

Estimation of Fluorinated Gases Emission from Semiconductor Industry

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Scope

1. Singapore's Greenhouse Gas (GHG) Inventory
2. Estimating Fluorinated Gas (F-gas) emissions from Semiconductor Industry
3. Addressing Challenges in the Estimation of F-gas Emissions

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Singapore's GHG Inventory

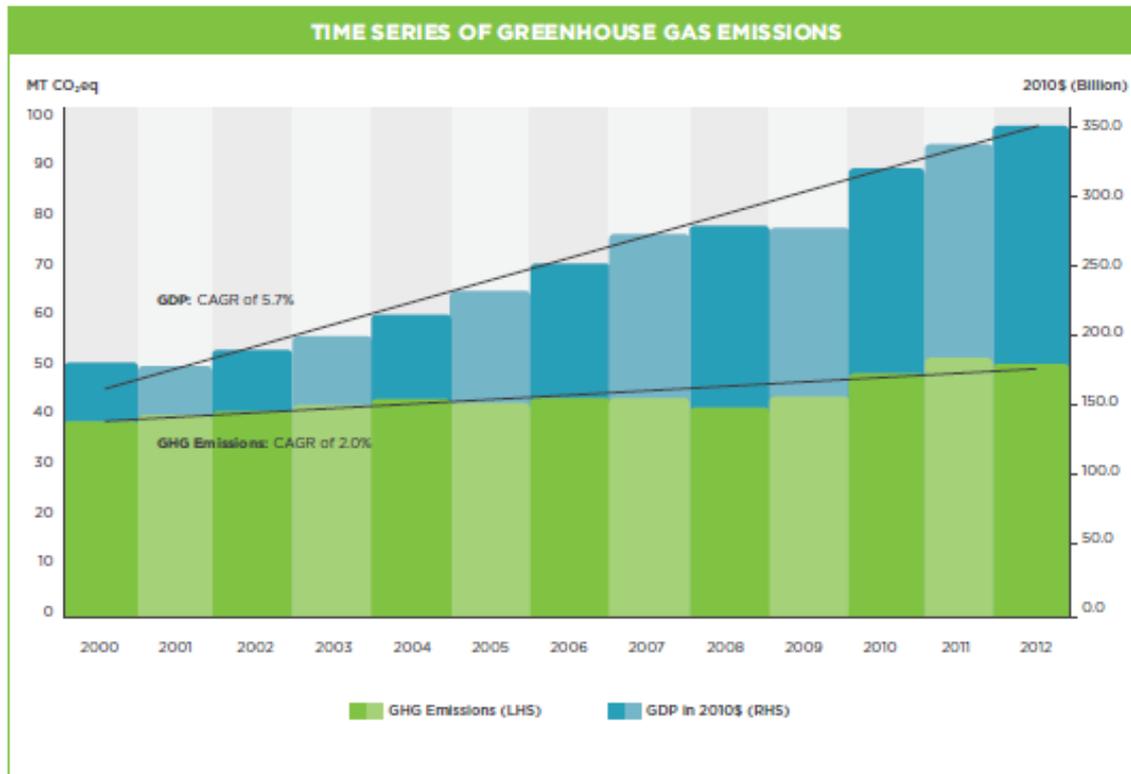
Singapore's GHG Inventory

- Singapore's 2012 emissions totaled 48,094.65 Gg CO₂ equivalent
- The most significant greenhouse gas (GHG) emitted in Singapore is carbon dioxide, primarily produced by the burning of fossil fuels to generate energy used by the industry, buildings, household and transport sectors.
- The breakdown by *Type of Gas* is as follows:

Greenhouse Gas	Emissions (Gg CO ₂ eq)	% of Total GHG Emissions
Carbon dioxide (CO ₂)	46,538.16	96.76%
Perfluorocarbons (PFCs)	930.83	1.93%
Nitrous oxide (N ₂ O)	411.68	0.86%
Sulphur hexafluoride (SF ₆)	89.33	0.19%
Methane (CH ₄)	86.73	0.18%
Hydrofluorocarbons (HFCs)	37.92	0.08%

Singapore's GHG Inventory

- From 2000 to 2012, Singapore's economy grew at a compounded annual growth rate (CAGR) of 5.7%.
- In the same period, Singapore's GHG emissions grew at a **slower** rate with a CAGR of 2.0%, or an increase of 26% (9,839 Gg CO₂eq) from 2000 to 2012.



Emission of Fluorinated Gases in 2010 and 2012

- Based on the data published in Singapore's BUR in 2010 and 2012, the emissions of F gases (in Gg CO₂ eq) - largely from the semiconductor industry - are as below.

Type of Gas	2010 (Gg CO ₂ e)	2012 (Gg CO ₂ e)
HFCs	39.94	37.92
PFCs	987.91	930.83
SF ₆	86.25	89.33

2 Estimating Fluorinated Gas (F-gas) Emissions from Semiconductor Industry

Reporting of GHG Emissions by Companies

- Reporting of GHG emissions are regulated under Energy Conservation Act (ECA) from 2013
- Companies report via online system EDMA (Emissions Data Monitoring and Analysis System)



Welcome to Emissions Data Monitoring and Analysis System

Announcements

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Estimation of Fluorinated Gases Emission from Semiconductor Industry

- The emissions of F-gases were estimated using Tier 2a methodology.
- 2006 IPCC Guidelines, Volume 3 IPPU, Chapter 6, Equation 6.2 to 6.6.

