797 | 0 |
| #25 | Pulp, Paper and Paper Products | 322 | 0 | 0 | 20,024 | 333 | 5,171 | 344 | 0 | 0 | 89 | 0 | 123,781 | 228,675 | 378,740 | 378,740 | 0 |
| #26 | Chemical and Allied Products, Oil and Coal Products | 1,051 | 49,884 | 0 | 1,838,713 | 34,826 | 27,260 | 0 | 0 | 0 | 0 | 0 | 204,731 | 365,869 | 2,522,335 | 964,981 | 1,557,354 |
| #27 | Ceramic, Stone and Clay Products | 128,254 | 17,780 | 0 | 97,328 | 4,255 | 28,179 | 6 | 0 | 0 | 6,582 | 0 | 72,081 | 19,889 | 374,355 | 374,174 | 181 |
| #28 | Iron and Steel | 258,193 | 972,911 | 0 | 77,484 | 20,273 | 76,514 | 0 | 0 | 0 | 387 | 0 | 258,467 | 118,085 | 1,782,315 | 1,782,128 | 186 |
| #29 | Non-Ferrous Metals | 2,314 | 8,661 | 0 | 24,276 | 1,024 | 16,292 | 0 | 0 | 0 | 137 | 0 | 52,474 | 10,665 | 115,843 | 115,843 | 0 |
| #30 | Machinery | 76 | 3,587 | 0 | 52,817 | 1,849 | 65,643 | 0 | 0 | 0 | 0 | 0 | 372,900 | 58,690 | 555,562 | 555,562 | 0 |
| #31 | Miscellaneous | 915 | 78 | 0 | 18,996 | 0 | 14,790 | 0 | 0 | 0 | 0 | 0 | 117,174 | 25,837 | 177,789 | 177,789 | 0 |
| #32 | Commercial Industry | 237 | 1,970 | 0 | 710,408 | 0 | 373,417 | 4,483 | 0 | 0 | 0 | 0 | 1,210,250 | 110,189 | 2,410,953 | 2,352,861 | 58,092 |
| #33 | Residential | 0 | 0 | 0 | 646,431 | 0 | 427,050 | 16,516 | 0 | 0 | 0 | 0 | 1,077,621 | 1,282 | 2,168,901 | 2,168,901 | 0 |
| #34 | Transportation | 43 | 0 | 0 | 3,316,427 | 0 | 4,667 | 0 | 0 | 0 | 0 | 0 | 65,679 | 0 | 3,386,816 | 3,351,340 | 35,476 |
| #35 | Passenger | 43 | 0 | 0 | 1,962,870 | 0 | 640 | 0 | 0 | 0 | 0 | 0 | 62,568 | 0 | 2,026,122 | 1,999,526 | 26,596 |
| #36 | Freight | 0 | 0 | 0 | 1,353,557 | 0 | 4,027 | 0 | 0 | 0 | 0 | 0 | 3,111 | 0 | 1,360,695 | 1,351,815 | 8,880 |
| #37 | Non-energy and Feedstock Use | 16 | 17,902 | 0 | 1,696,536 | 16,575 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,731,028 | 0 | 1,731,028 |

| *2015FY* | *Row $* | *$0100* | *$0200* | *$0300* | *$0400* | *$0500* | *$0600* | *$0700* | *$0800* | *$0900* | *$1000* | *$1100* | *$1200* | *$1300* | *$1400* | *$1401* | *$1402* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ** | | Coal | Coal Products | Crude Oil | Oil Products | Natural Gas | City Gas | Renewable (excl. hydro) | Hydraulic Power Generation (excl. pumped) | Pumped Storage | Effective Recovery Use of Wasted Energy | Nuclear Power Generation | Electricity | Heat | Total | Energy Use Total | Non-Energy Use Total |
| **Line #** | | | | | | | | | | | | | | | | | |
| #01 | Primary Energy Supply | 5,096,871 | 57,471 | 7,406,284 | 731,279 | 4,658,056 | -833 | 728,470 | 725,930 | 0 | 537,296 | 78,638 | 0 | 0 | 20,019,460 | 18,221,383 | 1,798,078 |
| #02 | Indigenously Produced | 31,982 | 0 | 20,896 | 0 | 110,598 | 0 | 696,397 | 725,930 | 0 | 537,296 | 78,638 | 0 | 0 | 2,201,738 | 0 | 0 |
| #03 | Import | 5,064,950 | 80,375 | 7,414,496 | 1,952,126 | 4,551,428 | 0 | 32,118 | 0 | 0 | 0 | 0 | 0 | 0 | 19,095,492 | 0 | 0 |
| #04 | Total Primary Energy Supply | 5,096,932 | 80,375 | 7,435,391 | 1,952,126 | 4,662,026 | 0 | 728,515 | 725,930 | 0 | 537,296 | 78,638 | 0 | 0 | 21,297,230 | 19,499,152 | 1,798,078 |
| #05 | Export | -62 | -22,999 | 0 | -1,265,963 | 0 | 0 | -45 | 0 | 0 | 0 | 0 | 0 | 0 | -1,289,068 | 0 | 0 |
| #06 | Stockpile Change / Supply (+: withdrawal/-: build-up) | 0 | 95 | -29,108 | 45,115 | -3,970 | -833 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11,299 | 0 | 0 |
| #07 | Domestic Primary Energy Supply (Supply) | 5,096,871 | 57,471 | 7,406,284 | 731,279 | 4,658,056 | -833 | 728,470 | 725,930 | 0 | 537,296 | 78,638 | 0 | 0 | 20,019,460 | 18,221,383 | 1,798,078 |
| | (Demand) | | | | | | | | | | | | | | 20,043,514 | 18,245,437 | 1,798,078 |
| #08 | Energy Transformation & Own Use | -4,717,988 | 946,659 | -7,406,973 | 5,867,082 | -4,603,419 | 1,072,604 | -712,916 | -725,930 | 0 | -512,036 | -78,638 | 3,464,532 | 887,051 | -6,519,974 | -6,404,115 | -115,859 |
| #09 | Manufacture of Coal Products (+: output/-: input) | -1,523,216 | 1,436,363 | 0 | -19,673 | 0 | 0 | 0 | 0 | 0 | -4,893 | 0 | 0 | 0 | -111,419 | -111,419 | 0 |
| #10 | Oil Products (+: output/-: input) | 0 | 0 | -7,191,157 | 7,208,200 | 4,204 | 0 | -14,525 | 0 | 0 | 0 | 0 | 0 | -119,254 | -112,532 | 0 | -112,532 |
| #11 | Gas Conversion and Production (+: output/-: input) | 0 | 0 | 0 | -68,503 | -1,669,358 | 1,738,071 | -116 | 0 | 0 | 0 | 0 | 0 | 0 | 95 | 95 | 0 |
| #12 | Power Generation | -2,375,953 | -201,063 | -226,562 | -382,134 | -2,924,727 | -121,063 | -53,914 | -588,695 | 0 | -5,484 | -78,638 | 2,945,950 | 0 | -4,012,282 | -4,012,282 | 0 |
| #13 | Auto Power Generation | -502,927 | -101,086 | -39 | -262,498 | -159,588 | -136,847 | -472,131 | -137,236 | 0 | -297,981 | 0 | 843,863 | 0 | -1,226,471 | -1,226,471 | 0 |
| #14 | Auto Steam Generation | -243,912 | -70,119 | -74 | -320,294 | -24,529 | -181,391 | -171,077 | 0 | 0 | -200,796 | 0 | 0 | 989,727 | -222,464 | -222,464 | 0 |
| #15 | District Heat Supply | 0 | 0 | 0 | -225 | 0 | -14,096 | -578 | 0 | 0 | -2,631 | 0 | -3,609 | 21,309 | 169 | 169 | 0 |
| #16 | Own Use and Loss | -20,270 | -120,506 | -83 | -304,499 | -13,393 | -46,590 | 0 | 0 | 0 | 0 | 0 | -321,672 | -4,730 | -831,743 | -831,743 | 0 |
| #17 | Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up) | -51,710 | 3,069 | 10,941 | 11,383 | 18,491 | 0 | -128 | 0 | 0 | -250 | 0 | 0 | 0 | -8,204 | 0 | -8,204 |
| #18 | Statistical Discrepancy (+: excess/-: shortage) | -52,944 | 48,080 | -690 | 195,986 | -7,176 | 75,252 | 4,842 | 0 | 0 | 0 | 0 | 46,363 | -57,246 | 252,467 | 208,930 | 43,537 |
| #19 | Final Energy Consumption | 431,827 | 956,049 | 0 | 6,598,801 | 61,813 | 1,071,770 | 15,553 | 0 | 0 | 25,260 | 0 | 3,418,170 | 944,297 | 13,523,540 | 11,841,322 | 1,682,219 |
| #20 | Industry | 431,788 | 956,049 | 0 | 2,985,844 | 61,813 | 668,128 | 5,233 | 0 | 0 | 25,260 | 0 | 2,391,174 | 943,195 | 8,468,483 | 6,822,698 | 1,645,786 |
| #21 | Agriculture, Fishery, Mining and Construction | 28 | 291 | 0 | 361,272 | 4,695 | 3,082 | 0 | 0 | 0 | 0 | 0 | 37,635 | 1,095 | 408,098 | 348,088 | 60,010 |
| #22 | Manufacturing | 431,413 | 952,800 | 0 | 2,055,828 | 57,118 | 248,435 | 390 | 0 | 0 | 25,260 | 0 | 1,215,152 | 878,520 | 5,864,916 | 4,322,677 | 1,542,239 |
| #23 | Food, Beverages, Tobacco and Feed | 245 | 80 | 0 | 34,705 | 0 | 31,205 | 0 | 0 | 0 | 0 | 0 | 91,843 | 83,786 | 241,864 | 241,864 | 0 |
| #24 | Textile Mill Products | 112 | 0 | 0 | 7,405 | 10 | 5,463 | 0 | 0 | 0 | 0 | 0 | 33,434 | 50,873 | 97,296 | 97,296 | 0 |
| #25 | Pulp, Paper and Paper Products | 1,793 | 0 | 0 | 15,889 | 534 | 4,531 | 324 | 0 | 0 | 1,018 | 0 | 112,153 | 205,821 | 342,063 | 342,063 | 0 |
| #26 | Chemical and Allied Products, Oil and Coal Products | 4,215 | 49,754 | 0 | 1,780,504 | 27,107 | 21,360 | 0 | 0 | 0 | 2,008 | 0 | 188,397 | 332,954 | 2,406,299 | 864,313 | 1,541,985 |
| #27 | Ceramic, Stone and Clay Products | 130,671 | 12,652 | 0 | 85,432 | 5,002 | 25,789 | 67 | 0 | 0 | 19,110 | 0 | 61,876 | 19,240 | 359,838 | 359,699 | 139 |
| #28 | Iron and Steel | 291,655 | 879,851 | 0 | 60,714 | 21,522 | 80,046 | 0 | 0 | 0 | 1,707 | 0 | 250,834 | 99,610 | 1,685,939 | 1,685,825 | 114 |
| #29 | Non-Ferrous Metals | 2,283 | 7,412 | 0 | 16,908 | 1,317 | 12,808 | 0 | 0 | 0 | 1,417 | 0 | 43,151 | 10,152 | 95,447 | 95,447 | 0 |
| #30 | Machinery | 77 | 2,994 | 0 | 41,778 | 1,627 | 55,813 | 0 | 0 | 0 | 0 | 0 | 325,560 | 42,832 | 470,682 | 470,682 | 0 |
| #31 | Miscellaneous | 363 | 56 | 0 | 12,492 | 0 | 11,421 | 0 | 0 | 0 | 0 | 0 | 107,904 | 33,253 | 165,489 | 165,489 | 0 |
| #32 | Commercial Industry | 348 | 2,958 | 0 | 568,744 | 0 | 416,611 | 4,842 | 0 | 0 | 0 | 0 | 1,138,387 | 63,579 | 2,195,469 | 2,151,933 | 43,537 |
| #33 | Residential | 0 | 0 | 0 | 531,546 | 0 | 400,326 | 10,320 | 0 | 0 | 0 | 0 | 963,813 | 1,102 | 1,907,107 | 1,907,107 | 0 |
| #34 | Transportation | 39 | 0 | 0 | 3,081,411 | 0 | 3,317 | 0 | 0 | 0 | 0 | 0 | 63,183 | 0 | 3,147,950 | 3,111,517 | 36,433 |
| #35 | Passenger | 39 | 0 | 0 | 1,793,910 | 0 | 320 | 0 | 0 | 0 | 0 | 0 | 60,289 | 0 | 1,854,558 | 1,826,899 | 27,659 |
| #36 | Freight | 0 | 0 | 0 | 1,287,501 | 0 | 2,996 | 0 | 0 | 0 | 0 | 0 | 2,894 | 0 | 1,293,392 | 1,284,617 | 8,774 |
| #37 | Non-energy and Feedstock Use | 9 | 17,701 | 0 | 1,652,935 | 11,574 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,682,219 | 0 | 1,682,219 |

