version 160615

ICA-RUS REPORT 2015

Alternatives Left to Humanity Faced with Global Climate Risks (Ver.1)

ICA-RUS
Integrated Climate Assessment - Risks, Uncertainties and Society

Comprehensive Research on the Development of Global Climate Change
Risk Management Strategies
S-10 Strategic Research Project
Supported by the Environmental Research and Technology Development Fund of
the Ministry of the Environment, Japan

September 2015

Preface

The 21st session of the Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) will be held in Paris at the end of 2015, when an agreement on a new framework for the global response to climate change from 2020 is anticipated. The parties to the UNFCCC have already agreed that "deep cuts in global greenhouse gas emissions are required, with a view to reducing global greenhouse gas emissions so as to hold the increase in global average temperature below 2 degrees Celsius above pre-industrial levels" (the 2°C goal). According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), achieving the 2°C goal with a high degree of probability will necessitate cutting global CO_2 emissions to almost zero by the end of this century. This is clearly not an easy goal, and there are currently no prospects in sight of the world cutting emissions at the pace required to achieve this.

Such a dire situation led some to claim that we should no longer aim for the 2°C goal. On the other hand, it is important to recognize that there are major political risks attendant on wavering from the 2°C goal ahead of COP21. We respect the 2°C goal, which has been arrived at through a process of international negotiations, and do not believe that it should be revised immediately.

We, however, argue that the global community should continue to review this goal. In Japan, since the crisis at the Fukushima Daiichi Nuclear Power Plant that followed the Great East Japan Earthquake in 2011, the "myth" of nuclear safety shared hitherto by the majority of Japanese society has come into question. The issue was not so much that nuclear power was not safe, but rather that people had stopped thinking about what nuclear safety actually meant. To ensure that the 2°C goal does not suffer a similar fate and assume "mythic" status, we must consider continuously what this goal means.

The ICA-RUS project ("Integrated Climate Assessment – Risks, Uncertainties and Society") was launched under a five-year plan commenced in 2012 as a "Comprehensive Research on the Development of Global Climate Change Risk Management Strategies" S-10 Strategic Research Project supported by the Environmental Research and Technology Fund of the Ministry of the Environment of Japan, and the present report integrates the findings that obtained up to the end of the third project year*. We looked into climate change risks from a global, long-term perspective, and identified alternatives left for humankind to tackle them. With discussion of the draft commitments made by each country heating up ahead of COP21, we believe that now is precisely the right time to put forward a case from a global perspective. We encourage society to join us in thinking about what choices humankind should make beyond COP21.

Seita Emori
ICA-RUS Project Leader

*This report is a summary of "Alternatives Left to Humanity Faced with Global Climate Risks (Ver. 1)" (full report, March 2015)(in Japanese). http://www.nies.go.jp/ica-rus/materials.html

ICA-RUS REPORT 2015

Alternatives Left to Humanity Faced with Global Climate Risks (Ver.1)

Integrated Climate Assessment-Risks, Uncertainties and Society

CONTENTS

Executive summary

For this report, three ”strategies” named T15S30, T20S30, and T25S30 for each were created. They correspond respectively to the GHGs emission pathways toward keeping the global temperature rise within 1.5°C, 2.0°C, and 2.5°C above the pre-industrial level with a 50% probability of success. (S30 means that the emission pathways were calculated assuming a climate sensitivity of 3.0°C, and corresponds to a probability of achieving the temperature rise target of around 50%.) The consequences of each “strategy” at the global level were then compared by assessing both risks and responses while allowing for uncertainty.

Impact assessment

Our assessment of the impacts on each of the categories—agriculture, ecosystems, water resources, floods, health, and tipping elements—showed that, as a general trend, the differences in impacts between any two “strategies” were smaller than those between any “strategy” and the “business as usual” (BaU) scenario (i.e., no action on climate change), and they were also less than the range of impacts caused by climate uncertainty. From the point of view of global risk, this suggests that taking definite action in an overall direction and devising ways of dealing with climate uncertainty are of greater importance than the specific choice of target (1.5°C, 2.0°C, or 2.5°C).

It needs to be noted, however, that the limited coverage of the impact assessment (expressed by risk inventories) and the absence of converting impacts into an integrated index (such as market value) hamper us from comparing among impact items and also between the total impact and action costs. Furthermore, the differences between “strategies” in impact in specific sectors and regions might not be small.

The choice of “strategies” can give rise to very different implications with specific regard to tipping elements. According to IPCC AR5, the tipping point for destabilization of the Greenland ice sheet can be crossed at a global temperature rise of between 1°C and 4°C from pre-industrial levels, and the latest research that takes into account the changes in ice sheet shape support a figure at the lower end. Thus, if the threshold is just 1.0°C, it will inevitably be passed regardless of which “strategy” is chosen. If, on the other hand, it is 2.0°C, the strategic choice will greatly affect the likelihood of the tipping point being passed. This question, including the uncertainties surrounding tipping points and the consequences of their being passed, is something that requires further detailed discussion.

Response assessment

Estimation using multiple integrated assessment models of the mitigation responsesneeded to achieve the mitigation target for each “strategy” and the economic costs of doing so revealed marked differences between the ””strategies”. Most notably, T15S30 was found to be even more challenging than RCP2.6, the most ambitious scenario assessed for IPCC AR5: the target is achievable only under exceptionally optimistic assumptions or, depending on the model, no solution is obtainable for it.

The choice of technology options for achieving the mitigation targets of these “strategies” differs considerably across the models. The targets can be achieved either with large-scale adoptions of nuclear power or renewable energy technologies. On the other hand, all the models suggest that large-scale implementations of the carbon capture and storage (CCS) will be necessary. Furthermore, it was found that CCS combined with biomass energy (BECCS) may compete with food production for land under pessimistic assumptions associated with crop yields and CCS capture efficiency.

Generally speaking, costs estimated by integrated assessment models tend to be optimistic because of the assumption of optimum economic rationality at the global level . Given that predicting unknown innovations that might transform technological and socioeconomic systems in the future is intrinsically impossible, however, our estimates may turn out to be more pessimistic than the reality. Modeling in addition produces solutions premised on target attainment, but there is always a risk that the target adopted may not actually be attainable.

In this report, we did not include an analysis of spillover risks and co-benefits other than the competition between BECCS and food production. We recognize the importance of this issue, and relevant work is underway for inclusion in the final report.

Effect of risk averseness

We setup three more “strategies”—T15S45, T20S45, and T25S45—to cap the global average temperature rise under 1.5°C, 2.0°C, and 2.5°C, respectively above pre-industrial levels with a higher risk-averse probability of around 80%. (S45 means that the emission pathways were calculated assuming a climate sensitivity of 4.5°C.) The results for T20S45 were broadly similar to those for T15S30, and T25S45 likewise produced similar results to T20S30.

T15S45 necessitates that extreme reductions be made in order to achieve negative global emissions within 10 years, and the response assessment produced no solution for this strategy.

T15S30, for which similar results to those for T20S45 were obtained, adopts a challenging target that is unachievable except under exceptionally optimistic conditions. This suggests that it might already be extremely difficult to pursue a 2°C target at a high probability level of, say, 80%.

Implications for choice of "strategy"

We found that a reduction in action costs is generally more sensitive to an upward target revision (e.g. T20S30 to T25S30) than an accompanying increase in impacts. Thus from the point of view of global economic rationality, T25S30 may result in less economic loss than T20S30. It is necessary to note, however, that this will not become apparent in the real world unless climate risks, spillover risks of responses, and co-benefits and so on are all converted to economic value so that the costs of actions can be comprehensively compared.

As far as tipping elements are concerned, more careful discussion is required as noted above. If, for example, the tipping point for destabilization of the Greenland ice sheet is assumed to be around 2°C, then it becomes more likely that the tipping point will be exceeded under T25S30 than under T20S30. If the economic loss due to the start of destabilization of the Greenland ice sheet were to be included and the impact damage of this were to be comparable with the difference in cost of action between T25S30 and T20S30, then choosing T25S30 might not be justifiable from the point of view of global economic rationality.

It is also important to remember that adopting a target and achieving it are two different things. Choosing a "strategy", whether T15S30, T20S30, or T25S30, thus becomes even more difficult when the practicalities of attainability are taken into consideration.

One final remark is that the pursuit of a challenging target such as T15S30 or T20S30 may be perceived not as a question of economic costs and introducing technologies premised on existing arrangements, but rather as an issue of "transforming society towards sustainability" (see, for example, WBGU, 2011)[1]. Following this line of thinking, one might argue that a "strategy" that sets a more challenging target should be actively embraced because it would encourage the transformation of existing social and economic systems based on new values, and so allow us to achieve the target more inexpensively than predicted by the models. . However, such a viewpoint reflects certain value judgments by the individual and the group, and this topic deserves public debate.

Future research plan

ICA-RUS plans to work on the followings before a publication of its final report in two years:

- Investigate adaptation efforts and geoengineering possibilities corresponding to the consequences of each "strategy"
- Expand the items of impact assessment and socioeconomic scenarios considered
- Incorporate into our analysis the classification and analysis of spillover risks and co-benefits associated with responses
- Conduct a study taking into account successive (multi-stage) decision-making (such as a target revision in 2050)
- Pursue a socially rational decision-making framework that gives due consideration to the characteristics of global climate risks

By exploring these issues, we aim to contribute to more in-depth consideration of the choices for humankind regarding global climate risks and so produce findings that will encourage and inform public debate.

[1] WBGU (2011), "The Transformation towards Sustainability," Factsheet No. 4.
http://www.wbgu.de/fileadmin/templates/dateien/veroeffentlichungen/factsheets/fs2011-fs4/wbgu_fs4_2011_en.pdf

1 Organization of ICA-RUS research

1.1 ICA-RUS research framework

The research framework employed by ICA-RUS since its commencement in 2012 is defined by the following three characteristics.

Firstly, human action to cope with global climate change due to rising levels of greenhouse gases (GHGs) in the atmosphere is viewed in terms of "risk management." The term "risk management" implies 1) decision-making under uncertainty, 2) decision-making based on scientific evidence, 3) consideration, insofar as possible, of all kinds of circumstances and options, 4) flexible revision according to changes in conditions, and 5) involvement of social value judgments.

Secondly, the project adopts a global, long-term (approximately century-long) perspective on climate change issues. In reality, decisions on these issues are made at various times by various actors. Often, however, such decisions are likely to be premised on determining what is preferable for the world as a whole, and in practice global discussion of targets and other subjects takes place under the UNFCCC. ICA-RUS therefore considers the options by which humankind as a whole can tackle these issues from a global, long-term perspective.

And thirdly, ICA-RUS presents several "strategies" as options. While options for action on climate change issues consist mainly of mitigation actions and adaptation actions, geoengineering is also a possibility, as is acceptance of a certain degree of risk. ICA-RUS has combined these options in various ways to produce risk management "strategies" for coping with climate change risks. These "strategies" are seen as providing options for humankind, and study of them is underway. (These are described in greater detail in later sections.)