EQUATION 6.2

TIER 2a METHOD FOR ESTIMATION OF FC EMISSIONS

$$E_i = (1 - h) \cdot FC_i \cdot (1 - U_i) \cdot (1 - a_i \cdot d_i)$$

Where:

E_i = emissions of gas i , kg

FC_i = consumption of gas i , (e.g., CF_4 , C_2F_6 , C_3F_8 , $c-C_4F_8$, $c-C_4F_8O$, C_4F_6 , C_5F_8 , CHF_3 , CH_2F_2 , NF_3 , SF_6), kg

h = fraction of gas remaining in shipping container (heel) after use, fraction

U_i = use rate of gas i (fraction destroyed or transformed in process), fraction

a_i = fraction of gas i volume used in processes with emission control technologies (company- or plant-specific), fraction

d_i = fraction of gas i destroyed by the emission control technology, fraction

Estimation of Fluorinated Gases Emission from Semiconductor Industry

- EDMA is designed for companies to report site-specific activity data based on *Type of Process Gas*.
- Companies are able to estimate the amount of F-gas consumption based on metering capabilities on-site.
 - *Metered*
 - *Non-metered calculated based on Total Purchased * (1 – h).*
{Default heel fraction, h is provided as 0.1}
- 2006 IPCC default factors are preset into EDMA
 - *Companies are also able to apply site-specific factors, if available.*

Estimation of Fluorinated Gases Emission from Semiconductor Industry

- EDMA is able to auto-compute the direct F-gas emissions based on IPCC Tier 2a methodology which is incorporated into the system.
- By-products emissions are also auto-computed based on the IPCC default factors.

Process Gas (i)	Greenhouse Gases with TAR GWP									Greenhouse Gases without TAR GWP			Non-GHG _s Producing FC By-products ²	
	CF ₄	C ₂ F ₆	CHF ₃	CH ₂ F ₂	C ₃ F ₈	c-C ₄ F ₈	NF ₃ Remote	NF ₃	SF ₆	C ₄ F ₆	C ₂ F ₈	C ₄ F ₈ O	F ₂	COF ₂
Tier 2a														
1-Ui	0.9	0.6	0.4	0.1	0.4	0.1	0.02	0.2	0.2	0.1	0.1	0.1	NA	NA
B _{CF₄}	NA	0.2	0.07	0.08	0.1	0.1	0.02 ^f	0.09	NA	0.3	0.1	0.1	0.02 ^f	0.02 ^f
B _{C₂F₆}	NA	NA	NA	NA	NA	0.1	NA	NA	NA	0.2	0.04	NA	NA	NA
B _{C₃F₈}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.04	NA	NA
Tier 2b														
Etch 1-Ui	0.7 [*]	0.4 [*]	0.4 [*]	0.06 [*]	NA	0.2 [*]	NA	0.2	0.2	0.1	0.2	NA	NA	NA
CVD 1-Ui	0.9	0.6	NA	NA	0.4	0.1	0.02	0.2	NA	NA	0.1	0.1	NA	NA
Etch B _{CF₄}	NA	0.4 [*]	0.07 [*]	0.08 [*]	NA	0.2	NA	NA	NA	0.3 [*]	0.2	NA	NA	NA
Etch B _{C₂F₆}	NA	NA	NA	NA	NA	0.2	NA	NA	NA	0.2 [*]	0.2	NA	NA	NA
CVD B _{CF₄}	NA	0.1	NA	NA	0.1	0.1	0.02 ^f	0.1 ^f	NA	NA	0.1	0.1	0.02 ^f	0.02 ^f
CVD B _{C₂F₆}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CVD B _{C₃F₈}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.04	NA	NA

Notes: NA denotes not applicable based on currently available information

Estimation of Fluorinated Gases Emission from Semiconductor Industry

- Companies are required to identify the type of abatement used on-site.
- Default abatement efficiency are provided as per 2006 IPPC GLs in the Table below.

Emission Control Technology	CF₄	C₂F₆	CHF₃	C₃F₈	c-C₄F₈	NF₃^f	SF₆
Destruction^c	0.9	0.9	0.9	0.9	0.9	0.95	0.9
Capture/Recovery^d	0.75	0.9	0.9	NT	NT	NT	0.9

- Companies are also able to apply site-specific factors based on individual OEM's technology.

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Addressing Challenges in the Estimation of F-gas Emissions

Addressing Challenges

- Nature of the semiconductor industry
 - Challenging for companies to develop a company-specific emission factor ($1-U_i$) due to changing of production / process recipes based on customer's requirements
 - Useful if IPCC could periodically update default factors where possible
- Improving accuracy of estimated F-gas emissions
 - We encourage companies to use company-specific abatement efficiency factors based on OEM specifications.

Addressing Challenges

- Robustness of data
 - Institutionalised inter-agency MRV Taskforce to endorse QC/QA process for compilation and computation of data
- Completeness of data
 - Good inter-agency cooperation to review data collected and to identify possible gaps
- Capacity building to build technical knowledge for continual improvements to the GHG inventory
 - Attend GHG inventory training programmes as and when they are organised

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