# Table A 4-22 Energy balance simplified table (General Energy Statistics, FY2017, 2018)

| *2017FY* | *Row $* | *$0100* | *$0200* | *$0300* | *$0400* | *$0500* | *$0600* | *$0700* | *$0800* | *$0900* | *$1000* | *$1100* | *$1200* | *$1300* | *$1400* | *$1401* | *$1402* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ** | | Coal | Coal Products | Crude Oil | Oil Products | Natural Gas | City Gas | Renewable (excl. hydro) | Hydraulic Power Generation (excl. pumped) | Pumped Storage | Effective Recovery Use of Wasted Energy | Nuclear Power Generation | Electricity | Heat | Total | Energy Use Total | Non-Energy Use Total |
| **Line #** | | | | | | | | | | | | | | | | | |
| #01 | Primary Energy Supply | 5,038,858 | 3,936 | 7,113,232 | 728,704 | 4,693,643 | 2,529 | 939,424 | 714,466 | 0 | 583,800 | 280,761 | 0 | 0 | 20,099,351 | 18,229,155 | 1,870,197 |
| #02 | Indigenously Produced | 33,574 | 0 | 19,645 | 0 | 119,167 | 0 | 886,197 | 714,466 | 0 | 583,800 | 280,761 | 0 | 0 | 2,637,609 | 0 | 0 |
| #03 | Import | 5,005,364 | 37,635 | 7,075,913 | 1,940,898 | 4,568,890 | 0 | 53,259 | 0 | 0 | 0 | 0 | 0 | 0 | 18,681,958 | 0 | 0 |
| #04 | Total Primary Energy Supply | 5,038,938 | 37,635 | 7,095,557 | 1,940,898 | 4,688,057 | 0 | 939,456 | 714,466 | 0 | 583,800 | 280,761 | 0 | 0 | 21,319,567 | 19,449,370 | 1,870,197 |
| #05 | Export | -80 | -36,027 | 0 | -1,228,902 | 0 | 0 | -32 | 0 | 0 | 0 | 0 | 0 | 0 | -1,265,041 | 0 | 0 |
| #06 | Stockpile Change / Supply (+: withdrawal/-: build-up) | 0 | 2,328 | 17,674 | 16,708 | 5,586 | 2,529 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44,825 | 0 | 0 |
| #07 | Domestic Primary Energy Supply (Supply) | 5,038,858 | 3,936 | 7,113,232 | 728,704 | 4,693,643 | 2,529 | 939,424 | 714,466 | 0 | 583,800 | 280,761 | 0 | 0 | 20,099,351 | 18,229,155 | 1,870,197 |
| | (Demand) | | | | | | | | | | | | | | 20,105,069 | 18,234,873 | 1,870,197 |
| #08 | Energy Transformation & Own Use | -4,641,267 | 987,825 | -7,089,045 | 5,766,154 | -4,638,400 | 1,099,219 | -925,731 | -714,466 | 0 | -555,628 | -280,761 | 3,482,970 | 895,342 | -6,613,789 | -6,435,266 | -178,523 |
| #09 | Manufacture of Coal Products (+: output/-: input) | -1,535,648 | 1,446,972 | 0 | -18,762 | 0 | 0 | 0 | 0 | 0 | -4,869 | 0 | 0 | 0 | -112,306 | -112,306 | 0 |
| #10 | Oil Products (+: output/-: input) | 0 | 0 | -7,024,862 | 6,982,103 | 2,496 | 0 | -19,101 | 0 | 0 | 0 | 0 | 0 | -122,642 | -182,006 | 0 | -182,006 |
| #11 | Gas Conversion and Production (+: output/-: input) | 0 | 0 | 0 | -76,876 | -1,761,650 | 1,838,541 | -143 | 0 | 0 | 0 | 0 | 0 | 0 | -128 | -128 | 0 |
| #12 | Power Generation | -2,706,684 | -205,468 | -79,828 | -371,040 | -2,981,791 | -157,692 | -229,749 | -691,397 | 0 | -134,714 | -280,761 | 3,309,933 | 0 | -4,529,191 | -4,529,191 | 0 |
| #13 | Auto Power Generation | -166,109 | -65,007 | -46 | -191,876 | -40,950 | -107,159 | -492,908 | -23,069 | 0 | -216,354 | 0 | 543,987 | 0 | -759,490 | -759,490 | 0 |
| #14 | Auto Steam Generation | -242,389 | -72,162 | -85 | -311,090 | -23,579 | -192,494 | -178,437 | 0 | 0 | -196,065 | 0 | 0 | 1,001,433 | -214,867 | -214,867 | 0 |
| #15 | District Heat Supply | 0 | 0 | 0 | -208 | 0 | -15,058 | -530 | 0 | 0 | -2,545 | 0 | -3,598 | 22,405 | 466 | 466 | 0 |
| #16 | Own Use and Loss | -11,456 | -121,048 | -3,094 | -248,917 | -16,326 | -42,208 | -3,491 | 0 | 0 | -4 | 0 | -367,353 | -5,854 | -819,750 | -819,750 | 0 |
| #17 | Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up) | 21,018 | 4,537 | 18,870 | 1,025 | -41,312 | 0 | -1,019 | 0 | 0 | -1,076 | 0 | 0 | 0 | 2,044 | 0 | 2,044 |
| #18 | Statistical Discrepancy (+: excess/-: shortage) | -31,724 | 55,553 | 24,186 | 213,268 | -7,195 | 75,245 | 4,567 | 0 | 0 | 0 | 0 | 9,934 | -56,018 | 287,817 | 245,449 | 42,367 |
| #19 | Final Energy Consumption | 429,315 | 936,207 | 0 | 6,495,312 | 62,438 | 1,101,748 | 13,693 | 0 | 0 | 28,172 | 0 | 3,473,036 | 951,360 | 13,491,280 | 11,799,607 | 1,691,673 |
| #20 | Industry | 429,274 | 936,207 | 0 | 2,892,157 | 62,438 | 670,980 | 4,839 | 0 | 0 | 28,172 | 0 | 2,426,063 | 950,221 | 8,400,351 | 6,746,585 | 1,653,766 |
| #21 | Agriculture, Fishery, Mining and Construction | 0 | 3 | 0 | 332,581 | 5,135 | 2,745 | 0 | 0 | 0 | 0 | 0 | 38,194 | 1,023 | 379,682 | 346,295 | 33,387 |
| #22 | Manufacturing | 428,601 | 931,881 | 0 | 2,032,574 | 57,303 | 254,889 | 272 | 0 | 0 | 28,172 | 0 | 1,221,130 | 884,409 | 5,839,231 | 4,261,220 | 1,578,012 |
| #23 | Food, Beverages, Tobacco and Feed | 16 | 42 | 0 | 24,328 | 0 | 29,618 | 0 | 0 | 0 | 0 | 0 | 89,406 | 82,000 | 225,410 | 225,410 | 0 |
| #24 | Textile Mill Products | 0 | 0 | 0 | 5,126 | 57 | 5,603 | 0 | 0 | 0 | 0 | 0 | 30,850 | 45,107 | 86,743 | 86,743 | 0 |
| #25 | Pulp, Paper and Paper Products | 986 | 0 | 0 | 14,969 | 505 | 4,477 | 227 | 0 | 0 | 624 | 0 | 110,115 | 203,310 | 335,213 | 335,213 | 0 |
| #26 | Chemical and Allied Products, Oil and Coal Products | 1,909 | 50,888 | 0 | 1,785,043 | 27,450 | 23,395 | 0 | 0 | 0 | 1,977 | 0 | 186,841 | 330,893 | 2,408,395 | 830,840 | 1,577,554 |
| #27 | Ceramic, Stone and Clay Products | 134,258 | 11,677 | 0 | 83,627 | 5,220 | 24,288 | 45 | 0 | 0 | 22,722 | 0 | 63,950 | 25,691 | 371,478 | 371,135 | 344 |
| #28 | Iron and Steel | 289,365 | 860,396 | 0 | 54,189 | 20,870 | 81,477 | 0 | 0 | 0 | 1,481 | 0 | 255,023 | 99,913 | 1,662,713 | 1,662,599 | 114 |
| #29 | Non-Ferrous Metals | 1,876 | 6,420 | 0 | 15,695 | 1,449 | 15,325 | 0 | 0 | 0 | 1,368 | 0 | 46,666 | 9,328 | 98,127 | 98,127 | 0 |
| #30 | Machinery | 191 | 2,456 | 0 | 36,839 | 1,752 | 59,308 | 0 | 0 | 0 | 0 | 0 | 328,315 | 43,892 | 472,754 | 472,754 | 0 |
| #31 | Miscellaneous | 0 | 1 | 0 | 12,759 | 0 | 11,400 | 0 | 0 | 0 | 0 | 0 | 109,964 | 44,275 | 178,399 | 178,399 | 0 |
| #32 | Commercial Industry | 672 | 4,323 | 0 | 527,002 | 0 | 413,346 | 4,567 | 0 | 0 | 0 | 0 | 1,166,738 | 64,789 | 2,181,437 | 2,139,070 | 42,367 |
| #33 | Residential | 0 | 0 | 0 | 566,849 | 0 | 428,376 | 8,854 | 0 | 0 | 0 | 0 | 983,819 | 1,138 | 1,989,036 | 1,989,036 | 0 |
| #34 | Transportation | 41 | 0 | 0 | 3,036,306 | 0 | 2,392 | 0 | 0 | 0 | 0 | 0 | 63,154 | 0 | 3,101,893 | 3,063,986 | 37,907 |
| #35 | Passenger | 41 | 0 | 0 | 1,780,110 | 0 | 171 | 0 | 0 | 0 | 0 | 0 | 60,364 | 0 | 1,840,686 | 1,811,667 | 29,019 |
| #36 | Freight | 0 | 0 | 0 | 1,256,196 | 0 | 2,221 | 0 | 0 | 0 | 0 | 0 | 2,790 | 0 | 1,261,206 | 1,252,319 | 8,888 |
| #37 | Non-energy and Feedstock Use | 13 | 19,271 | 0 | 1,661,975 | 10,415 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,691,673 | 0 | 1,691,673 |