To guide its investigations within the framework defined by these three characteristics, ICA-RUS has adopted five themes of research, each involving experts from a number of universities and research institutes in Japan (Table 1).

1.2 Dialogue with stakeholders

ICA-RUS places a strong emphasis in its research on dialogue with stakeholders, who are widely defined as actors with an interest or opinion on long-term global climate change risks. These include government organizations, industries and businesses, NGOs, the media, and researchers. Through dialogue with stakeholders, we endeavor to ascertain their perceptions and priorities regarding the risks and to incorporate them into broadening the scope of research by ICA-RUS. Out of dialogue with and between stakeholders, there also emerge areas of controversy and consensus that can serve as a guide for issues to be considered by ICA-RUS.

Table 1 Overview of research themes

THEME 1 Synthesis of global climate risk management strategies	● Proposal of risk management strategy for rationally determining the course of comprehensive options against climate change (including climate stabilization targets).
THEME 2 Optimization of land, water and ecosystem uses for climate risk management	● Presentation of results of simulations to quantitatively assess (including uncertainties) the interactions of climate change impacts and response options against climate change with water, energy, food, ecosystems, etc., and analysis of co-benefits and trade-offs based on these results.
THEME 3 Identification and analysis of critical climate risks	● Comprehensive assessment (including uncertainties) of factors including the levels of temperature rises at which the potential effects of climate change that humankind should avoid become apparent, and the scale and nature of their adverse impacts, and analysis of the risks at each climate change level.
THEME 4 Evaluation of climate risk management options under technological, social and economic uncertainties	● Method and model development for the comprehensive assessment (factoring in uncertainties) of the potentials and costs of various options to deal with climate changes (including mitigation, adaptation, and geoengineering), analysis of their outcomes and rational ways of combining response options.
THEME 5 Interactions between scientific and social rationalities in climate risk management	● Analysis of distribution of public opinion concerning the various value judgments impacting on the determination of climate stabilization targets, etc. ● Analysis of the social elements of public perceptions of climate change risks and their key attributes from scientific and risk communication perspectives.

2 Methodology for a assessment of "strategies"

2.1 Concept of "strategy"

ICA-RUS bundles mitigation targets, the ranges of their consequences, and consideration of adaptation (plus geoengineering) derived through Steps 1 to 3 to produce a "strategy" for each mitigation target. These "strategies" are treated as the risk management options that are available to society (Figure 1).

In this report, however, we do not report on Step 3, as research on this step is not yet sufficiently advanced.

Step 1 : Setting mitigation targets

Pathways for global greenhouse gas (GHG) emissions over the long term (up to 2100 or 2200) are mapped out to provide mitigation targets for lowering actual emissions. Mitigation targets are defined by three choices: (a) target temperature level, (b) risk averseness, and (c) assumptions made regarding the pathway.

Choice of target temperature level means deciding how close (in degrees Celsius) the peak global average temperature should be kept to pre-industrial levels.

The choice regarding risk averseness means deciding how likely it is that the target temperature level will be exceeded given scientific uncertainty.

The key choice to make regarding the assumptions behind a pathway is whether to adopt an outlook that allows zero or negative global emissions to be achieved in order to allow a reduction of the concentrations of GHGs in the atmosphere (i.e., "overshoot," where the concentration decreases after first increasing).

Step 2 : Deriving range of consequences for each mitigation target under uncertain conditions

The range of consequences of mitigation targets is determined taking into account various uncertainties, such as climate (and impact) uncertainties, uncertainties concerning mitigation actions, and socioeconomic uncertainties.

Climate uncertainties arise from uncertainties over the scientific estimates of factors such as "climate sensitivity" and "climate-carbon cycle feedback," which have a bearing on the susceptibility of the global temperature to increase.

Uncertainties over mitigation actions arise from the possibility that a mitigation action considered necessary to achieve a target is only partially implemented, or else is fully implemented but does not prove as effective as anticipated, and gives rise to the risk that the temperature rise may be greater than initially projected.

Socioeconomic uncertainties (excluding those relating to climate policy) arise from uncertainties over future projections of variables such as world population, economic development, and social inequality.

Step 3 : Considering necessary adaptation level (plus need for geoengineering)

The necessary level of adaptation action is considered for each mitigation target and costs are estimated where possible.

As a range of consequences is possible for each mitigation target due to the existence of various uncertainties, there is a particular risk that the temperature rise may exceed the target. It is therefore important to take this possibility into account when considering what adaptation action will be required. Where a mitigation target remains subject to the risk of a large temperature rise, consideration should also be given to geoengineering, and in particular to the use of solar radiation management.

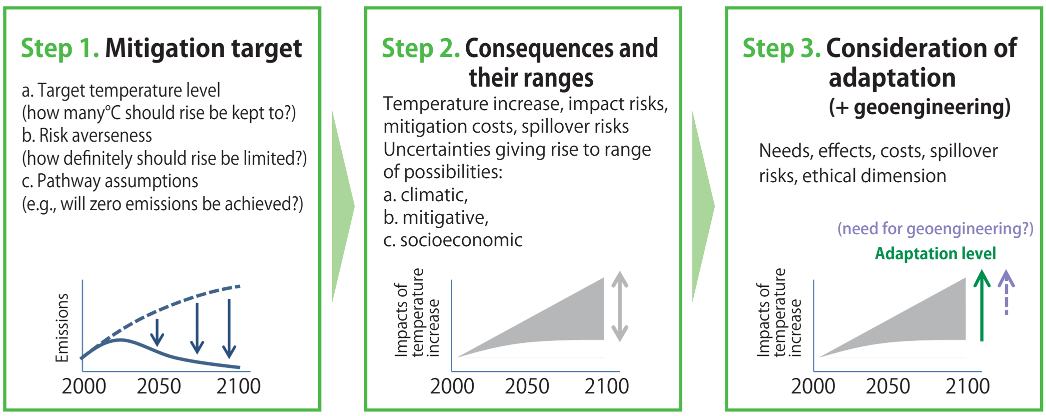


Figure 1 Concept of "strategy" used by ICA-RUS

2.2 Points to note when considering "strategies"

When considering the "strategies" put forward by ICA-RUS, therefore, the following provisos regarding comprehensiveness, uncertainties, and value judgments should be borne in mind.

Comprehensiveness

Climate change risks, action options, and the spillover risks associated with actions extend over a variety of fields, making them hard to assess comprehensively. Care is required, however, as research that is insufficiently comprehensive in scope can produce biased findings. To make explicit the limits to the comprehensiveness of research by ICA-RUS, therefore, we have listed the climate change risks, action options, and spillover risks associated with actions (in the form of risk inventories and action inventories) to make it clear which are being considered. Efforts are also being made to enhance comprehensiveness by focusing on surveying existing knowledge alongside conducting original analyses of a limited range of risk categories.

Uncertainty

Coping with uncertainty is at the heart of risk management. The uncertainties bearing on global climate risk management that ICA-RUS addresses are diverse, and taking into consideration all kinds of uncertainties is by no means easy. While this report deals with uncertainties as explicitly as possible, attention should be paid to how uncertainties are dealt with and which uncertainties cannot be taken into account.

In this report, for example, climate uncertainties are expressed using five different climate models. While the five models largely cover the upper and lower limits of the ranges of global average temperatures and precipitation projections generated by the CMIP5 climate model ensemble, they should be regarded as being for illustrative purposes only due to variations in factors such as the geographical distributions of the projections.

Regarding uncertainty pertaining to mitigation actions, it is possible that even if the international community adopts a mitigation target, the reduction pathway toward that target might not be achieved due to political or economic judgments in individual countries or some other reason. The effects on the consequences of "strategy" choice of such failures to implement mitigation actions can be incorporated into the analysis by modeling under correspondingly non-optimal conditions.

A further key uncertainty that ICA-RUS cannot explicitly deal with that should be noted is uncertainty over the impact assessment methods themselves. When estimating the impact of climate change on "rice productivity," for example, results can vary considerably according to the type of crop model used. ICA-RUS only estimates each impact assessment indicator using one impact assessment method at a time, and cannot tackle the range of uncertainty associated with choice of impact assessment method.

Regarding action analysis, on the other hand, effort has been made to render explicit uncertainties pertaining to the assessment methods used, at least for illustrative purposes, by conducting the analyses under the same assumptions using multiple, differently configured integrated assessment models (MARIA, EMEDA, GRAPE, and AIM)[2]. However, unknown innovation of the kind that causes technological and socioeconomic systems to change significantly cannot be modeled, and all that can be considered is the improvement and spread of currently known technologies.

Value judgments

Every step of strategy involves value judgments, whether overtly or tacitly. The basic stance adopted for ICA-RUS is to prepare and present "strategies" as unbiased options excluding as far as possible researchers' value judgments based on an awareness of where value judgments are involved, and to leave the choice of "strategy" informed by value judgments of some kind to public debate. Our stance is, in other words, to leave to the judgment of society questions such as what levels of economic loss and consumption loss should be borne in order to achieve mitigation, and what level of residual impact risk is acceptable. Having said that, value judgments cannot be entirely eliminated and are implicit in, for example, some aspects of model choice and selection of parameters for the quantitative analyses.

---

[2] For example, MARIA and GRAPE employ land use and climate change blocks for bottom-up energy economy modeling by dynamic optimization, while EMEDA and AIM are based on applied general equilibrium models that express top-down multi-sector economic activity. For details, see "Alternatives Left to Humanity Faced with Global Climate Risks, Ver. 1" (full report, March 2015) (in Japanese).

2.3 "Strategy" assessment process and components

For this report, two analyses were performed—one of actions and one of impacts—regarding six different choices (mitigation targets), and results for the sectors and perspectives shown in Table 2 were pulled together and presented in the form of "strategies."

Table 2 Sectors affected and indicators subject to assessment

Impact assessment	Action assessment
a. Agricultural damage b. Terrestrial ecosystem damage c. Hydrological and water resource damage d. Flood damage e. Health damage f. Oceans and marine ecosystems	a. GHG emissions and reduction pathways b. GDP and consumption loss c. Energy supply and demand d. Technological options e. Land use and food supply and demand f. Impacts by industry and region

The analyses performed using each impact model only analyzed the impacts in "cases for analysis" (explained in 2.4), and the impacts corresponding to "strategies" were simply assessed by making integrated use of these findings and the projected global average temperature rise for each "strategy" using AD-DICE.[3] This was performed as follows.

1. Global average temperature pathways were calculated for four RCP scenarios[4] (RCP2.6, RCP4.5, RCP6.0, and RCP8.5) using the simplified climate model formula in AD-DICE.