| *2018FY* | *Row $* | *$0100* | *$0200* | *$0300* | *$0400* | *$0500* | *$0600* | *$0700* | *$0800* | *$0900* | *$1000* | *$1100* | *$1200* | *$1300* | *$1400* | *$1401* | *$1402* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ** | | Coal | Coal Products | Crude Oil | Oil Products | Natural Gas | City Gas | Renewable (excl. hydro) | Hydraulic Power Generation (excl. pumped) | Pumped Storage | Effective Recovery Use of Wasted Energy | Nuclear Power Generation | Electricity | Heat | Total | Energy Use Total | Non-Energy Use Total |
| **Line #** | | | | | | | | | | | | | | | | | |
| #01 | Primary Energy Supply | 4,944,024 | 3,398 | 6,762,810 | 651,820 | 4,509,574 | 51 | 1,033,125 | 689,820 | 0 | 580,100 | 553,171 | 0 | 0 | 19,727,893 | 17,900,439 | 1,827,455 |
| #02 | Indigenously Produced | 23,366 | 0 | 17,833 | 0 | 104,813 | 0 | 971,210 | 689,820 | 0 | 580,100 | 553,171 | 0 | 0 | 2,940,313 | 0 | 0 |
| #03 | Import | 4,921,481 | 46,929 | 6,765,782 | 1,901,650 | 4,406,588 | 0 | 61,941 | 0 | 0 | 0 | 0 | 0 | 0 | 18,104,370 | 0 | 0 |
| #04 | Total Primary Energy Supply | 4,944,847 | 46,929 | 6,783,614 | 1,901,650 | 4,511,401 | 0 | 1,033,150 | 689,820 | 0 | 580,100 | 553,171 | 0 | 0 | 21,044,683 | 19,217,229 | 1,827,455 |
| #05 | Export | -823 | -41,727 | 0 | -1,252,139 | 0 | 0 | -26 | 0 | 0 | 0 | 0 | 0 | 0 | -1,294,715 | 0 | 0 |
| #06 | Stockpile Change / Supply (+: withdrawal/-: build-up) | 0 | -1,804 | -20,804 | 2,309 | -1,827 | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -22,075 | 0 | 0 |
| #07 | Domestic Primary Energy Supply (Supply) | 4,944,024 | 3,398 | 6,762,810 | 651,820 | 4,509,574 | 51 | 1,033,125 | 689,820 | 0 | 580,100 | 553,171 | 0 | 0 | 19,727,893 | 17,900,439 | 1,827,455 |
| | (Demand) | | | | | | | | | | | | | | 19,723,499 | 17,896,044 | 1,827,455 |
| #08 | Energy Transformation & Own Use | -4,537,250 | 983,878 | -6,780,653 | 5,580,157 | -4,411,579 | 1,065,004 | -1,018,699 | -689,820 | 0 | -550,152 | -553,171 | 3,430,832 | 881,861 | -6,599,592 | -6,385,591 | -214,001 |
| #09 | Manufacture of Coal Products (+: output/-: input) | -1,528,522 | 1,437,066 | 0 | -18,779 | 0 | 0 | 0 | 0 | 0 | -4,627 | 0 | 0 | 0 | -114,862 | -114,862 | 0 |
| #10 | Oil Products (+: output/-: input) | 0 | 0 | -6,740,876 | 6,704,469 | 2,081 | 0 | -19,366 | 0 | 0 | 0 | 0 | 0 | -125,124 | -178,817 | 0 | -178,817 |
| #11 | Gas Conversion and Production (+: output/-: input) | 0 | 0 | 0 | -77,073 | -1,720,302 | 1,796,888 | -118 | 0 | 0 | 0 | 0 | 0 | 0 | -604 | -604 | 0 |
| #12 | Power Generation | -2,576,505 | -147,129 | -41,672 | -272,213 | -2,809,032 | -158,175 | -259,742 | -661,791 | 0 | -155,589 | -553,171 | 3,225,499 | 0 | -4,409,520 | -4,409,520 | 0 |
| #13 | Auto Power Generation | -175,754 | -113,235 | -41 | -179,350 | -41,805 | -117,976 | -551,054 | -28,029 | 0 | -204,158 | 0 | 582,672 | 0 | -828,730 | -828,730 | 0 |
| #14 | Auto Steam Generation | -236,261 | -69,925 | -77 | -303,150 | -23,880 | -198,541 | -178,858 | 0 | 0 | -184,661 | 0 | 0 | 990,028 | -205,326 | -205,326 | 0 |
| #15 | District Heat Supply | 0 | 0 | 0 | -133 | 0 | -14,512 | -450 | 0 | 0 | -2,334 | 0 | -3,687 | 22,767 | 1,651 | 1,651 | 0 |
| #16 | Own Use and Loss | -14,173 | -119,558 | -1,902 | -254,891 | -15,555 | -35,748 | -6,912 | 0 | 0 | 0 | 0 | -373,652 | -5,809 | -828,200 | -828,200 | 0 |
| #17 | Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up) | -6,034 | -3,341 | 3,916 | -681 | -10,019 | 0 | -1,855 | 0 | 0 | 1,218 | 0 | 0 | 0 | -16,797 | 0 | -16,797 |
| #18 | Statistical Discrepancy (+: excess/-: shortage) | -7,332 | 61,610 | -17,843 | 209,918 | 36,065 | 38,521 | 4,628 | 0 | 0 | 0 | 0 | 26,289 | -94,135 | 257,722 | 207,662 | 50,060 |
| #19 | Final Energy Consumption | 414,106 | 925,667 | 0 | 6,232,237 | 61,929 | 1,065,055 | 14,426 | 0 | 0 | 29,948 | 0 | 3,404,544 | 975,996 | 13,123,907 | 11,510,453 | 1,613,454 |
| #20 | Industry | 414,064 | 925,667 | 0 | 2,748,813 | 61,929 | 662,332 | 4,886 | 0 | 0 | 29,948 | 0 | 2,402,778 | 974,891 | 8,225,308 | 6,650,375 | 1,574,933 |
| #21 | Agriculture, Fishery, Mining and Construction | 0 | 63 | 0 | 319,730 | 4,888 | 2,773 | 0 | 0 | 0 | 0 | 0 | 35,173 | 972 | 363,598 | 336,105 | 27,494 |
| #22 | Manufacturing | 413,466 | 921,488 | 0 | 1,919,875 | 57,041 | 275,192 | 258 | 0 | 0 | 29,948 | 0 | 1,227,040 | 909,792 | 5,754,099 | 4,256,719 | 1,497,380 |
| #23 | Food, Beverages, Tobacco and Feed | 24 | 0 | 0 | 23,527 | 0 | 30,559 | 0 | 0 | 0 | 0 | 0 | 91,854 | 118,620 | 264,585 | 264,585 | 0 |
| #24 | Textile Mill Products | 0 | 0 | 0 | 5,156 | 62 | 6,078 | 0 | 0 | 0 | 0 | 0 | 30,012 | 47,396 | 88,704 | 88,704 | 0 |
| #25 | Pulp, Paper and Paper Products | 986 | 0 | 0 | 14,509 | 496 | 4,057 | 211 | 0 | 0 | 497 | 0 | 110,558 | 202,116 | 333,431 | 333,431 | 0 |
| #26 | Chemical and Allied Products, Oil and Coal Products | 2,808 | 52,820 | 0 | 1,690,658 | 28,126 | 22,368 | 0 | 0 | 0 | 1,961 | 0 | 183,979 | 320,448 | 2,303,169 | 806,483 | 1,496,686 |
| #27 | Ceramic, Stone and Clay Products | 130,935 | 13,246 | 0 | 79,969 | 4,925 | 26,362 | 47 | 0 | 0 | 24,563 | 0 | 65,166 | 23,851 | 369,065 | 368,494 | 571 |
| #28 | Iron and Steel | 277,083 | 846,902 | 0 | 49,208 | 20,103 | 88,324 | 0 | 0 | 0 | 1,534 | 0 | 251,470 | 97,837 | 1,632,460 | 1,632,338 | 123 |
| #29 | Non-Ferrous Metals | 1,364 | 6,034 | 0 | 14,186 | 1,410 | 19,511 | 0 | 0 | 0 | 1,393 | 0 | 43,937 | 10,223 | 98,058 | 98,058 | 0 |
| #30 | Machinery | 264 | 2,484 | 0 | 32,458 | 1,919 | 64,303 | 0 | 0 | 0 | 0 | 0 | 342,755 | 42,305 | 486,488 | 486,488 | 0 |
| #31 | Miscellaneous | 0 | 1 | 0 | 10,202 | 0 | 13,630 | 0 | 0 | 0 | 0 | 0 | 107,308 | 46,996 | 178,137 | 178,137 | 0 |
| #32 | Commercial Industry | 599 | 4,116 | 0 | 509,208 | 0 | 384,367 | 4,628 | 0 | 0 | 0 | 0 | 1,140,565 | 64,128 | 2,107,611 | 2,057,551 | 50,060 |
| #33 | Residential | 0 | 0 | 0 | 482,979 | 0 | 400,774 | 9,540 | 0 | 0 | 0 | 0 | 938,612 | 1,104 | 1,833,008 | 1,833,008 | 0 |
| #34 | Transportation | 42 | 0 | 0 | 3,000,445 | 0 | 1,949 | 0 | 0 | 0 | 0 | 0 | 63,154 | 0 | 3,065,590 | 3,027,070 | 38,520 |
| #35 | Passenger | 42 | 0 | 0 | 1,755,971 | 0 | 121 | 0 | 0 | 0 | 0 | 0 | 60,364 | 0 | 1,816,498 | 1,786,917 | 29,581 |
| #36 | Freight | 0 | 0 | 0 | 1,244,474 | 0 | 1,829 | 0 | 0 | 0 | 0 | 0 | 2,790 | 0 | 1,249,092 | 1,240,153 | 8,939 |
| #37 | Non-energy and Feedstock Use | 24 | 20,175 | 0 | 1,582,815 | 10,440 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,613,454 | 0 | 1,613,454 |

### A4.2.2 General Energy Statistics and CRF

In order to report $CO_2$ emissions in CRF, emissions reported under the sectors in *General Energy Statistics* (Energy Balance Table) were reported under each sector in CRF. The correspondence of categories between *General Energy Statistics* and CRF table 1.A(a) 'sectoral approach' is indicated in Table A 4-23.