2. The two global average temperature rises under the four scenarios that were closest to the global average temperature rises generated by AD-DICE for the strategies were selected, and the weighting coefficients for the two RCPs were calculated according to distance from the temperature rise for the corresponding strategy.

3. Using the impact estimated for each case for analysis based on the two RCP scenarios selected at step 2, the impact for the corresponding strategy was calculated by interpolation using the weighting coefficients calculated at step 2.

The action analyses, on the other hand, were performed by assessing each case for analysis and similarly assessing each "strategy" using the integrated assessment models.

In this report, six "strategies" defined by these specifications as shown in Table 3 were assessed. These six "strategies" address only "target temperature level" and "risk averseness," and consideration of "assumptions regarding pathways" remains an issue for future research.

Table 3 The six strategies assessed

Strategy name	Target temperature level (relative to pre-industrial)	Climate sensitivity (°C) assumed by AD-DICE emission pathway analysis (risk averseness)	Climate sensitivity setting for simplified climate model when estimating temperature change by AD-DICE (°C)	Probability of meeting target allowing for climate uncertainty
T15S30	1.5	3.0	3.0	About 50%
T15S45	1.5	4.5	3.0	About 80%
T20S30	2.0	3.0	3.0	About 50%
T20S45	2.0	4.5	3.0	About 80%
T25S30	2.5	3.0	3.0	About 50%
T25S45	2.5	4.5	3.0	About 80%

※ Baseline (no action) socioeconomic scenario was SSP2.

[3] DICE (Dynamic Integrated model of Climate and Economy) is an economic model developed at Yale University for integrated assessment of global warming impacts and action (mitigation) costs. AD-DICE is an extension of this model, and is designed to allow simultaneous assessment of the reduction in impact due to investment in adaptation too.

[4] RCP (Representative Concentration Pathways) are scenarios of GHG emissions and concentrations used for future projections performed using climate models.

2.4 Cases for analysis

ICA-RUS employs several “cases for analysis” to provide data for assessing “strategies”, and impact and action assessments were made of them as shown in Table 4.

Table 4 Items of assessment for each ICA-RUS case for analysis
(Asterisks indicate items that are not addressed in this report and will be examined in the final report.)

Assessment of climate change impact	Magnitude of overall impact (cost of damage, etc.)*
	Timing, scope, and scale of damage caused by each impact
Assessment of actions	Actions necessary to achieve mitigation target
	Details of responsive options and their costs
	Spillover risk caused by implementation of actions*
Interactions of impacts, actions, etc. and water, food, and energy	Risk trade-off feedback, etc.*

Each case for analysis is defined by a combination of GHG emission scenario (time-series data on emissions and in some cases also data on GHG concentrations and radiative forcing), climate model (used for future projections of temperature, precipitation, etc.), and socioeconomic scenario (time-series demographic, economic, and land use data, etc.), and is used to provide common premises for impact assessment and action assessment.

Climate change scenarios are developed following a process for international coordination called the “new scenario process,” and the cases for analysis used by ICA-RUS are selected in a manner consistent with this process.

Consistency with the new scenario process here means that the cases for analysis (i) use the CMIP5 climate model outputs on which the RCPs** are premised as the climate scenarios for impact assessment, (ii) use SSPs** as the socioeconomic scenarios for impact assessment, (iii) use an SSP as the baseline socioeconomic scenario (i.e., the scenario assuming no action is taken) for action assessment (assessment of mitigation policy), and (iv) analyze stabilization at the radiative forcing level assumed by the RCPs as a mitigation policy target (level of mitigation) for action assessment.

(**For details of RCPs and SSPs, see ICA-RUS Report 2014. [5])

Regarding the choice of climate scenarios for impact assessment, it is important to ascertain the range of projections using climate scenarios generated by multiple climate models, as considerable differences can emerge between climate scenarios. Given the constraints on research resources, we decided to use the climate scenarios envisaged for the emission scenarios (RCP2.6, RCP4.5, RCP6.0, and RCP8.5) generated by five climate models (GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, and NorESM1-M) selected based on past international use as the cases for analysis performed by all the ICA-RUS research teams responsible for impact assessments.

For the socioeconomic scenarios, three types of scenario were used (SSP1, SSP2, and SSP3) in order to limit the range of uncertainty.

For action assessment, on the other hand, the cases for analysis adopted of two scenarios—SSP2 and SSP3—as baseline socioeconomic scenarios, and stabilization on the radiative forcing level envisaged by four emission scenarios (RCP2.6, RCP4.5, RCP6.0, and RCP8.5) as the mitigation level.

Note that this report describes only the results of impact assessment and action assessment for each “strategy”. The results of impact assessment and action assessment of each case for analysis are reported in detail in graph form in Chapter 3 of the full report.[6]

[5] http://www.nies.go.jp/ica-rus/materials.html
[6] “Alternatives Left to Humanity Faced with Global Climate Risks, Ver. 1” (March 2015). See note 5 for URL.

3 Results of a assessment of “strategies”

3.1 Results of risk assessment

Overall trends

Grouping the six “strategies” assessed in this report into the highly risk aversive (T15S45, T20S45, and T25S45) and the moderately risk averse (T15S30, T20S30, and T25S30) and comparing their impact assessment results, we find that the results for T20S45 were similar to those for T15S30, and the results for T25S45 were similar to those for T20S30. Below, therefore, we focus on comparing the three moderately risk-averse “strategies”. To facilitate comparison, Figure 2 (p. 10) presents the results by arranging the three “strategies” and BaU (“business as usual,” i.e., no response to climate change, using SSP2 for the socioeconomic scenario) column-wise and the climate changes (temperature change and rate of change in precipitation) and sector impact indices under each scenario row-wise. The scenario corresponding to SSP2 (“middle of the road”) is adopted as the socioeconomic scenario for all the “strategies”. Regarding the climate changes and impact indices for each sector, the graphs show the changes (absolute or percentage) in the middle (2050s) and near the end (2080s) of this century compared to the present (1981-2000) in the form of regional averages (dividing the world into five blocks, namely A: Asia, L: Latin America, M: Middle East and Africa, O: OECD, R: Eastern Europe and former Soviet Union) and world averages (W). (However, hypoxic water mass volume and export production (flux of organic carbon produced in the marine layer through a depth of 100 m) are shown by sea sub-area in Figure 2). The width of the vertical lines in the graphs represents the range of projections envisaged by the five different climate scenarios, and the red dots on the lines denote the averages of the five change projections. Here, the data are organized to show the overall climate change risk tendencies of each “strategy”.

From Figure 2 and the findings described in the full report, the following is apparent.

1. In the case of all the impact indicators, the differences between the three “strategies” (T15S30, T20S30, and T25S30) are on the whole smaller than those between the three “strategies” and BaU (where no climate change response is adopted) (Figure 2). This is basically because the climate change range between the three “strategies” is smaller than the climate change range from RCP2.6 to RCP8.5. Regarding water-stressed population, no clear difference is observable between BaU and the three “strategies”. This is because water-stressed population is highly sensitive to changes in socioeconomic factors (population), while its sensitivity to climate change is relatively small.

2. Insofar as the present analysis (including BaU) is concerned, the positive impacts on some indicators (in terms of food security and carbon management) rise uniformly as climate change increases. These indicators include rice productivity, spring wheat productivity, net primary production, and plant biomass. Even where the indicators manifest positive impacts at the wide area level, a more detailed examination of the differences between and within regions reveals instances where the positive impacts do not always increase uniformly. Common to all the indicators exhibiting uniform growth as climate change increases is their enjoyment of a fertilizing effect that results from higher concentrations of atmospheric CO_2.

3. When comparisons are made between “strategies”, there also emerge impact indicators that manifest sharply rising negative impacts as the scale of climate change increases. Typical examples include biomass fires, population exposed to flooding, economic exposure to flooding, and excess mortality due to heat stress. The main reason for the upward trend in two of these indicators—population exposed to flooding and economic exposure to flooding—is the increased frequency of heavy rain due to climate change and the consequently greater probability of flooding. Regarding extreme phenomena and their impacts, the results indicate a need to be aware of the nonlinear responses to strength of mitigation action. The greater tendency of biomass fires and excess mortality due to heat stress to increase uniformly compared with other impact indicators, on the other hand, is because, out of the various climate-related factors, they are more directly susceptible to temperature rise. The risks evidenced by these impact indicators might be described as risks where the effects of mitigation measures manifest themselves directly.

4. “Strategies” that involve greater climate change tend to exhibit a greater range of uncertainty depending on the climate model used (Figure 2). This applies to both

impact indicators that see positive impacts and impact indicators that see negative impacts due to climate change. While the implications for consideration of actions of the differences in this range of uncertainty differ according to the nature of the impacts and the risk perception and values of those who experience them, they need to be noted from the point of view of risk management to cope with unpredictable events.

5. The range of uncertainty due to differences in climate projections under the same "strategy" are often greater than the differences in the scale of impacts between "strategies". This suggests that it may be more important when considering what actions to take in order to adapt to climate change and its impacts to confront the uncertainty in climate projections that remains regardless of whether 1.5°C, 2.0°C, or 2.5°C is adopted as the long-term target to aim for.

6. The complexity of comparative assessment of "strategies" pertaining to major phenomena that have tipping points was reaffirmed by assessment of the passing of the tipping point temperature for melting of the Greenland ice sheet and disappearance of Arctic Ocean summer sea ice. Regarding melting of the Greenland ice sheet, the tipping point temperature would probably not be reached this century, even allowing for climate model uncertainty, under T15S30 if the global average temperature rises 2°C from pre-industrial levels. However, it is projected that the tipping point would be passed during the 2030s with T25S30 (depending on the climate model), and around the 2060s taking the average of the five climate models. The individual climate models produce similar results for T20S30 and T25S30, and although in some cases the tipping point is passed during the 2030s, it is not passed during the 21st century when the average of the five climate models is used. Although it may be possible to delay when the tipping point is passed by adopting a mitigation level designed to achieve a more challenging target, the import of delaying when the tipping point is passed remains open to some debate because, even if the tipping point is passed, actual problems (a major rise in sea levels and the damage caused by this) will not occur until hundreds or thousands of years into the future. It should be noted that if the tipping point temperature is assumed to be a 1°C rise in the global average temperature relative to pre-industrial levels, the tipping point will be immediately passed under all "strategies" (and has already been passed depending on the climate scenario). Similarly regarding the loss of Arctic summer sea ice, if the tipping point is the median of the range of uncertainties (a global average temperature rise from pre-industrial levels of 2.45°C), then it appears possible that the tipping point may be avoidable during the 21st century with T15S30 and T20S30. In the case of T25S30, however, if the higher end of range of uncertainty of climate projections turns out to be true, the tipping point will be passed in around 2060.

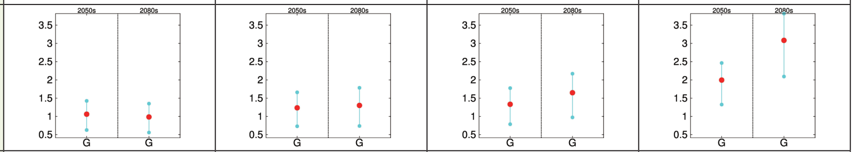
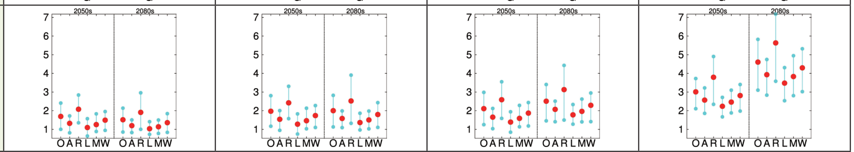
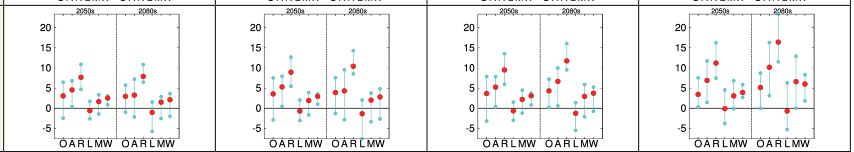
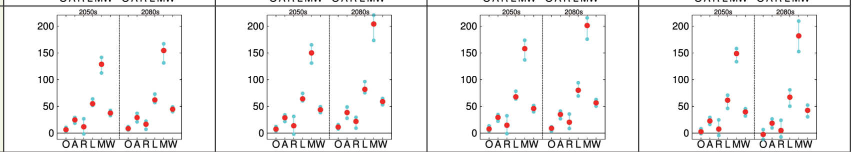
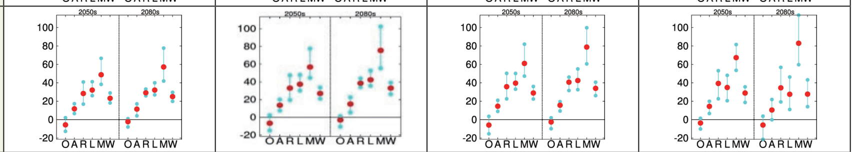
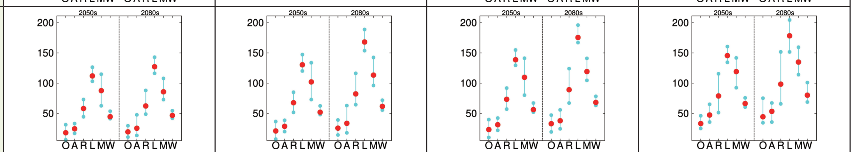
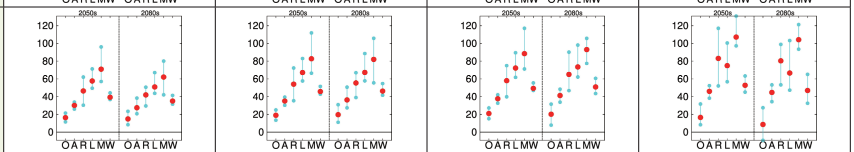
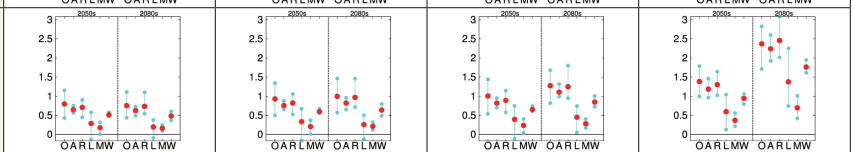
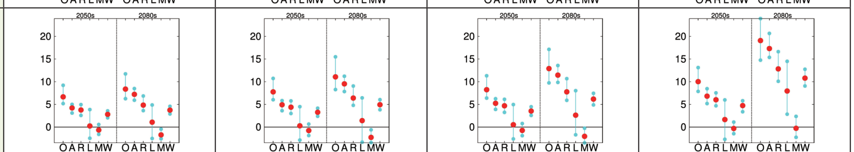
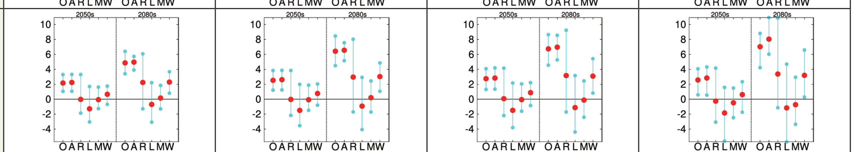
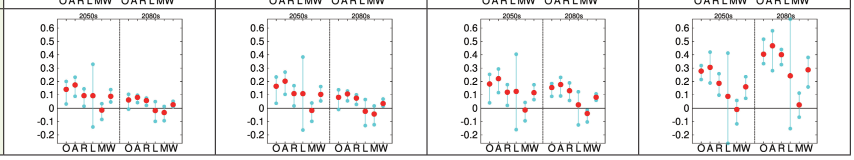
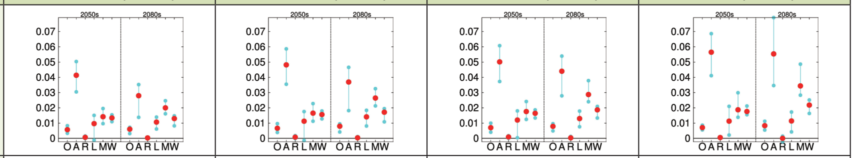
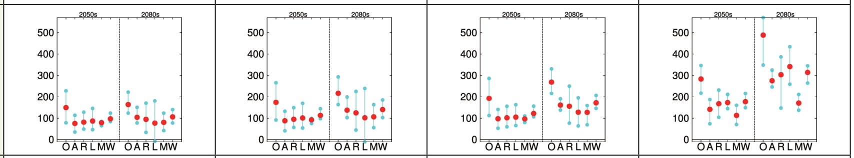
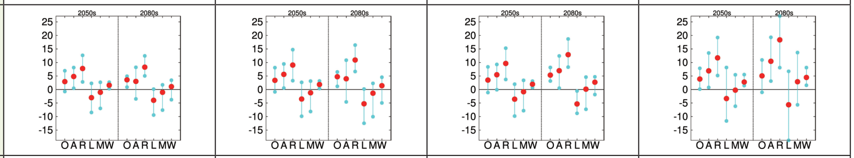
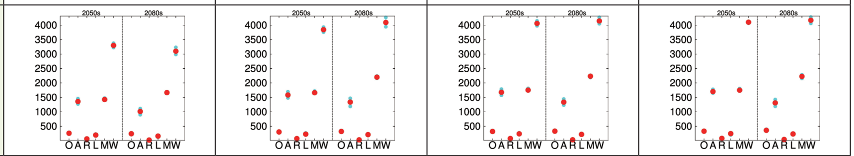
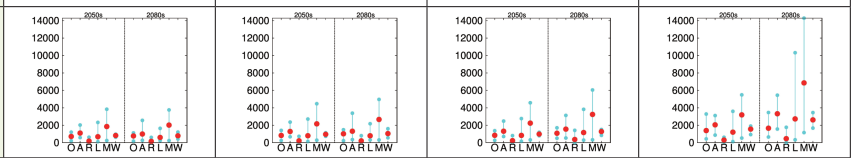
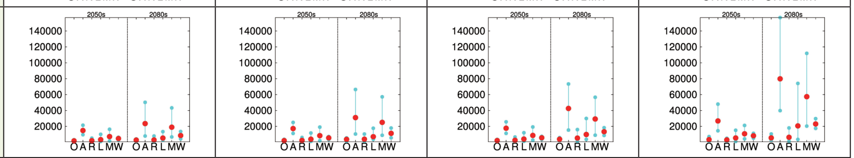
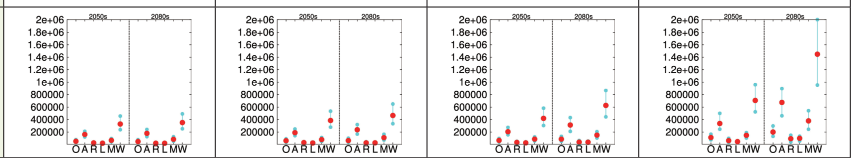
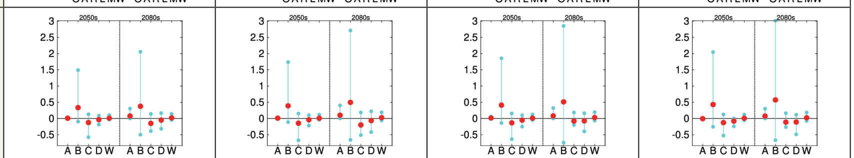
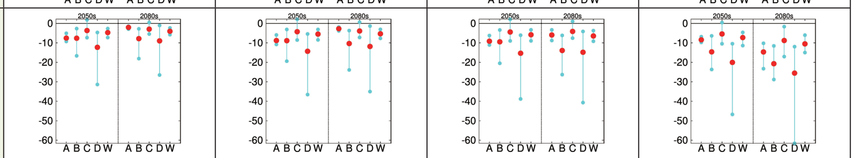
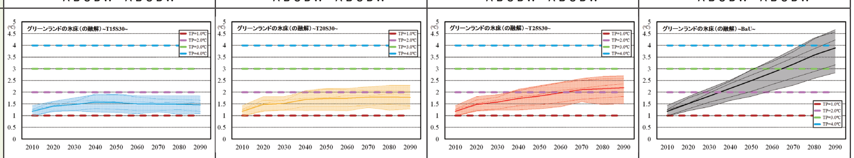
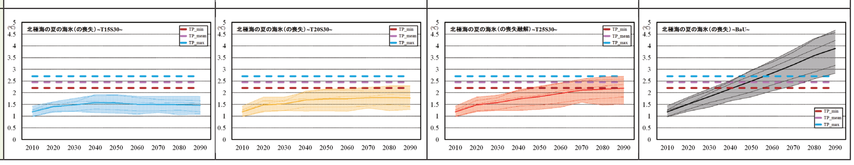
Strategy	T15S30（SSP2）	T20S30（SSP2）	T25S30（SSP2）	BaU（SSP2）
Max. temperature rise target (compared with pre-industrial levels)	1.5℃	2.0℃	2.5℃	―
Estimated climate sensitivity when calculating optimum emission pathway	3.0℃	3.0℃	3.0℃	―
Global average temperature change (℃; change from 1981-2000) *0.5℃ added to convert to change from pre-industrial levels				
Terrestrial average temperature change by region (℃; change with 1981-2000)				
Percentage change in precipitation by region (%; change from 1981-2000)				
Maize productivity (%; now = zero)				
Rice productivity (%; now = zero)				
Spring wheat productivity (%; now = zero)				
Soybean productivity (%; now = zero)				
Change in net primary production of vegetation (MgC/ha/year)				
Change in plant biomass (MgC/ha)				
Change in soil carbon pool (MgC/ha)				
Change in net ecosystem production (MgC/ha/year)				