Values subtracting energy consumption reported under 'non-energy and feedstock use' [#950000] from energy consumption reported under 'energy transformation & own use' [#200000], 'industry' [#600000], 'residential' [#700000], and 'transportation' [#800000] in *General Energy Statistics* (Energy Balance Table) are used for activity data. Because energy consumption reported under 'non-energy and feedstock use' [#950000] was used for the purposes other than combustion and was considered not emitting $CO_2$, these values were deducted. However, out of this amount deducted as feedstock and non-energy use, the emissions from what is used or collected as energy during waste incineration are separately estimated and reported.

The *2006 IPCC Guidelines* requires carbon dioxide emitted from auto power generation, etc., to be counted in the corresponding sector. In Japan's Energy Balance Table (*General Energy Statistics*), fuel consumption used for auto power generation and auto steam generation are presented under 'auto power generation' [#250000], 'auto steam generation' [#260000] in the energy transformation sector. However, auto power generation and auto steam generation actually belong to industry sector. Hence, carbon dioxide emissions from "auto power generation" and "auto steam generation" are allocated to each section of '1.A.2 Manufacturing industries and construction' and '1.A.4 Other sectors'.

In 'energy transformation & own use', 'manufacture of coal products' [#210000], 'oil products' [#220000], 'gas conversion and production' [#230000], 'power generation' [#240000], 'auto power generation' [#250000], 'auto steam generation' [#260000], 'district heat supply' [#270000], and 'own use & loss' [#300000] are calculated, and other sectors ('other energy transformation' and 'transformation and consumption stockpile change') are excluded from calculations.

The category 'manufacture of coal products' [#210000] corresponds to the balance between input amount of feedstock and output amount of coal products under coke manufacturing process. The difference between the coke-making carbon input and carbon output is considered to be the portion that is oxidized in the atmosphere (burned) from the time that red-hot coke is extruded from a coke oven until it enters the coke dry quenching facility. It was considered appropriate to count this as $CO_2$ emissions, and it was calculated as carbon emissions from this category. (Ministry of the Environment, 2006)

The category 'oil products' [#220000] corresponds to the balance between input amount of feedstock and output amount of oil products under oil refining process. The difference between the carbon input and carbon output is considered to be the burned carbon precipitated on catalysts in fluid catalytic cracking facilities. The burning is aimed at recovering the catalytic activities lowered by the cracking reaction of slack fuel oil. The difference is also considered to be heat recovery at boilers of the off-gas, mainly consisting of CO, generated in the fluid catalytic cracking facilities. The difference is also regarded as $CO_2$ as by-product of hydrogen generating facilities. It was considered appropriate to count the difference as $CO_2$ emissions, and it was calculated as carbon emissions from this category. (Ministry of the Environment, 2015)

Table A 4-23 Correspondence between sectors of General Energy Statistics (Detailed Sector) and of the CRF table 1.A(a)

| CRF | | General Energy Statistics | |
|---|---|---|---|
| 1A1 | Energy industries | | |
| 1A1a | Public electricity and heat production | Power generation | #240000 |
| | | Own use; Power generation | #301400 |
| | | District heat supply | #270000 |
| | | Own use; District heat supply | #301500 |
| | | Auto power generation; Production, transmission and distribution of electricity (until 2015) | #255330 |
| 1A1b | Petroleum refining | Oil products | #220000 |
| | | Own use; Oil products | #301200 |
| | | Auto power generation; Manufacture of petroleum products | #253171 |
| | | Auto steam generation, Manufacture of petroleum products | #263171 |
| | | Final energy consumption, Manufacture of petroleum products | #626510 |
| | | Non-energy and feedstock use; Manufacture of petroleum products | #951540 |
| 1A1c | Manufacture of solid fuels and other energy industries | Manufacture of coal products | #210000 |
| | | Own use; Coal products | #301100 |
| | | Auto power generation; Manufacture of coal products and miscellaneous | #253175 |
| | | Auto steam generation, Manufacture of coal products and miscellaneous | #263175 |
| | | Final energy consumption; Manufacture of coal products and miscellaneous | #626550 |
| | | Gas conversion and production | #230000 |
| | | Own use; Gas conversion and production | #301300 |
| 1A2 | Manufacturing industries and construction | | |
| 1A2a | Iron and steel | Auto power generation; Manufacture of iron and steel | #253250 |
| | | Auto steam generation; Manufacture of iron and steel | #263220 |
| | | Final energy consumption; Manufacture of iron and steel | #629100 |
| | | Non-energy and feedstock use; Manufacture of iron, steel and steel products | #951560 |
| 1A2b | Non-ferrous metals | Auto power generation; Manufacture of non-ferrous metals and products | #253230 |
| | | Auto steam generation; Manufacture of non-ferrous metals and products | #263260 |
| | | Final energy consumption; Manufacture of non-ferrous metals and products | #629300 |
| | | Non-energy and feedstock use; Primary smelting and refining of copper, lead, zinc and aluminium | #951570 |
| 1A2c | Chemicals | Auto power generation; Manufacture of chemical and allied products | #253160 |
| | | Auto steam generation; Manufacture of chemical and allied products | #263160 |
| | | Final energy consumption; Manufacture of chemical and allied products | #626100 |
| | | Non-energy and feedstock use; Manufacture of petrochemical, ammonia, soda products | #951530 |
| 1A2d | Pulp, paper and print | Auto power generation; Manufacture of pulp, paper and paper products | #253140 |
| | | Auto power generation; Printing and allied industries | #253150 |
| | | Auto steam generation; Manufacture of pulp, paper and paper products | #263140 |
| | | Auto steam generation; Printing and allied industries | #263150 |
| | | Final energy consumption; Manufacture of pulp, paper and paper products | #624000 |
| | | Final energy consumption; Printing and allied industries | #625000 |
| | | Non-energy and feedstock use; Manufacture of pulp, paper and paper products, large scale | #951520 |
| 1A2e | Food processing, beverages and tobacco | Auto power generation; Manufacture of food | #253090 |
| | | Auto power generation; Manufacture of beverages, tobacco and feed | #253100 |
| | | Auto steam generation; Manufacture of food | #263090 |
| | | Auto steam generation; Manufacture of beverages, tobacco and feed | #263100 |
| | | Final energy consumption; Manufacture of food, beverages, tobacco and feed | #621000 |
| 1A2f | Non-metallic minerals | Auto power generation; Manufacture of ceramic, stone and clay products | #253210 |
| | | Auto steam generation; Manufacture of ceramic, stone and clay products | #263210 |
| | | Final energy consumption; Manufacture of ceramic, stone and clay products | #628100 |
| | | Non-energy and feedstock use; Manufacture of ceramic, stone and clay products | #951550 |
| 1A2g | Other | Auto power generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#251010-#251040]) | #251000 |
| | | Auto power generation; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f) | #252000 |
| | | Auto steam generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#261010-#261040]) | #261000 |
| | | Auto steam generation; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f) | #262000 |
| | | Final energy consumption; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#611000]) | #610000 |
| | | Final energy consumption; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f) | #620000 |
| | | Non-energy and feedstock use; Agriculture, fishery, mining and construction (except for agriculture, forestry and fishery) | #951100 |
| | | Non-energy and feedstock use; Manufacturing industry, large scale (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f) | #951500 |
| | | Non-energy and feedstock use; Manufacturing industry, small and medium scale | #951700 |

Table A 4-23 Correspondence between sectors of General Energy Statistics (Detailed Sector) and of the CRF table 1.A(a) (cont.)

| CRF | | | General Energy Statistics | |
|---|---|---|---|---|
| 1A3 | Transport | | | |
| | 1A3a | Domestic aviation | Final energy consumption; Passenger; Air passenger transport | #815000 |
| | | | Final energy consumption; Freight; Air freight transport | #854000 |
| | | | Non-energy and feedstock use; Transportation (air) | #953000 |
| | 1A3b | Road transportation | | |
| | | i Cars | Final energy consumption; Passenger; Passenger vehicle | #811000 |
| | | | Non-energy and feedstock use; Transportation (passenger vehicle) | #953000 |
| | | ii Light duty trucks | IE (1A3biii) | - |
| | | iii Heavy duty trucks and buses | Final energy consumption; Passenger; Bus | #811500 |
| | | | Final energy consumption, Freight; Freight truck and lorry | #851000 |
| | | | Non-energy and feedstock use; Transportation (bus, freight truck and lorry) | #953000 |
| | | iv Motorcycles | Final energy consumption; Passenger; Motorcycles | #812000 |
| | | | Non-energy and feedstock use; Transportation (Motorcycles) | #953000 |
| | | v Other | IE (1A3biii) | - |
| | 1A3c | Railways | Final energy consumption; Passenger; Railway passenger transport | #813000 |
| | | | Final energy consumption; Freight; Railway freight transport | #852000 |
| | | | Non-energy and feedstock use; Transportation (railways) | #953000 |
| | 1A3d | Domestic navigation | Final energy consumption; Passenger; Water passenger transport | #814000 |
| | | | Final energy consumption; Freight; Water freight transport | #853000 |
| | | | Non-energy and feedstock use; Transportation (water) | #953000 |
| | 1A3e | Other transportation | NO | - |
| 1A4 | Other sectors | | | |
| | 1A4a | Commercial/institutional | Auto power generation (except for Production, transmission and distribution of electricity [#255330] (until 2015), Agriculture, fishery, mining and construction [#251000] and Manufacturing [#252000]) | #255000 |
| | | | Auto steam generation (except for Agriculture, fishery, mining and construction [#261000] and Manufacturing [#262000]) | #265000 |
| | | | Final energy consumption; Commercial industry | #650000 |
| | | | Non-energy and feedstock use; Commercial | #951800 |
| | 1A4b | Residential | Final energy consumption; Residential | #700000 |
| | | | Non-energy and feedstock use; Household | #952000 |
| | 1A4c | Agriculture/forestry/fishing | | |
| | | i Stationary | Auto power generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery) | #251000 |
| | | | Auto steam generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery) | #261000 |
| | | | Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources (estimates) | |
| | | | Non-energy and feedstock use; Agriculture, fishery, mining and construction (agriculture, forestry and fishery) | #951100 |
| | | ii Off-road vehicles and other machinery | Final energy consumption; Agriculture [#611100]; mobile sources (estimates) | |
| | | | Final energy consumption; Forestry [#611200]; mobile sources (estimates) | |
| | | iii Fishing | Final energy consumption; Fishery, except aquaculture [#611300]; mobile sources (estimates) | |
| | | | Final energy consumption; Aquaculture [#611400]; mobile sources (estimates) | |
| 1A5 | Other | | NO | - |

Note: #9xxxxx items are subtracted as a Non-energy use activity.