Figure 2 Climate changes and sector impact indicators for each strategy (absolute or percentage change from present (1981-2000) unless otherwise

Strategy	T15S30（SSP2）	T20S30（SSP2）	T25S30（SSP2）	BaU（SSP2）
Change in soil erosion (MgC/ha/year)				
Change in biomass burning (kgC/ha/year)				
Change in surface runoff (%; now = zero)				
Change in water-stressed population (population of basins where water resources per capita do not exceed 1,700 (m^2/person/year); 10^6 people)				
Change in population exposed to flooding (%; now = zero)				
Change in economic asset exposed to flooding (%; now = zero)				
Change in excess mortality due to heat stress (deaths/year)				
Change in hypoxic water mass volum ($10^{12}m^3$) A: western Bering Sea, B: central equatorial Pacific, C: eastern equatorial Pacific off Peru, D: northern Indian Ocean, E: all oceans				
Change in ocean export production (%; now = zero) A: northern Pacific, B: northern Atlantic, C: eastern equatorial Pacific off Peru, D: around Arabian Sea, E: all oceans				
Comparison of TPs for melting of Greenland ice sheet and projection global temperature rise under each strategy (from pre-industrial levels) (horizontal lines denote 1°C, 2°C, 3°C, and 4°C TPs relative to pre-industrial levels)				
Comparison of TPs for Arctic summer sea ice loss and global average temperature rise under each strategy (from pre-industrial levels) (horizontal lines denote 2.2°C, 2.45°C, and 2.7°C TPs relative to pre-industrial levels)				

indicated; vertical lines denote GCM uncertainty)

Comparison of strategies by assessment indicator

Below we examine the differences in impacts between strategies by looking at the indicators for each sector in turn.

● Maize productivity

Globally, T20S30 exhibits the highest rate of growth in maize productivity, followed by T25S30 and then, somewhat further behind, by T15S30 and BaU. This trend is common to almost all regions, although productivity does decline in the OECD, Eastern Europe, and the former Soviet Union depending on the climate model (GCM) used.

The range of uncertainty of impact on maize productivity due to differences in the projections of economic development (SSP) is slightly smaller than the range due to differences between strategies in impacts.

● Rice productivity

Globally, T20S30 and T25S30 have the highest rates of increase in rice productivity at the end of this century, followed by T15S30 and BaU. This trend is replicated in almost all regions, although a decline is projected in the OECD, and the differences between plans are small.

The range of uncertainty of impact on rice productivity due to SSP differences is almost the same, or slightly larger, than the differences in impacts between strategies.

● Spring wheat productivity

Globally, BaU has the highest rate of increase in spring wheat productivity at the end of this century, followed by T20S30 and T25S30, and then, somewhat further behind, T15S30. This trend is shared by almost all regions.

The range of uncertainty of impact on spring wheat productivity due to differences in SSP is smaller than the differences in impacts between strategies.

● Soybean productivity

Globally, T20S30 and T25S30 have the highest rates of increase in soybean productivity at the end of this century, followed by BaU and T15S30. However, this trend does not apply to all regions.

The range of uncertainty of impact on soybean production due to SSP differences is almost the same as the differences between strategies in impacts.

● Net primary production of vegetation

Of the three strategies, T15S30 results in the smallest change in production of vegetation due to its limitation of temperature rise. T20S30 produces projections between T15S30 and T25S30. T25S30 results in overall growth in production of vegetation as temperatures rise over the course of the century (including the effects of an increase in the concentration of atmospheric CO_2). Although productivity is kept to the bottom end or lower of the GCM range of BaU in most regions (including the global average), an impact around this bottom end is observed in some regions.

Production of vegetation generally increases due to the effects of the lengthening of growing seasons as temperatures rise and higher concentrations of atmospheric CO_2. While Latin America showed a slight downward tendency, most other regions saw growth.

While projections of vegetation production are affected by differences in changes in land use, the differences between SSPs are extremely small compared with those between strategies.

● Plant biomass

Of the three strategies, T15S30 produces the smallest change in plant biomass due to its limitation of temperature rise. The projections for T20S30 fell between those for T15S30 and T25S30. T25S30 resulted in overall growth in plant biomass as temperatures rise over the course of the century (including the effects of a rise in concentration of atmospheric CO_2.).

In the Middle East and Africa, there is practically no increase even with BaU due to the impact of changes in land use. Biomass tended to decrease with T15S30, T20S30, and T25S30, however, due to smaller environmental change factors Latin America also exhibits a downward trend in some cases depending on the GCM used.

Although there are differences between SSPs in some region, the difference from SSP1 to SSP3 is overall smaller than the difference between strategies.

● Soil carbon pool

Of the three strategies, T15S30 produces the smallest change in soil carbon due to its limitation of temperature rise. The prediction for T20S30 lies between those for T15S30 and T25S30. With T25S30, soil carbon will increase overall as temperatures rise in the 21st century. In almost all regions, it produces around the same change as BaU.

Soil carbon is found to largely increase from the 2040s in many regions as a result of the balance between acceleration of promotion of decomposition in the soil and the supply of carbon from vegetative detritus. In both Latin

America and the Middle East/Africa, however, declines are also possible,despite the existence of considerable uncertainty.

While differences in land use between SSPs affect the supply of organic matter to the soil and runoff, there is on the whole little difference between strategies in their impact on soil carbon.

● Net ecosystem production (net CO_2 balance)

Of the three strategies, T15S30 results in the least change in net ecosystem production due to its restriction of temperature rise. T20S30 produces projections between T15S30 and T25S30. With T25S30, net ecosystem production first increases as temperatures rise in the 21st century, and then it begins to trend downward from around the 2070s.

As regards the balance between growth of vegetation production and acceleration of soil degradation, it is estimated that terrestrial ecosystems would often function as a net CO_2 sink. However, rate of absorption is found to begin to trend downward in the latter half of the century. Considerable differences were also found between regions; while there were no major future changes in Latin America or the Middle East/Africa, rate of absorption generally increased in Asia and the OECD.

The impact of SSPs on the net CO_2 balance of ecosystems is found to be small compared with the differences between strategies. However, different results may be obtained if the effects of afforestation and biofuel cultivation are included among the impacts of land use.

● Soil erosion

Of the three strategies, T15S30 results in the least change in soil erosion due to its limitation of temperature rise. T20S30 produces projections between T15S30 and T25S30. With T25S30, soil erosion gradually increases as temperatures rise during the 21st century (including the impacts of changes in precipitation). On the whole, soil erosion is similar in scale to that with BaU in all regions.

Soil erosion is observed to increase with growth in precipitation and cultivated land. Regional differences are observed; runoff peakes in Asia in the second half of the century, but increases linearly in the Middle East/Africa, where land use will increase. The differences between strategies are smaller than those for other ecosystem variables.

As differences between SSPs in progress in land use exert a major impact on soil erosion, differences between SSPs have a more marked impact than differences between strategies in limiting temperature rise. The margin of increase is comparatively greater in the case of SSP3, which assumes growth in cultivated land.

● Biomass burning

Of the three strategies, T15S30 results in the least change in biomass burning due to its limitation of temperature rise. T20S30 produces projections between T15S30 and T25S30. With T25S30, biomass burning gradually increases as temperatures rise during the 21st century (including the impacts of changes in precipitation). In almost all regions, the scale of occurrence of biomass burning is around 50%-70% of that with BaU.

As biomass burning is affected by the quantities and combustibility of inflammables, which are in turn affected by growth in plant biomass, decreases in precipitation, and increases in evapotranspiration as temperatures rise, an overall increase in biomass burning is observed. While BaU produces marked increases in the second half of the century, the strategy cases kept the increase to just a little over half the BaU level.

As the SSPs do not take account of the effects of firefighting activities and cities, roads, and cultivated land preventing the spread of fires, no major differences in the degree of change in biomass burning are observed between the SSPs.

● Surface runoff

Of the three strategies, T15S30 results in the least change in surface runoff volume due mainly to its limitation of change in precipitation. T20S30 produces projections between T15S30 and T25S30. With T25S30, changes in surface runoff steadily emerge as precipitation changes in the 21st century. In the 2080s, the change in surface runoff volume is projected to be 1.5 to 2 times that of T15S30. Depending on the region, the average of the five GCMs is around the same as with BaU.

Compared with the present (1981-2000), surface runoff is projected to increase by approximately 5% globally taking the 5GCM average (the GCM range is approximately 1%-8%) up to the 2080s with BaU (SSP2). With T20S30, on the other hand, for example, the increase is limited to around 1.5% taking the 5GCM average. Although there is little difference in the 5GCM average between strategies, the GCM range is greatest for T25S30, and as a result there may occur an increase of 4.5% with HadGEM2-ES, which assumes the greatest temperature rise. At the regional level, too, relative sizes among the strategies are roughly the same as at the global level. However, there are marked regional differences in the sizes and patterns of changes. For example, while surface runoff tends to increase globally as precipitation increases, only in Latin America does it decrease.

● Water-stressed population based on the Falkenmark indicator (water resources per capita)

Of the three strategies, T15S30 results in the smallest water-stressed population due mainly to its limitation of change in precipitation. T20S30 produces projections between those of T15S30 and T25S30. With T25S30, water-stressed population increases as surface runoff on arid land declines during the 21st century. It is important to note that the results are highly dependent on population scenarios, and that the growth in water-stressed population is higher under scenarios that assume greater population growth.

The range of uncertainty due to differences in population projections is greater than the differences between strategies. A comparison of the differences between SSP1, SSP2, and SSP3 taking the global totals for T20S30 as an example shows that water stressed population is projected to increase by approximately 3.0 billion (5GCM average) up to the 2050s under SSP1, which assumes the smallest population increase, while an increase of approximately 5.0 billion is projected for SSP3, which assumes the largest population increase. The differences in water-stressed population are smaller between T20S30, T25S30, and BaU than between SSP1, SSP2, and SSP3. The differences between GCMs are slightly greater in Asia. This appears to be due mainly to the somewhat greater variation in precipitation in this region.

● Population exposed to flooding

T15S30 results in the lowest rate of growth in population exposed to flooding of the three strategies. T20S30 produces projections between T15S30 and T25S30. T25S30 produces the highest rate of growth in population exposed to flooding of the three strategies, and relatively clear growth in population exposed to flooding is observed in Asia in the 2080s.

The population exposed to flooding in the second half of the 21st century is considerably smaller under all strategies than with BaU. Looking at the global change in population exposed to flooding compared with the present, 15- to 30-fold growth by the end of the century is projected with BaU (SSP2). On the other hand, T15S30, for example, is projected to produce around 10-fold growth in population exposed to flooding by around the end of the century. At the regional level, T25S30 tends to produce a greater end-of-century population exposed to flooding than T15S30, and in the case of strategy T25S30, the population exposed to flooding continues to follow an upward trend as the end of the century approaches in Asia and the Middle East/Africa.

The range of uncertainty due to differences in population projections is greater than between strategies. A comparison of the differences between SSP1, SSP2, and SSP3 shows that, in the case of the global totals for T20S30, for example, SSP1, which has the smallest population growth, will see population exposed to flooding increase around 5- to 13-fold by the 2080s, while SSP3, which has the highest population growth, is projected to see around a 7- to 25-fold increase. The range of uncertainty due to differences in population projections thus tends to be greater than the differences between strategies T15S30 and T25S30.

● Economic exposure to flooding

T15S30 results in the lowest rate of growth in economic exposure to flooding of the three strategies. T20S30 produces projections between T15S30 and T25S30. T25S30 has the highest rate of growth in economic exposure to flooding of the three strategies, and is projected to produce major growth in economic exposure to flooding in Asia, especially in the 2080s.

All strategies project considerably less economic exposure to flooding in the second half of the 21st century than BaU. Looking at the global change in economic exposure to flooding from the present, exposure is projected to grow almost 200- to 400-fold by the end of the century with BaU (SSP1 and SSP2). In the case of T25S30, which has the highest growth in economic exposure to flooding of the three strategies, exposure will grow a little under 200-fold by the end of the century (SSP1 and SSP2). At the regional level, there is a relatively clear upward trend in economic exposure to flooding as time progresses in Asia and the Middle East/Africa under all strategies.

The range of uncertainty due to differences in socioeconomic scenarios tends to be greater than the differences between strategies. A comparison of the differences between SSP1, SSP2, and SSP3 shows that, in the case of BaU, economic exposure to flooding at the end of the century is projected to grow 200- to 400-fold with SSP1 and SSP2. With SSP3, on the other hand, 100- to 200-

fold growth is projected. In contrast, if we focus on SSP2, for example, we find that with strategy T25S30, economic exposure to flooding is projected to grow 100- to 200-fold by the end of the century, and around 60- to 100-fold with strategy T15S30.

● Excess mortality due to heat stress

Of the three strategies, T15S30 results in the least increase in excess deaths due to its limitation of temperature rise. It also produces the smallest change over time during the 21st century. T20S30 produces projections between those for T15S30 and T25S30. With T25S30, excess mortality gradually increases as temperature rises this century. In the 2080s, it is expected to result in around 1.5 to 2 times the increase in excess deaths of T15S30. Further, the upper end of the GCM range will reach the increase in excess deaths at around the lower end of the GCM range with BaU.

Taking the 5GCM global average, it is projected that BaU (SSP2) will produce 1.5 million more excess deaths due to heat stress than at present (the GCM range is approximately 1.0 to 2.0 million) by the 2080s. On the other hand, T20S30, for example, keeps the 5GCM average increase down to 500,000. T25S30 and T15S30 respectively produce increases of 600,000 and 400,000 (both 5GCM averages).

At the regional level, relative sizes among the strategies are generally the same as at the global level. In Eastern Europe and the former Soviet Union, however, it is hard to discern any difference between strategies, and the increase also becomes somewhat more gradual over time.

The range of uncertainty due to differences in population projections is about the same or slightly smaller than the differences between strategies. A comparison of the differences between SSP1, SSP2, and SSP3 shows that in the case of T20S30, for example, approximately 450,000 more excess deaths (taking the global 5GCM average) are projected up to the 2080s under SSP1, which has the smallest population growth. On the other hand, approximately 550,000 more deaths are projected with SSP3, which has the highest population growth. The range of uncertainty due to differences in population projections was found to be about the same or slightly smaller than the difference between strategies T15S30 and T25S30.

● Hypoxic water mass volume (O_2 < 30 mmol m^{-3})

Of the three strategies, T15S30 results in the least change in hypoxic water mass volume due to its limitation of temperature rise, and it has the smallest GCM range. T20S30 produces projections between T15S30 and T25S30. With T25S30, transportation of oxygen to hypoxic water mass and consumption of oxygen due to decomposition of organic matter in and around such masses increase or decrease as temperatures rise, and the hypoxic water mass volume gradually changes in keeping with balance between the two (increase or decrease according to water area and GCM). In the 2090s, the change in hypoxic water mass volume is projected to be around 1.5 times that of T15S30. In addition, the upper and lower ends of the GCM range are similar to the GCM range with BaU.

Taking the world as a whole, the change in hypoxic water mass volume from the present with BaU (SSP2) increases by approximately 0.2 ($10^{12}m^3$) at the upper end of the GCM range by the 2090s as temperatures rise during the 21st century, and decreases by approximately 0.1 ($10^{12}m^3$) at the lower end. Almost the same results were obtained for T25S30 and T20S30 too. With T15S30, on the other hand, which limits the temperature rise the most, the change at both the upper and lower ends of the GCM range is less than in the case of BaU, T25S30, and T20S30, and as a result the GCM range shrinks.

● Ocean export production (flux of organic carbon produced in marine layer through a depth of 100 m)

Of the three strategies, T15S30 results in the least decline in export production due to its limitation of temperature rise, and its GCM range is the smallest. T20S30 produces projections between T15S30 and T25S30. With T25S30, export production gradually decreases as temperatures rise. In the 2090s, export production is projected to decline by around 1.5 times as much as with T15S30. In addition, the lower end of the GCM range reaches around the average with BaU.

Taking the world as a whole, export production declines under all strategies. However, the rates of decline differ depending on the strategy. Globally, the change in export production decreases by approximately 5% at the upper end and by 15% at the lower end of the GCM range up to the 2090s with BaU as temperatures rise during the century. As limitation of temperature rise increases going from T25S30 to T15S30, however, the rates of decline shrink at both the upper and lower ends of the GCM range compared to BaU, and the GCM range also shrinks.

3.2 Results of assessment of responses

Overall trends

This section first summarizes the overall trends in response-related indicators discernable from Chapter 4 (assessment results by "strategy") of the full report. It then outlines the assessment results for some indicators outputted by the integrated assessment models. Note that although we focus in the description on summarizing the results for the moderately risk-averse "strategies" (T15S30, T20S30, and T25S30), the figures also show the results for the highly risk-averse "strategies" (T15S45, T20S45, and T25S45). As in the case of the impact assessment, the results for T20S45 were similar to those for T15S30, and the results for T25S45 were similar to those for T20S30.

1. Clear differences in the assessment results were observed between the three "strategies" (T15S30, T20S30, and T25S30) regarding all the assessment indicators (e.g., Figures 3 and 4). T15S30 requires greater emission reductions from an early stage through to the end of the century (including almost zero emissions in the 2020s) than T20S30 and T25S30, and it is projected that these would not be achievable without accepting very considerable GDP and consumption losses. A solution was in addition unobtainable in some cases, depending on the model, as the emission reductions required exceeded the realistic range. Despite some differences in the assessment results between models, clear differences were also observed between T20S30 and T25S30 in emission reduction intensity and the GDP and consumption losses that would have to be borne to achieve them. With T25S30, the emission reduction projected to be achieved in the first half of the 21st century is not more than half that required by T20S30.

2. Even when the world is divided into just five regions, large regional differences were observed in the emission reductions and GDP and consumption losses needed to achieve the "strategies" (e.g., Figure 4). Regarding, for example, GDP and consumption losses, losses are low in regions where fossil fuel dependence is low (OECD) with BaU, but high in all the regions where fossil fuel dependence is high (Latin America, Eastern Europe, and the former Soviet Union). However, the analysis of "strategies" in this report only shows the emission reductions and economic loss allowing attainment of mitigation targets when the optimum response is implemented economically and efficiently at the global level. It should therefore be borne in mind that we have yet to investigate the fairness of distribution of reduction responsibilities between regions, and that separate consideration has to be given to possible policies to effect transfers of wealth between states.

3. Clear differences exist between the models when final energy consumption shifts from BaU to each "strategy." This is due to inter-model differences in the assumptions made regarding the flexibility of energy consumption; in other words, assumptions concerning the substitutability of energy demand with other factors (e.g., Figure 5). This difference in assumptions is particularly important when assessing challenging mitigation targets such as those posed by T15S30 and T20S30.

4. Regarding the primary energy supply mix, the models differed considerably in their degree of dependence on nuclear power, emphasis on renewables, and so on (e.g., Figures 7 and 8). The differences between models in the primary energy supply mix for any single "strategy" are greater than those between the three "strategies" simulated using the same single model. Although these differences may be treated as model uncertainty, they may also be regarded in a different light perspective; namely, as showing that freedom of choice remains in the energy supply mix that humanity can adopt in pursuing challenging mitigation targets.

5. Although there are widespread concerns that pursuing an ambitious mitigation target could lead to serious competition for land between biomass energy use and food supply, the analysis by ICA-RUS using multiple integrated assessment models suggests that, if each model is considered separately (comparing energy use and economic activity), there are no major differences between "strategies" in cultivated land area trends, and changes from BaU are also projected to be limited. However, as different findings are likely to be obtained if more pessimistic assumptions are made regarding crop productivity, additional analysis under more diverse conditions is required. As discussed on the basis of a spatially more detailed assessment in Chapter 3 of the full report, consideration should also be given to the possibility that more pessimistic assumptions may also be made regarding the efficiency and feasible capacity of BECCS (carbon capture and storage combined with biomass

energy) in the integrated assessment model analysis. If the BECCS efficiency and feasibility capacity assumptions of the integrated assessment models are revised downwards, it is likely that it will be necessary to allocate more cultivated land to cultivation of biomass crops in order to adopt BECCS on the scale envisaged.

6. As with GDP loss at the global level, clear differences were observed between T20S30 and T25S30 in the loss of added value experienced in each sector of industry. While the loss of added value peaks at an early stage in the case of T20S30, it gradually expands until the end of the present century with T25S30. This is thought to be because large emission reductions will be required sooner than with T20S30. No major differences are observed between sectors of industry, which is thought to be because while the loss in manufacturing, whose emission reduction costs will be relatively high, will be mitigated by economic activity, a repercussion of this will be an increase in loss of added value in other sectors.

Comparison of strategies by assessment indicator

Below we summarize the assessment indices outputted for each strategy by multiple integrated assessment models (MARIA, EMEDA, GRAPE, and AIM).

● GHG emission/reduction pathways (Figure 3)

There are models that give CO2 emission pathways directly and models that limit cumulative emissions for the same “strategy”. Consequently, the pattern of results becomes dispersed. For T15S30 and T20S45, which entail challenging emission constraints, only one model (AIM) produces results.