The ERT recommended that Japan provide a table in the NIR mapping the various types of fuels as reported in the energy balance with the corresponding fuels as reported in CRF table 1.A(d) (FCCC/ARR/2014/JPN). Table A 4-24 shows the correspondence of fuels among *General Energy Statistics*, CRF table 1.A(b) 'reference approach' and CRF table 1.A(d) 'non-energy use of fuels'.

Table A 4-24 Correspondence of fuels among *General Energy Statistics*, CRF table 1.A(b) and (d)

| Fuel in CRF table 1.A(b) and (d) | | | Fuel in General Energy Statistics | Code |
|---|---|---|---|---|
| Liquid fossil | Primary fuels | Crude oil | Crude oil for refinery use | $0310 |
| | | | Crude oil for power generation use | $0320 |
| | | Orimulsion | Bituminous mixture fuel | $0321 |
| | | Natural gas liquids | Natural gas liquid (NGL) & condensate | $0330 |
| | Secondary fuels | Gasoline | Gasoline | $0431 |
| | | Jet kerosene | Jet fuel oil | $0432 |
| | | Other kerosene | Kerosene | $0433 |
| | | Gas/diesel oil | Gas oil or diesel oil | $0434 |
| | | Residual fuel oil | Fuel oil A | $0436 |
| | | | Fuel oil B | $0438 |
| | | | Fuel oil C for general use | $0439 |
| | | | Fuel oil C for power generation use | $0440 |
| | | Liquefied petroleum gas | Liquefied petroleum gas (LPG) | $0458 |
| | | Naphtha | Pure naphtha | $0420 |
| | | | Reformed feedstock Oil | $0421 |
| | | Bitumen | Other heavy oil products | $0452 |
| | | Lubricants | Lubricant oil | $0451 |
| | | Petroleum coke | Oil coke | $0455 |
| | | Refinery feedstocks | Slack gasoline | $0412 |
| | | | Slack kerosene | $0413 |
| | | | Slack diesel oil or gas oil | $0414 |
| | | | Slack fuel oil | $0415 |
| | | | Cracked gasoline | $0416 |
| | | | Cracked diesel oil or gas oil | $0417 |
| | | | Feedstock oil for refinery and mixing | $0418 |
| | | Other oil | Refinery gas | $0457 |
| Solid fossil | Primary fuels | Anthracite | Hard coal, anthracite & lignite | $0130 |
| | | Coking coal | Steel making coal | $0110 |
| | | Other bituminous coal | Imported steam coal for general use | $0121 |
| | | | Imported steam coal for power generation use | $0123 |
| | | Sub-bituminous coal | Indigenous produced steam coal | $0124 |
| | Secondary fuels | BKB and patent fuel | Coal briquette | $0213 |
| | | Coke oven/gas coke | Coke | $0211 |
| | | | Coke oven gas | $0221 |
| | | | Blast furnace gas | $0222 |
| | | | Converter furnace gas | $0225 |
| | | Coal tar | Coal tar | $0212 |
| Gaseous fossil | | Natural gas | Liquefied natural gas (LNG) | $0510 |
| | | | Indigenous natural gas | $0521 |
| | | | Coal mining gas | $0522 |
| | | | Boil off gas from crude oil | $0523 |
| | | | City gas | $0610 |
| | | | Small scale community gas | $0620 |
| Biomass | | Solid biomass | Woods | $N131 |
| | | | Waste Woods | $N132 |
| | | | Thermal Use of Black Liquor | $N136 |
| | | Liquid biomass | Bioethanol | $N134 |
| | | | Biodiesel | $N135 |
| | | Gas biomass | Gas Biomass | $N137 |

## A4.3. Quality Standard for Diesel Oil

The carbon emission factor for liquid fuels (diesel oil) in 1.A.3.b (Road transportation) is the lowest in Annex I Parties for two reasons. One is because the quality standard for diesel oil in Japan is different from other countries. Crude oil with high sulfur content imported from the Middle East must be decomposed and go through ultra-deep desulfurization to become low-sulfur diesel oil (<10 ppm) according to Japanese automobile exhaust gas regulations. The other reason is because gas oil used for purposes other than road transport is called "fuel oil A" to distinguish it from diesel oil. The carbon balance of Japanese petroleum refineries including diesel oil and fuel oil A nearly matches according to statistics, so these carbon emission factors are not irregular.

In the individual review on Japanese greenhouse gas inventory conducted in September 2012, the ERT (Expert Review Team) asked Japan for the possibility of involving the information on Japanese quality standard of diesel oil in the future NIR. In correspondence to the question, Japan has provided the information on Japanese quality requirement of diesel oil mainly used for automobile engine in the Table A 4-25 below. In this standard, the diesel oil is classified into five types based on the pour point difference. Also, the standard meets with the Japanese law “Act on the Quality Control of Gasoline and Other Fuel” as a matter of course.

Table A 4-25 Required quality of diesel oil in Japan

| Test item | Unit | Type | | | | |
|---|---|---|---|---|---|---|
| | | S1 | 1 | 2 | 3 | S3 |
| Flash point | °C | 50 or more | | | 45 or more | |
| 90 % distilling temperature | °C | 360 or less | | 350 or less | 330 or less [1)] | 330 or less |
| Pour point | °C | +5 or less | -2.5 or less | -7.5 or less | -20 or less | -30 or less |
| Cold filter plugging point | °C | − | -1 or less | -5 or less | -12 or less | -19 or less |
| Residual carbon ratio in 10 % residual oil | % in weight | 0.1 or less | | | | |
| Cetane index [2)] | − | 50 or more | | 45 or more | | |
| Kinetic viscosity at 30 °C | $mm^2/s$ | 2.7 or more | | 2.5 or more | 2.0 or more | 1.7 or more |
| Sulfur ratio | % in weight | 0.0010 or less | | | | |
| Density at 15 °C | $g/cm^3$ | 0.86 or less | | | | |

1) 350 or less, if the kinetic viscosity at 30 °C is 4.7 $mm^2/s$ or less.
2) Cetane number is also available for cetane index.
Reference: Japanese Industrial Standards, Diesel Fuel (JIS K 2204:2007)

## A4.4. Conversion factors of calorific values

The ERT recommended that Japan include in the NIR detailed information on the conversion factors used to convert gross calorific values (GCV) to net calorific values (NCV) for all fuels (FCCC/ARR/2014/JPN). For reference, the following table provides the ratio of NCV to GCV, which are derived from GCV and NCV obtained from the standard values of FY2018.

Table A 4-26 Ratio of NCV to GCV for selected fuels (for reference)

| Fuel | NCV/GCV | Fuel | NCV/GCV |
|---|---|---|---|
| Coal | | Oil Products | |
| Imported steel making coal | 0.92 | LPG | 0.93 |
| Coking coal | 0.92 | Naphtha | 0.94 |
| PCI coal | 0.92 | Gasoline | 0.94 |
| Imported steam coal | 0.95 | Jet fuel oil | 0.94 |
| Imported anthracite | 0.97 | Kerosene | 0.94 |
| Coal products | | Diesel oil | 0.94 |
| Coke | 0.98 | Fuel oil A | 0.94 |
| Coke oven gas | 0.79 | Fuel oil C | 0.95 |
| Blast furnace gas | 0.98 | Lubricants | 0.94 |
| Converter furnace gas | 1.00 | Other heavy oil products | 0.95 |
| Oil | | Petroleum coke | 0.98 |
| Crude oil | 0.94 | Refinery gas | 0.92 |
| NGL/condensate | 0.94 | Combustible natural gas | |
| | | Imported natural gas (LNG) | 0.91 |
| | | Indigenous natural gas | 0.91 |
| | | City gas | 0.91 |

Reference: Calculated from Agency for Natural Resources and Energy (2020)

## *References*

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2. UNFCCC, *Report of the individual review of the annual submission of Japan submitted in 2010*, FCCC/ARR/2010/JPN, 2011.
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5. OECD/IEA, *World Energy Statistics*
6. Agency for Natural Resources and Energy, *General Energy Statistics*
7. Agency for Natural Resources and Energy, *Explanation on Standard Calorific Values and Carbon Emission Factors for Fuel Combustion Revised in FY2018*, 2020.
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11. Kainou, K., *Explanation of General Energy Statistics*, 2012.

# Annex 5 Assessment of Completeness, Definition of Notation Keys, and Sources and Sinks Reported as "NE"

## A5.1. Assessment of Completeness

Current inventory is submitted in accordance with the common reporting format (CRF), which requires entering emission data or a notation key such as "NO", "NE", or "NA" for all sources. This chapter presents the definition of notation keys and decision trees for the application of them (including applicability criteria of "NE" when the emissions are considered insignificant), both of which are based on the UNFCCC reporting guidelines (Decision 24/CP.19) and the results of Committee for Greenhouse Gases Emissions Estimation Methods in FY2002, 2012, and 2014.

This chapter also indicates classification of emission source categories reported as "NE" into one which are considered insignificant and the other which are not estimated.

## A5.2. Definition of Notation Keys

In Japan, notation keys are used in accordance with UNFCCC reporting guidelines (Decision 24/CP.19). The following table A5-1 indicates definitions of notation keys provided in the UNFCCC reporting guidelines.

Table A 5-1 Definitions of notation keys indicated in UNFCCC reporting guidelines

| Notation Key | Explanation |
|---|---|
| NO<br>(Not Occurring) | "NO" (not occurring) for categories or processes, including recovery, under a particular source or sink category that do not occur within an Annex I Party. |
| NE<br>(Not Estimated) | "NE" (not estimated) for AD and/or emissions by sources and removals by sinks of GHGs which have not been estimated but for which a corresponding activity may occur within a Party. Where "NE" is used in an inventory to report emissions or removals of $CO_2$, $N_2O$, $CH_4$, HFCs, PFCs, $SF_6$ and $NF_3$, the Annex I Party shall indicate in both the NIR and the CRF completeness table why such emissions or removals have not been estimated. Furthermore, a Party may consider that a disproportionate amount of effort would be required to collect data for a gas from a specific category that would be insignificant in terms of the overall level and trend in national emissions and in such cases use the notation key "NE". The Party should in the NIR provide justifications for exclusion in terms of the likely level of emissions. An emission should only be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions, and does not exceed 500 kt $CO_2$ eq. The total national aggregate of estimated emissions for all gases and categories considered insignificant shall remain below 0.1 per cent of the national total GHG emissions. Parties should use approximated AD and default IPCC EFs to derive a likely level of emissions for the respective category. Once emissions from a specific category have been reported in a previous submission, emissions from this specific category shall be reported in subsequent GHG inventory submissions. |
| NA<br>(Not Applicable) | "NA" (not applicable) for activities under a given source/sink category that do occur within the Party but do not result in emissions or removals of a specific gas. If the cells for categories in the CRF tables for which "NA" is applicable are shaded, they do not need to be filled in. |
| IE<br>(Included Elsewhere) | "IE" (included elsewhere) for emissions by sources and removals by sinks of GHGs estimated but included elsewhere in the inventory instead of under the expected source/sink category. Where "IE" is used in an inventory, the Annex I Party should indicate, in the CRF completeness table, where in the inventory the emissions or removals for the displaced source/sink category have been included, and the Annex I Party should explain such a deviation from the inclusion under the expected category, especially if it is due to confidentiality. |
| C<br>(Confidential) | "C" (confidential) for emissions by sources and removals by sinks of GHGs of which the reporting could lead to the disclosure of confidential information, given the provisions of paragraph 36. (Paragraph 36: Emissions and removals should be reported at the most disaggregated level of each source/sink category, taking into account that a minimum level of aggregation may be required to protect confidential business and military information.) |

Source : UNFCCC reporting guidelines on annual greenhouse gas inventories (Decision 24/CP.19)

Applicability criteria for "NE" when the emissions are considered insignificant was stipulated by the Committee for the Greenhouse Gas Emissions Estimation Methods in FY2012 and FY2014, as shown in the following decision tree (Figure A5-2).

If the UNFCCC reporting guidelines are revised in the future, the definition of notation keys and the reporting method will be reviewed.

## A5.3. **Decision Tree for Application of Notation Keys**

Decision tree for the application of notation keys, based on UNFCCC reporting Guidelines (Decision 24/CP.19) and the results of Committee for Greenhouse Gases Emissions Estimation Methods in FY2002, FY2012, and FY2014, is shown in Figure A5-1.

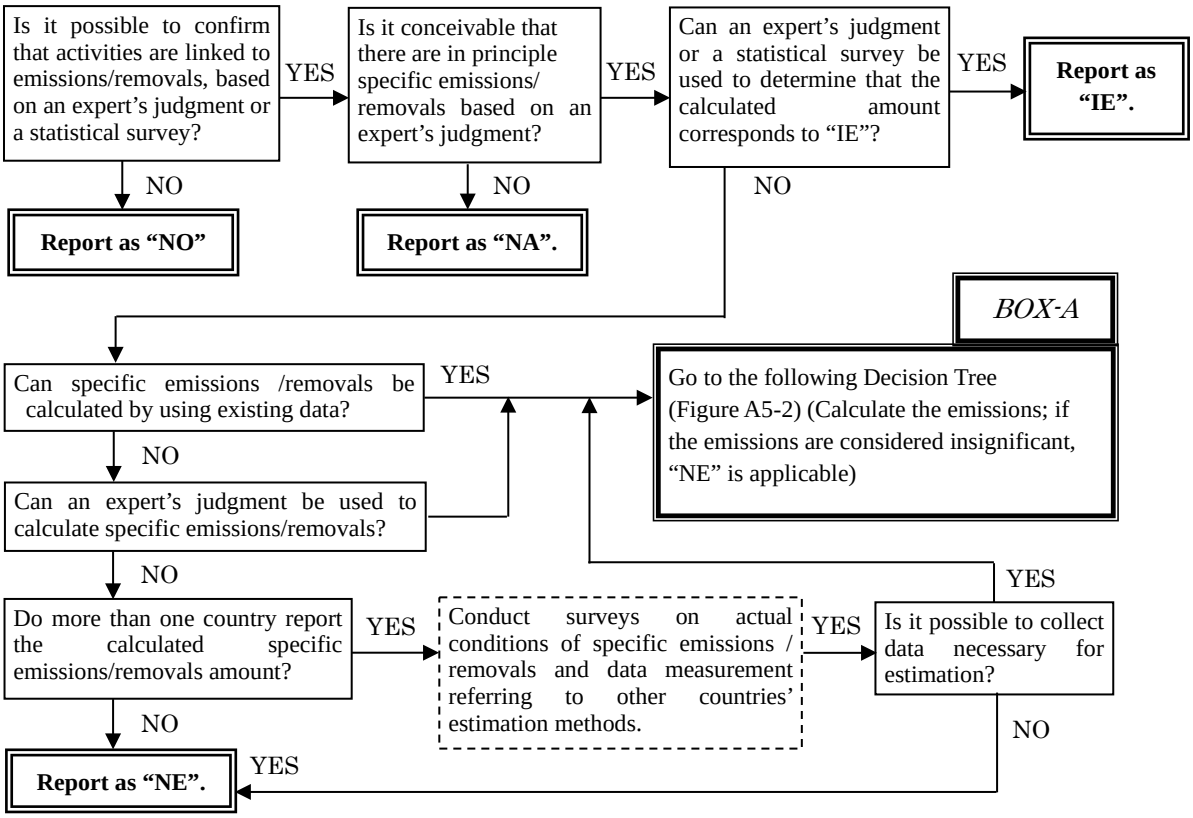


Figure A 5-1 Decision tree for application of notation keys

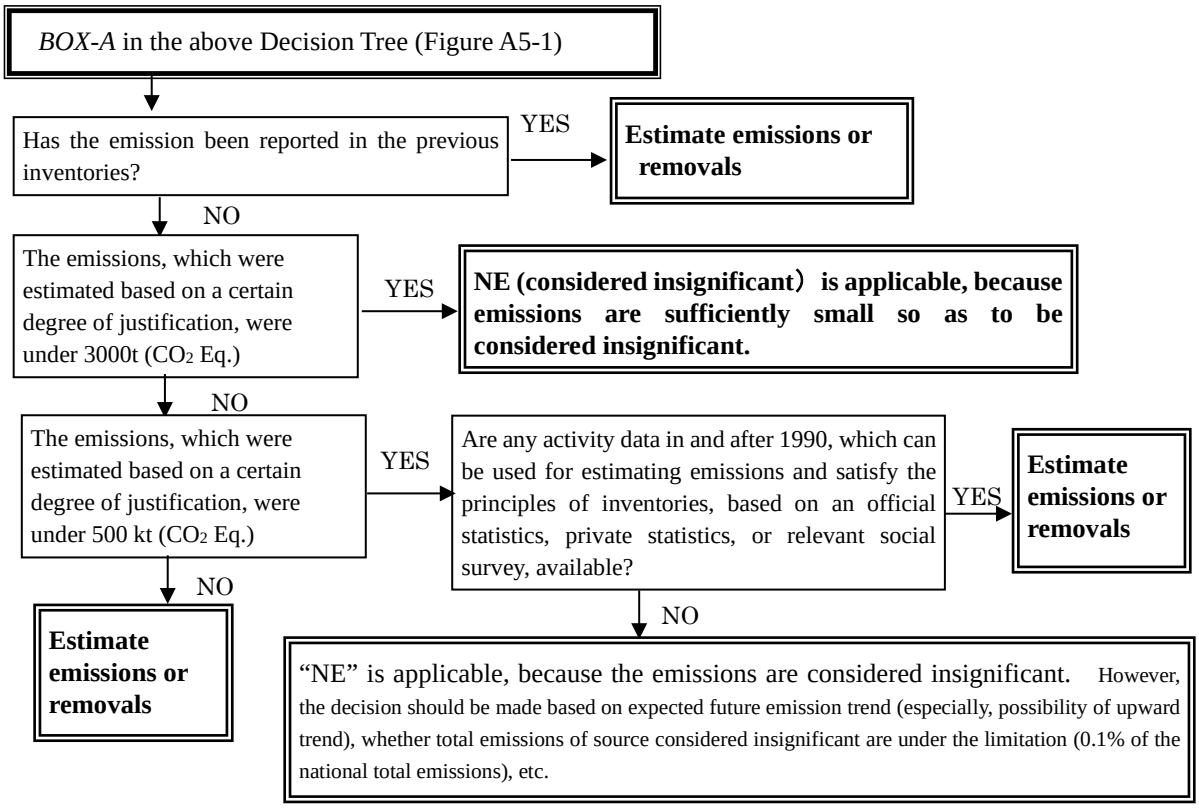


Figure A 5-2 Decision tree for determining applicability of "NE" when the emissions are considered insignificant

When emissions by sources and removals by sinks of GHGs could be confidential information, they are reported as "C".

## A5.4. **Emission sources reported as "NE" (considered insignificant) in Japan**

The notation key NE (considered insignificant) was used for the emission source categories indicated in the following Table A5-2, because the emissions are sufficiently small so as to be considered insignificant. Since the approximate total amount of emissions from these emission sources (excluding removal) is 122kt (in $CO_2$ eq.) at maximum, it is not expected to exceed 0.1% of the national total emissions (approximately 1.24Mt in $CO_2$ eq. for Japan), which is stipulated in paragraph 37(b) in the UNFCCC reporting guidelines (Decision 24/CP.19) as the upper limit of applicability of "NE" for being considered insignificant.