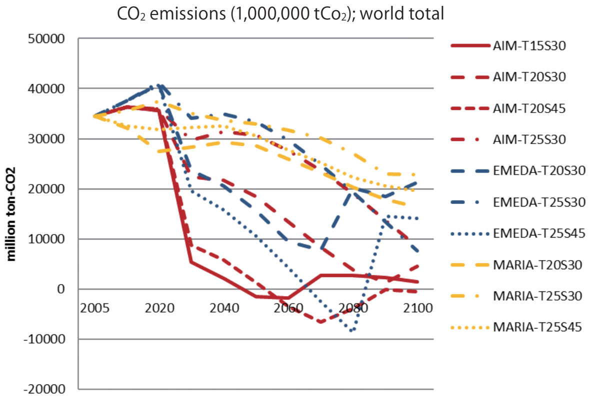


Figure 3 CO_2 emissions
(1,000,000 tCO_2; BaU = SSP2; AIM/EMEDA/MARIA)

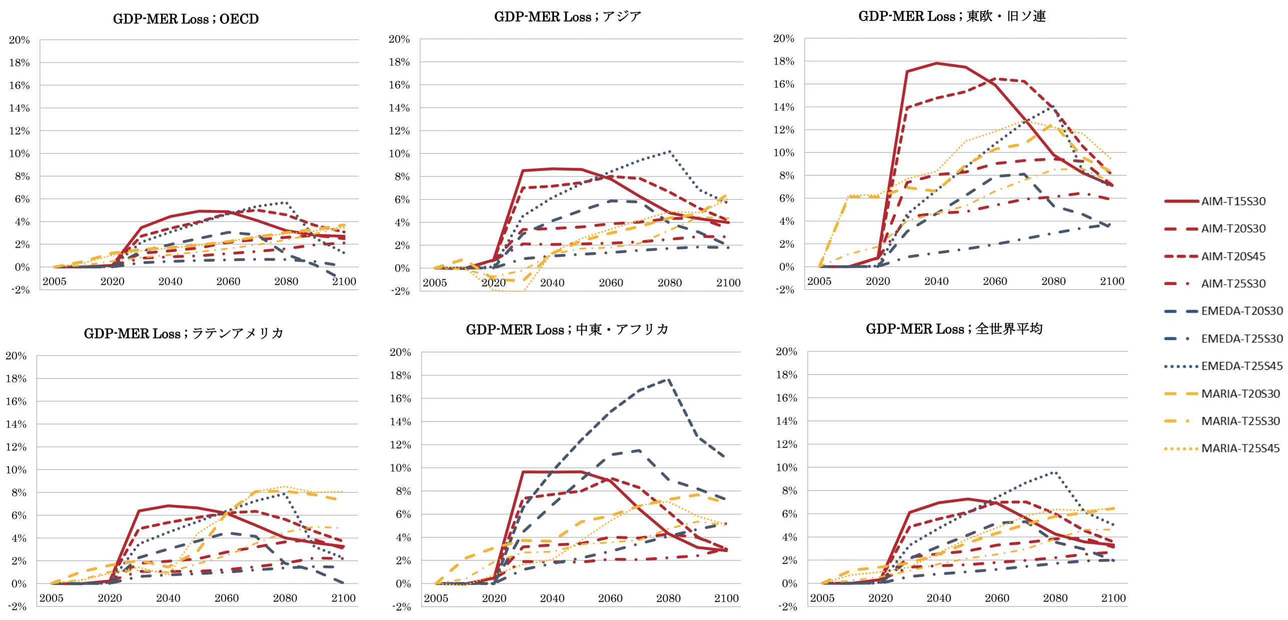


Figure 4 Change in GDP (MER) (by region; % change from BaU (SSP2); AIM/EMEDA/MARIA)

● GDP and consumption loss (Figure 4)

All models predict world macro-level GDP loss of around 2% with T25S30, and loss with T20S30 will be almost 7% at the end of the 21st century. Regional differences and the differences between models also widen as the strategy constraints grow more challenging. With BaU, however, loss would be lower in regions with low fossil fuel dependence (OECD), and greater in all regions where dependence is higher (Latin America, Eastern Europe, and the former Soviet Union).

Trends in final energy consumption (Figure 5)

The models exhibit clear differences in the change from BaU to each "strategy" in final energy consumption. This appears to be a reflection of how pessimistic or optimistic the assumptions regarding flexibility of energy consumption are.

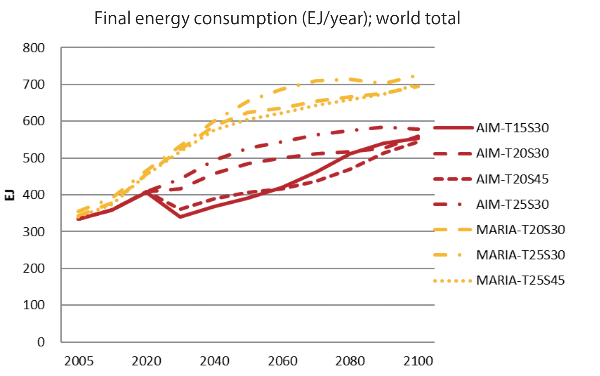


Figure 5 Final energy consumption
(EJ; BaU = SSP2; AIM/MARIA)

Trends in primary energy supply (Figure 6)

The strategy cases offer considerable scope for public choice on whether to give a leading role to nuclear power or to renewables. On the other hand, specific significance of the spread of the figures for primary energy supply, including differences in definitions of the conversion efficiencies of nuclear power and renewable energy as well as advances in energy conservation, require discussion informed by more detailed data.

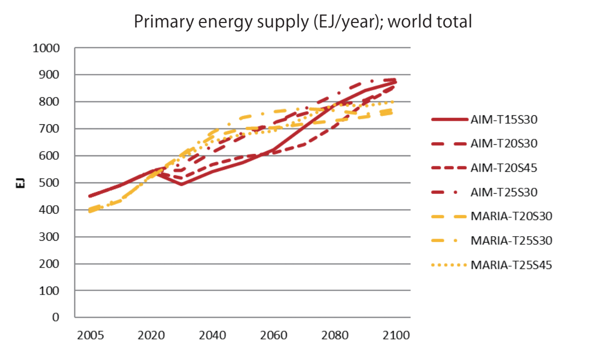


Figure 6 Primary energy supply
(EJ; BaU = SSP2; AIM/MARIA)

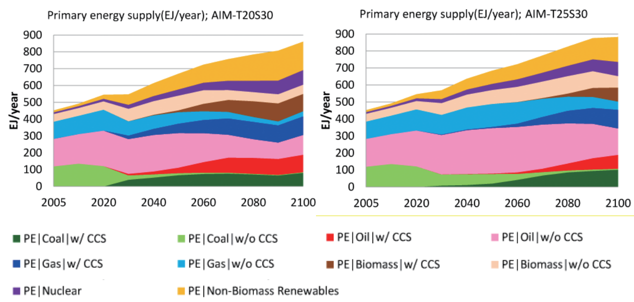


Figure 7 Primary energy mix
(EJ/year; BaU = SSP2; AIM)

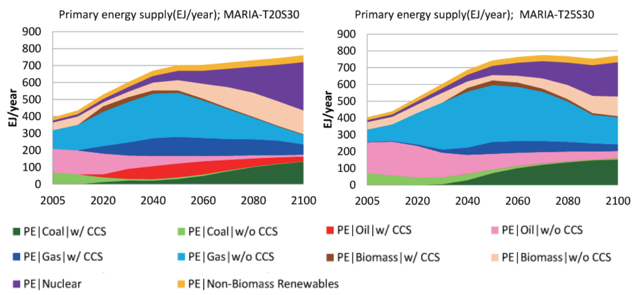


Figure 8 Primary energy mix
(EJ/year; BaU = SSP2; MARIA)

Energy technologies (Figures 7, 8, and 9)

The analysis of energy technologies was performed using only AIM and MARIA. In the case of T15S30, both models providing energy technology mixes—AIM and MARIA—project the adoption of strict measures from the 2030 stage; namely, large-scale adoption of CCS (carbon capture and storage), adoption of non-fossil fuel power sources (nuclear power and renewables), and electrification in all sectors (Figures 7 and 8). AIM also requires the large-scale adoption of BECCS (CCS combined with biomass energy) from 2030. While these conditions were obtained as numerical solutions, they would be quite difficult to achieve in practice.

The models differ considerably in the principal reduction technologies used: nuclear power with MARIA, and solar/wind power and BECCS with AIM. This means, conversely, that they offer a diversity of options, and suggests that there is a wide range of "technology strategies" from which to choose, depending on degree of technological development and social preferences.

The results showed introduction of BECCS to be essential. However, there is freedom over the amount of capacity to install and timing of introduction. More demanding CO2 constraints will necessitate earlier adoption. Figure 8 shows installed BECCS capacity according to AIM and MARIA.

With T15S30, AIM predicts that BECCS will rise sharply from 2030. The higher the target temperature is, the later the introduction of BECCS will occur. MARIA does not assume such extreme adoption as AIM, but predicts steady adoption from around 2050 with T15S30.

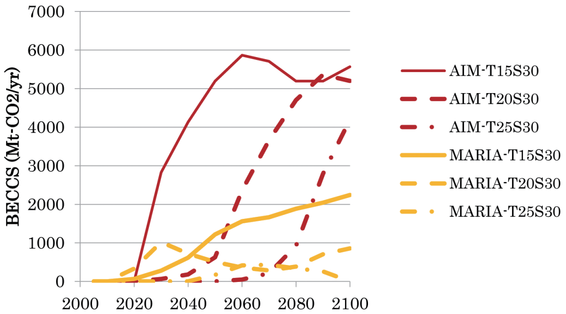


Figure 9 Installed BECCS capacity (1,000,000 tCO_2/year; BaU = SSP2; AIM/MARIA)

Land use and food supply and demand

Despite some differences in the range of crops covered by each model, none of the strategies differ much from BaU in terms of area of cultivated land, production volume, or yields, suggesting that competition between biomass use and food supply will not be serious. However, this depends on the assumptions made regarding yields.

Impacts by sector of industry and region (Figures 10 and 11)

The economies of each region of the world are composed of multiple industrial sectors, and the results of EMEDA, which is a model that allow analyses to be made sector by sector, T20S30 will see large declines in added value in all industrial sectors, although the margin of decline will decline by the end of the present century (Figure 10). The loss of added value increases in all sectors of industry until around 2070, reaching a maximum of 6% in agriculture and manufacturing and 5% in services. These figures fall to 2%-3% at the end of the century. With T25S30, The loss of added value steadily increases in all sectors of industry, and peaks at the end of the century at 3% in agriculture, 2.5% in manufacturing, and 2% in services. No solution could be obtained for T15S30 that lay within the assumed model parameters.

Figure 11 shows the impacts on economic growth rates of T20S30 by region. Overall, T20S30 sees a rapid transition from high growth to low growth in Asia, maintenance of high growth in Africa, and convergence on low growth in developed countries.

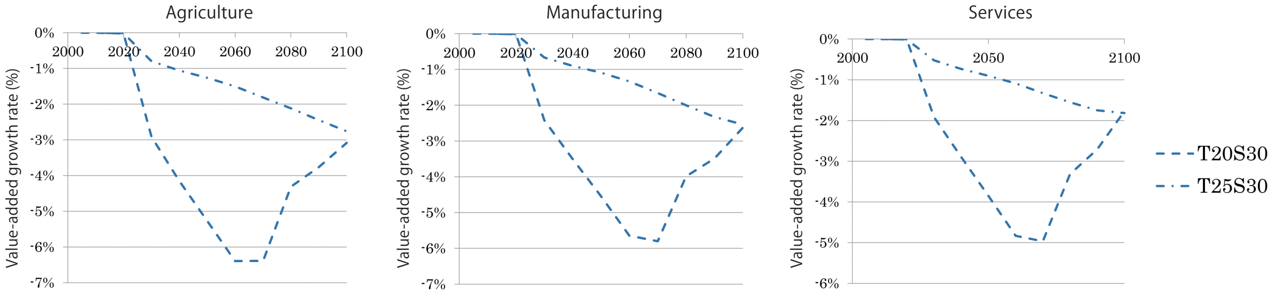


Figure 10 Value-added growth rate (global/by industry; % change from BaU (SSP2); EMEDA)

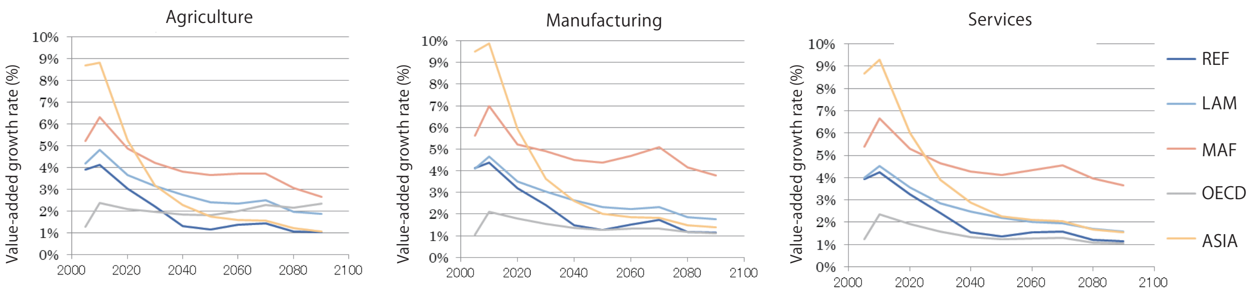


Figure 11 Regional value-added growth rates (by region/T20_S30; % change from BaU (SSP2); EMEDA)

4 Climate change risk perceptions and decision-making patterns

4.1 Distinguishing characteristics of climate issues compared with other risk events

Characteristics of climate change risks: insights from research on risk perception

Many studies on public risk perceptions have indicated that most people tend to perceive risks associated with climate change as threats that affect distant places or other flora and fauna in the future, and not of pressing concern to themselves.

More specifically, analyses of the factors that influence public perceptions of climate change risks have revealed the risks to be characterized as follows: (1) their causes are invisible; (2) the causes and effects are distant in both time and space; (3) it is hard to grasp instinctively how humans affect climate and also how to deal with the anticipated consequences; and (4) as there are still no socially established mechanisms to adequately deal with climate change risks in place , and as personal interests and numerous social forces insist on the status quo, it makes it harder for lay people to perceive climate change risks as a pressing concern.

Personal characteristics and climate change risk perception

The literatures shows that factors including personal values, worldviews, and political orientations affect interpretation of information concerning climate change risks (see also 4.2).

Gap between perception and engagement

It is known that knowledge of environmental issues, including climate change, does not necessarily prompt environmentally friendly behaviors and active commitments to these issues. As individual behavior is guided not only by personal thinking and intentions but also by social incentives and feedback, people can be led to behave contrary to their intentions if it appears (both in their view and that of others) that their contribution has only a very fractional impact and/or that their sacrifices are negated by overconsumption by others.

Dual routes of decision-making: the Elaboration Likelihood Model

The elaboration likelihood model (ELM) proposes that when we experience persuasive communication, we use two major routes to process the information, central and peripheral, depending on the likelihood of consideration (elaboration) of the message, and that these result in different levels of attitudinal changes. The likelihood of elaboration of climate change risk information seems to be low for most people, and it may be regarded as a phenomenon that tends not to give rise to central, thus significant attitudinal changes.

Reconsideration of social rationality

The governance of global climate change risks has long been an international policy concern. Because there is little motivation for most citizens to actively engage in decision-making on this issue, however, it remains as difficult for them to discuss and express an opinion on it as on issues associated with emerging science and technologies. What to ask the public and what to expect in response, therefore, need to be closely examined.

4.2 Classification of values by people concerning risk events

Social groups are collective representations of unique worldviews—social, cultural, and political approaches to the world that act as guides to behavior when facing complex situations—and patterns of social control formed in the course of everyday activities. Worldviews are incorporated subconsciously into the consciousness of the individual, and affect the individual whether he/she likes it or not. There have been numerous studies in recent years that have analyzed how these worldviews relate to public perceptions of climate change risks by classifying them by grid (strength of social norms governing individual behavior) and group (strength of pressure to be conscious of being a member of a group during individual decision-making). For this project, a survey was made of citizens in Japan and the U.S. in order to investigate the relationship between grid-group scores and other socio-demographic variables on the one hand and factors such as attitudes to targets on climate change, target levels, and support for implementation of various mitigation measures on the other. This showed that whereas the Japanese respondents were generally skewed toward the high end on the grid side, the U.S. respondents were skewed toward the low end on the group side. Such cultural differences between the two countries are reflected in, for example, differences in attitudes toward climate change targets (58.3% in Japan support legislation and 69.1% in the U.S. oppose legislation) (Figure 12), differences regarding what impacts to be concerned about (whereas there is a tendency to be strongly concerned about damage in developing countries in Japan, in the U.S. no difference was observed between developing and developed countries) (Table 5), and differences regarding the areas in which mitigation responses should be implemented (in Japan there is strong support for mitigation response by developed countries in energy conversion, energy conservation, actions in agriculture, forestry, and fisheries, and everything to do with waste, while in the U.S. no difference was observed between developed countries and developing countries in any of the fields of response). A multivariate regression analysis using the acceptable total reduction as the object variable confirmed that there tends to be an association between positive attitude to reduction and a higher group score, and negative attitude to reduction and a higher grid score.

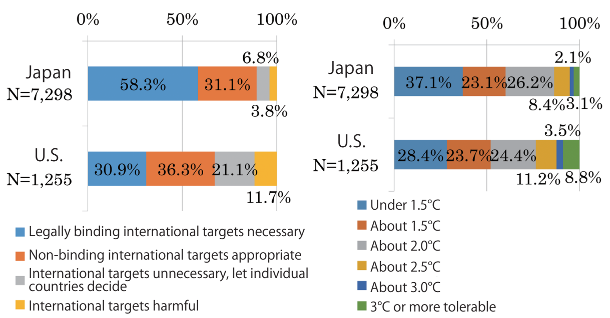


Figure 12 Attitudes to and levels of targets

Table 5 Concerns about damage

		Water	Ecosystems	Food
Japan	Concerned about damage in developing countries	46.4%	44.0%	50.8%
	Concerned about damage in developed countries	40.7%	40.0%	44.2%
U.S.	Concerned about damage in developing countries	49.0%	43.3%	47.8%
	Concerned about damage in developed countries	47.7%	42.2%	44.2%

Note: Items found to be significantly different are shown in red.

4.3 Public perception of risks associated with climate change spillover patterns

(1) Need for public participation

The model for public participation in the social decision-making process is democracy. The current approach to decision-making on climate change risk management is viewed by some as deficient in light of the democratic model. In actuality, interviews with members of the general public indicated that public participation in the decision-making process (by, for example, suggesting solutions that transcend budget frameworks and using metaphors drawn from everyday life) might complement current approaches. If so, the presently limited nature of the opportunities for public participation will make it necessary to consider means of enabling public participation at low cost and topics for discussion that are especially amenable to public input.

(2) Psychological barriers from the perspective of the public

From the perspective of the public, climate change risks are not issues that can be urgently tackled. As they also tend to attract little interest and have low priority, the cost of participation in the debate on them is expected to be high (see 4.1).
On the other hand, a questionnaire carried out following the World Wide Views ("WWViews") world citizens' conference on climate change issues in 2009 showed that many of the participants were interested in taking part in similar events in the future. In order to help identify possible ways of lowering the cost of participation, we analyzed how experience of WWViews served to lower the psychological barriers to participation.

- **Pre-contemplation stage:** Regarding the "cannot be interested" barrier, sensitivity to information on global warming policy increased after deciding to participate and after participation.
- **Contemplation stage:** Demonstrating clear benefits apart from the event itself (e.g., travel) and emphasizing the low cost of participation proved effective.
- **Preparatory action stage:** The confidence to "be able to debate even with first-time acquaintances" is crucial. A conducive environment and others aids to discussion allow participants to experience engaging in debate.
- **Maintenance stage:** Positive reaction from others maintains activity and motivates to participants to persuade others to also become involved.

(3) Issues requiring more public participation

Issues of interest were identified based on the findings of interviews with the public.

It was found that even when asked about numerical targets for temperature increases and cost sharing, ordinary members of the public discussed things such as their own non-negotiable values and principles in the context of prioritization of climate risks relative to other risks and deciding whether action should be taken. This suggests that value-based discussion of what to avoid above all of is of greater important to the public than concrete figures. It is hoped, therefore, that discussion of this kind will be assisted by, for example, providing information in a manner that allows climate change risks to be compared with other risks. How questions are framed, the organizations providing data, and trust in people were also found to affect debate.

(4) Arrangements for reflecting public opinion

There are typically trade-offs between proper public understanding and consideration of the issues, and costs of implementing means of ascertaining opinion and ensuring statistical representativeness. Consideration therefore needs to be given to using a combination of questionnaire surveys, simple simulator surveys, and debate-based polling to determine opinion on individual questions. Use of debate-based polling as a mechanism to complement the electoral system and better protecting the rights of minorities was also studied. This mechanism may make it possible to mediate the diverse positions of ordinary citizens precisely because they do not have a stake.

ICA-RUS
Integrated Climate Assessment - Risks, Uncertainties and Society

http://www.nies.go.jp/ica-rus/en/materials.html

For more information about this research project, please contact:

Climate Change Risk Assessment Research Section
Center for Global Environmental Research
National Institute for Environmental Studies, Japan
Email: s10-info@nies.go.jp

2015.9