Table A 5-2 Emission sources reported as "NE" (considered insignificant)

| Code | Category No. | Sector and Category | | | Gas | Likely Level of Emissions [kt-$CO_2$eq] |
|---|---|---|---|---|---|---|
| 1 | 1.C. | Energy | $CO_2$ transport and storage | | $CO_2$ | <0.007 |
| 2 | 2.D.3. | IPPU | NMVOC incineration | | $CH_4$ | <0.2 |
| 3 | 2.D.3. | IPPU | NMVOC incineration | | $N_2O$ | <1.0 |
| 4 | 2.F.1. | IPPU | Refrigeration and Air Conditioning Equipment | Fugitive emissions from refrigerant containers | HFCs | <63 |
| 5 | 2.F.4. | IPPU | Product uses as substitutes for ODS | Aerosols | HFCs | <1.8 |
| 6 | 2.G.2. | IPPU | $SF_6$ and PFCs from other product use | Soundproof windows | $SF_6$ | <0.3 |
| 7 | 3.A.4.- | Agriculture | Enteric Fermentation | Deer | $CH_4$ | <2.3 |
| 8 | 3.A.4.- | Agriculture | Enteric Fermentation | Alpaca | $CH_4$ | <0.07 |
| 9 | 3.B.4.- | Agriculture | Manure Management | Deer | $CH_4$ | <0.03 |
| 10 | 3.B.4.- | Agriculture | Manure Management | Reindeer | $CH_4$ | <0.01 |
| 11 | 3.B.4.- | Agriculture | Manure Management | Silver Fox | $CH_4$ | <0.04 |
| 12 | 3.B.4.- | Agriculture | Manure Management | Other Poultry (Duck, Turkey, Quail, Goose, Guinea Fowl, Pheasant) | $CH_4$ | <0.8 |
| 13 | 3.B.4.- | Agriculture | Manure Management | Deer | $N_2O$ | <0.6 |
| 14 | 3.B.4.- | Agriculture | Manure Management | Reindeer | $N_2O$ | <0.02 |
| 15 | 3.B.4.- | Agriculture | Manure Management | Silver Fox | $N_2O$ | <0.01 |
| 16 | 3.B.4.- | Agriculture | Manure Management | Other Poultry (Duck, Turkey, Quail, Goose, Guinea Fowl, Pheasant) | $N_2O$ | <0.3 |
| 17 | 4.D. | LULUCF | Wetlands | Peat extraction | $CO_2$ | <50 |
| 18 | 4.D. | LULUCF | Wetlands | Biomass Burning | $CH_4$ | <0.14 |
| 19 | 4.D. | LULUCF | Wetlands | Biomass Burning | $N_2O$ | <0.16 |
| 20 | 5.B.2 | Waste | Anaerobic digestion at biogas facilities | | $CH_4$ | <1.4 |
| **Total** | | | | | | **<122** |

Note: Maximum possible amount of emissions between FY 1990 and the latest year, under certain assumptions and based on simple estimation methods such as Tier 1

## A5.5. **Source and sink categories not estimated in Japan's inventory**

The following table A5-3 indicates source and sink categories which were not estimated, excluding "NE" applicable categories for being "considered insignificant" as described above.

Table A 5-3 Source and sink categories which were not estimated in Japan's inventory

| Code | Sector | Source and sink category | | | | GHG |
|---|---|---|---|---|---|---|
| 1 | Energy | Fuel Combustion, Transportaion | Liquid Fuels | Domestic Aviation | Cruise | $CH_4$ |
| 2 | Energy | Fuel Combustion | Liquid Fuels | Lubricants | | $CH_4$ |
| 3 | Energy | Fuel Combustion | Liquid Fuels | Lubricants | | $N_2O$ |
| 4 | Energy | Fugitive Emissions from Fuels | Solid Fuels | Coal Mining and Handling | Recovery/Flaring | $CH_4$ |
| 5 | Energy | Fugitive Emissions from Fuels | Solid Fuels | Others (Uncontrollable Combustion) | | $CO_2$ |
| 6 | Energy | Fugitive Emissions from Fuels | Oil and Natural Gas | Oil | Refining/Storage | $CO_2$ |
| 7 | Energy | Fugitive Emissions from Fuels | Oil and Natural Gas | Oil | Distribution of Oil Products | $CO_2$ |
| 8 | Energy | Fugitive Emissions from Fuels | Oil and Natural Gas | Oil | Distribution of Oil Products | $CH_4$ |
| 9 | IPPU | Chemical Industry | Ammonia Production | | | $CH_4$ |
| 10 | LULUCF | Wetlands | Wetlands remaining Wetlands | Flooded land | Living Biomass | Carbon Stock Change |
| 11 | LULUCF | Wetlands | Wetlands remaining Wetlands | Flooded land | Dead Organic Matter | Carbon Stock Change |
| 12 | LULUCF | Wetlands | Wetlands remaining Wetlands | Flooded land | Soil | Carbon Stock Change |
| 13 | LULUCF | Wetlands | Land converted to Wetlands | Cropland converted to Wetlands | Soil | Carbon Stock Change |
| 14 | LULUCF | Wetlands | Land converted to Wetlands | Grassland converted to Wetlands | Soil | Carbon Stock Change |
| 15 | LULUCF | Wetlands | Land converted to Wetlands | Settlements converted to Wetlands | Soil | Carbon Stock Change |
| 16 | LULUCF | Wetlands | Land converted to Wetlands | Other Land converted to Wetlands | Soil | Carbon Stock Change |
| 17 | LULUCF | Settlements | Settlements remaining Settlements | Other than Urban Green Areas | Living Biomass | Carbon Stock Change |
| 18 | LULUCF | Settlements | Settlements remaining Settlements | Other than Urban Green Areas | Dead Organic Matter | Carbon Stock Change |
| 19 | LULUCF | Settlements | Settlements remaining Settlements | Other than Urban Green Areas | Soil | Carbon Stock Change |
| 20 | LULUCF | Settlements | Settlements remaining Settlements | Urban Green Areas not subject to RV | Dead Organic Matter | Carbon Stock Change |
| 21 | LULUCF | Settlements | Settlements remaining Settlements | Urban Green Areas not subject to RV | Soil | Carbon Stock Change |

# Annex 6. Hierarchical Structure of Japan's National GHG Inventory File System

Multiple MS Excel files have been used when estimating Japanese inventory. The explanation of each MS Excel file and the hierarchical structure of Japanese National GHGs Inventory (JNGI) file system are shown below.

Table A6-1 Explanation of each MS Excel file

| Category | Excel file name | Contents |
|---|---|---|
| | JPN_20xx_1990 - JPN_20xx_20yy | Common reporting format generated by CRF reporter |
| 1. Energy | 1A-L3-CO2-1990-20xx - 1A-L3-CO2-20yy-20xx | $CO_2$ emissions from fuel combustions |
| | 1A-L3-CRF-20xx | CRF format data of GHG emissions from fuel combustion (including emissions by energy use of waste) |
| | 1A-L3-timeseries-20xx | Time-series data of GHG emissions from fuel combustion |
| | 1A-L2-MAP_EB-1990-20xx - 1A-L2-MAP_EB-20yy-20xx | Activity Data for furnaces |
| | 1A-L3-Biomass-20xx | GHG emissions from biomass combustion |
| | 1A-L3-CO-20xx | CO emissions from furnace and off-road vehicle |
| | 1A-L3-HC-20xx | $CH_4$, NMVOC emissions from furnace and off-road vehicle |
| | 1A-L3-N2O-20xx | $N_2O$ emissions from furnace and off-road vehicle |
| | 1A-L3-NOxSO2-20xx | NOx, $SO_2$ emissions from fuel combustion (except transport sector) |
| | 1A-L2-nonCO2-ADEF-20xx | Activity Data and Emission Factors of Non-$CO_2$ from fuel combustion (except transport sector) |
| | 1A-L2-NOxSO2-ADEF-20xx | Activity Data and Emission Factors of NOx, $SO_2$ from fuel combustion (except transport sector) |
| | 1A-L3-Lub-20xx | $CO_2$ emissions from lubricant |
| | 1A-L2-EBEF-20xx | Emission Factors for $CO_2$ from fuel combustion |
| | 1A-L1-EB-20xx | Data of the General Energy Statistics using in categorires other than stationary combustion |
| | 1A3-L3-CH4N2O-20xx | GHG emissions from Mobile Combustion (transport sector) (except $CO_2$) |
| | 1A3-L2-ADEF-20xx | Activity Data and Emission Factors for Mobile Combustion (transport sector) |
| | 1A3-L2-2wADEF-20xx | Activity Data and Emission Factors for Motorcycles |
| | 1B-L3-20xx | Fugitive GHG emissions from fuels |
| | 1B-L2-ADEF-20xx | Activity Data and Emission Factors for Fugitive Emissions from Fuels |
| 2. Industrial processes and other product use (IPPU) | 2-L2-ADEF-20xx | Activity Data and Emission Factors of Sector 2 (IPPU) (except F-gases) |
| | 2-L3-20xx | GHG emissions from Sector 2 (IPPU) |
| | 2-L3-Fgas-20xx | F-gas (HFCs, PFCs, $SF_6$, $NF_3$) emissions |
| | 2-L3-NMVOC-20xx | NMVOC emissions from the IPPU sector |
| | 2-L2-NMVOC-20xx | AD and EF for NMVOC emissions from the IPPU sector |
| 3. Agriculture | 3A-L3-CH4-20xx | $CH_4$ emissions from enteric fermentation |
| | 3B-L3-CH4N2O-20xx | GHG emissions from manure management |
| | 3C-L3-CH4-20xx | $CH_4$ emissions from rice cultivation |
| | 3D-L3-N2O-20xx | $N_2O$ emissions from agricultural soils |
| | 3F-L3-CH4N2OCO-20xx | GHG emissions from field burning of agricultural residues |
| | 3GH-L3-CO2-20xx | $CO_2$ emissions from lime application and urine application to agricultural soil |
| | 3-L2-ADEF-20xx | Activity Data and Emission Factors of Sector 3 (Agriculture) |
| | 3AB-L2-EF-20xx | Emission factors of livestock |
| 4. LULUCF | 4-L3-nonCSC-20xx | GHG emissions excluding carbon stock change |
| | 4-L3-4A-CO2-20xx | $CO_2$ emissions and removals from forest land |
| | 4-L3-4B-CO2-20xx | $CO_2$ emissions and removals from cropland |
| | 4-L3-4C-CO2-20xx | $CO_2$ emissions and removals from grassland |
| | 4-L3-4D-CO2-20xx | $CO_2$ emissions and removals from wetlands |
| | 4-L3-4E-CO2-20xx | $CO_2$ emissions and removals from settlements |
| | 4-L3-4F-CO2-20xx | $CO_2$ emissions and removals from other land |
| | 4-L3-4G-CO2-20xx | $CO_2$ emissions and removals from HWP |
| | 4-L2-Area(Pref.)-20xx | Mineral and Organic Soil Area |
| | 4-L2-LandArea-20xx | Land area for each land use category |
| | 4-L2-LandArea-Matrix-20xx | Land-use matrix |
| | 4-L2-Orchard-20xx | Carbon stock changes in orchard |
| | 4-L2-Parameter-20xx | Parameters for each land use category |
| | 4-L2-Soil-20xx | Land area and carbon stock changes in cropland and grassland |
| | 4-L2-Biochar-20xx | Organic carbon stocks from biochar amendments in mineral soil in cropland |
| 5. Waste | 5A3-L2-AD-20xx | Activity data of solid waste disposal (other) |
| | 5A-L3-20xx | GHG emissions from solid waste disposal |
| | 5A-L2-AD-20xx | Activity data of solid waste disposal (managed disposal site) |
| | 5B-L3-20xx | GHG emissions from biological treatment of solid waste |
| | 5B-L2-AD-20xx | Activity data of biological treatment of solid waste |
| | 5C-L2-AD-20xx | Activity data of incineration and open burning of waste |
| | 5C-L3-20xx | GHG emissions from incineration and open burning of waste |
| | 5C-L3-Energy-20xx | GHG emissions from waste incineration and energy use (reported in the energy sector) |
| | 5D-L3-20xx | GHG emissions from waste water treatment and discharge |
| | 5D-L2-AD-20xx | Activity data of waste water treatment and discharge |
| | 5E-L3-20xx | GHG emissions from other |
| | 5E-L2-AD-20xx | Activity data of other |
| | 5-L2-EF-20xx | Emission factors of Sector 5 (Waste) |
| 6. Other | 6-L3-20xx | CO emissions from smoking |
| 7. Indirect $CO_2$ | 7-L3-Indirect CO2-20xx | Indirect $CO_2$ emissions |
| Memo item | 1D-L3-bunker-20xx | GHG emissions from international bunker fuels |
| KP-LULUCF | 4KP-3-Summary-20xx | GHG emissions and removals from KP3.3 and 3.4 activities |
| | 4KP-2-AR-20xx | GHG emissions and removals from Afforestation/Reforestation |
| | 4KP-2-CM-20xx | GHG emissions and removals from Cropland Management |
| | 4KP-2-D-20xx | GHG emissions and removals from Deforestation |
| | 4KP-2-FM-20xx | GHG emissions and removals from Forest Management |
| | 4KP-2-HWP-20xx | $CO_2$ emissions and removals from HWP in Forest Management |
| | 4KP-2-GM-20xx | GHG emissions and removals from Grazing Land Management |
| | 4KP-2-RV-20xx | GHG emissions and removals from Revegetation |

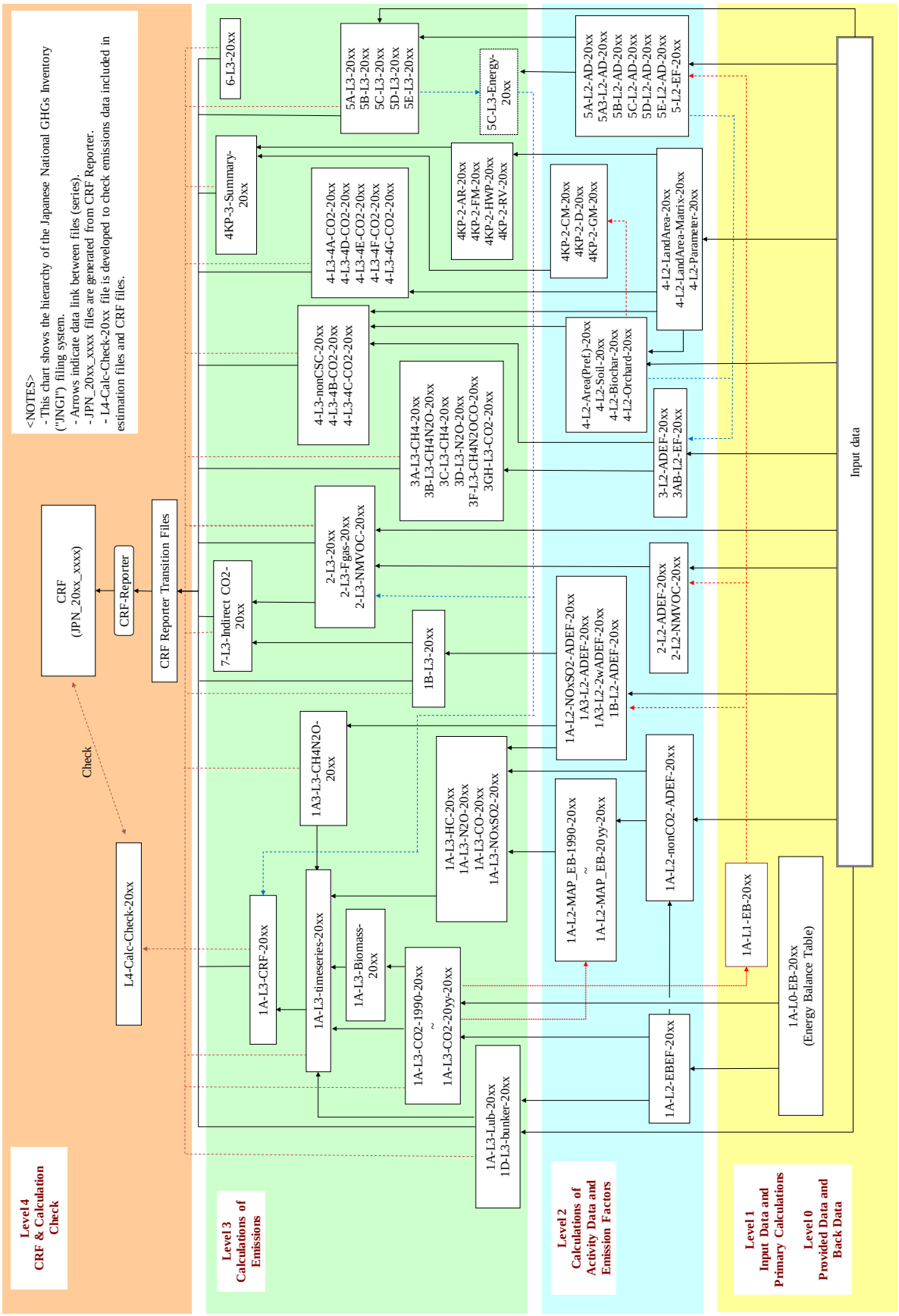


Figure A 6-1 Hierarchical structure of Japan's National GHG Inventory File System

# Abbreviations

## 1. Greenhouse Gases

Table AB-1 Greenhouse Gases

| Term | Gas |
|---|---|
| $CO_2$ | Carbon dioxide |
| $CH_4$ | Methane |
| $N_2O$ | Nitrous oxide |
| HFCs | Hydrofluorocarbons |
| PFCs | Perfluorocarbons |
| $SF_6$ | Sulfur hexafluoride |
| $NF_3$ | Nitrogen trifluoride |

Table AB-2 Precursors and $SO_X$

| Term | Gas |
|---|---|
| NOx | Sum of nitrogen oxide and nitrogen dioxide |
| CO | Carbon monoxide |
| NMVOC | Non-methane volatile organic compounds |
| $SO_x$ | Sulfur oxide |

## 2. Prefixes and Units

Table AB-3 Prefixes

| Term | Prefix | Definition |
|---|---|---|
| P | peta | $10^{15}$ |
| T | tera | $10^{12}$ |
| G | giga | $10^{9}$ |
| M | mega | $10^{6}$ |
| k | kilo | $10^{3}$ |
| h | hecto | $10^{2}$ |
| da | deca | $10^{1}$ |
| d | deci | $10^{-1}$ |
| c | centi | $10^{-2}$ |
| m | milli | $10^{-3}$ |
| μ | micro | $10^{-6}$ |

Table AB-4 Units

| Term | Definition |
|---|---|
| $m^3$ | cubic metre |
| L | litter |
| a | are |
| ha | hectare |
| g | gram |
| t | tonne |
| J | joule |
| °C | degree Celsius |
| yr | year |
| cap | capita |
| d.m. | dry matter |

## 3. Notation Keys

Table AB-5 Notation keys (See Annex 5 for details)

| Notation Key | Definition |
|---|---|
| NO | Not Occurring |
| NE | Not Estimated |
| NA | Not Applicable |
| IE | Included Elsewhere |
| C | Confidential |

## 4. Other Abbreviations

Table AB-6 Abbreviations

| | Terms | Definition |
|---|---|---|
| A | AAU | Assigned Amount Units |
| | AD | Activity Data |
| | ARD | Afforestation, Reforestation and Deforestation |
| B | BFG | Blast Furnace Gas |
| | BOD | Biochemical Oxygen Demand |
| C | CFG | Converter Furnace Gas |
| | CGER | Center for Global Environmental Research |
| | CM | Cropland Management |
| | $CO_2$ eq. | Gas Emission in $CO_2$ equivalent |
| | COD | Chemical Oxygen Demand |
| | COG | Coke Oven Gas |
| | CRF | Common Reporting Format |
| | CS-EF | Country-Specific Emission Factor |
| | CY | Calendar Year |
| E | EEA | European Environment Agency |
| | EF | Emission Factor |
| | EMEP | European Monitoring and Evaluation Programme |
| F | FM | Forest Management |
| | FY | Fiscal Year |
| G | GCV | Gross Calorific Value |
| | GHG | Greenhouse Gas |
| | GIO | Greenhouse Gas Inventory Office |
| | GM | Grazing Land Management |
| | GPG | Good Practice Guidance |
| | GPG (2000) | Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000) |
| | GPG-LULUCF | Good Practice Guidance for Land Use, Land-Use Change and Forestry |
| | GWP | Global Warming Potential |
| I | IEA | International Energy Agency |
| | IEF | Implied Emission Factor |
| | IPCC | Intergovernmental Panel on Climate Change |
| J | JNGI | Japanese National GHG Inventory |
| K | KP | Kyoto Protocol |
| L | LNG | Liquefied Natural Gas |
| | LPG | Liquefied Petroleum Gas |
| | LTO | Landing and Take-off |
| | LULUCF | Land-Use, Land-Use Change and Forestry |
| M | MAFF | Ministry of Agriculture, Forestry and Fisheries |
| | MDI | Metered Dose Inhalers |
| | METI | Ministry of Economy, Trade and Industry |
| | MOE | Ministry of the Environment |
| | MOFA | Ministry of Foreign Affairs of Japan |
| | MIC | Ministry of Internal Affairs and Communications |
| | MLIT | Ministry of Land, Infrastructure and Transport and Tourism |
| | MSW | Municipal Solid Waste |
| N | NCV | Net Calorific Value |
| | NFRDB | National Forest Resource DataBase |
| | NGL | Natural Gas Liquids |
| | NIES | National Institute for Environmental Studies |
| | NIR | National Inventory Report |
| Q | QA/QC | Quality Assurance / Quality Control |
| | QAWG | Quality Assurance Working Group |

Table AB-6 Abbreviations (Continued)

| | Terms | Definition |
|---|---|---|
| R | RDF | Refuse Derived Fuel |
| | RPF | Refuse Paper and Plastic Fuel |
| | RV | Revegetation |
| S | SEF | Standard Electronic Format |
| T | THC | Total Hydrocarbon |
| | TOE | Tonnes of Oil Equivalent |
| U | UNFCCC | United Nations Framework Convention on Climate Change |