Integrated Assessment of Greenhouse Gas Stabilization Concentrations, Emission Pathways, and Impact Threshold Values for Control of Global Warming

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Abstract

To mitigate the dangerous impacts of global warming to the greatest extent possible, various greenhouse gas stabilization scenarios have been proposed. Integrated studies are proceeding on emission pathways and the costs of achieving climate stabilization, as well as on the impact risks of global warming. This paper summarizes the existing knowledge on temperature rise, mitigation measures and impact threshold values, with a particular emphasis on climate stabilization scenarios. It also gives an outline of the AIM/Impact[Policy] policy support tool developed for integrated assessment of global warming, and reports on the results of analyses of global mean temperature increase, emission pathways, and global warming impacts under GHG concentration stabilization constraints.

Key words: emission pathway, global warming impact, greenhouse gas stabilization scenario, integrated assessment

1. Introduction

The concentration of carbon dioxide in the atmosphere reached approximately 370 ppm in the year 2000, compared to approximately 280 ppm prior to the industrial revolution, and the global mean temperature is reported to have risen by $0.6 \pm 0.2^\circ$C through the 20th century up to the present time (Folland et al., 2001). This increase in temperature has been attributed mainly to greenhouse gases (GHGs) emitted into the atmosphere as a result of human activity (Mitchell, 2001). The impacts of global warming are already manifesting in various places around the world (Folland et al., 2001), and with further progress of global warming in the future, significant impacts have been projected in diverse areas including natural ecosystems, living environments, agriculture, water resources, and so on (Hitz & Smith, 2004; Hare, 2003). There is also concern over the possibility of a shutdown of thermohaline circulation, which would result in instability of the climate system; melting of the West Antarctic and Greenland ice sheets, which would cause an irreversible sea level rise; and melting of permafrost, which could lead to a sudden release of GHGs (Church et al., 2001).

Efforts must be made for climate stabilization in order to mitigate global warming to the greatest extent possible. The United Nations Framework Convention on Climate Change (1992) sets forth the ultimate objective of “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” However, it has not been shown in concrete terms at what level GHG concentrations need to be stabilized, nor by how much and via what types of pathways GHG emissions need to be reduced, in order to achieve this objective. The European Union has proposed that the rise in the global mean temperature be limited to $2^\circ$C compared to that prior to the industrial revolution as the “level that would prevent dangerous anthropogenic interference (Commission of the European Comunities, 2005).” To accomplish this long-term goal, studies have been progressing on targeted GHG stabilization concentrations, GHG emission reduction plans (mitigation measures) and their costs, and global warming impact risks in various sectors (WBGU, 2003; RCEP, 2000; MIES, 2004; SEPA, 2002).

In this paper, we summarize the existing knowledge on mitigation measures, temperature rise and impact threshold values, with particular emphasis on climate stabilization scenarios. We also introduce an integrated analysis method using AIM/Impact[Policy] (Hijioka, 2005), a policy support tool for compre-
hensive analysis and assessment of GHG stabilization concentration targets and emission pathways for realizing them, as well as impacts and risks under such targets.

2. Stabilization Concentrations, Emission Pathways, and Impact Threshold Values

2.1 Climate stabilization scenarios and emission pathways

In order to mitigate the impacts of global warming, it will be necessary to establish targets that incorporate stabilization concentrations, temperature rises, and mitigation measures in an integrated way, taking impact threshold values into consideration. Discussions of these issues have continued since the 1980s (Harasawa, 2005a). At a symposium on the stabilization of greenhouse gases held at the Hadley Centre in the United Kingdom in 2005, scientific knowledge on the most recent impacts of climate change, the possibility of achieving stabilization targets and concrete mitigation measures for achieving these targets (Cramer et al., 2006) were discussed and summarized.

Various stabilization scenarios have been developed thus far (Meinshausen et al., 2004) for use in studies on GHG stabilization concentration targets and mitigation measures for achieving them. These can be broadly classified into scenarios under which only carbon dioxide (CO₂) concentrations are stabilized (S profile (Houghton et al., 1994), WRE profile (Wigley et al., 1996), etc.) and scenarios under which all GHGs are stabilized by converting them into CO₂ equivalent concentrations (EMF-21 (De la Chesnaye, 2003), EQW (Meinshausen et al., 2004), etc.). In the CO₂ concentration stabilization scenarios, no stabilization constraints are imposed on the scenarios of GHGs other than CO₂ and aerosols that have a cooling effect, so the relationship between the global mean temperature and CO₂ stabilization concentration is not standardized among the scenarios. Attention must therefore be paid to this point when establishing target values for temperature rise using CO₂ concentration stabilization scenarios.

Representative stabilization scenarios are outlined below.

1. S profile (Houghton et al., 1994) and WRE profile (Wigley et al., 1996) (Fig. 1)

S profile scenarios are CO₂ concentration stabilization scenarios released by the Intergovernmental Panel on Climate Change (IPCC) in its Second Assessment Report (Houghton et al., 1994), describing CO₂ emission pathways when CO₂ concentrations are stabilized at 450, 550, 650, 750 and 1,000 ppm. In the case of the S profile, when a low stabilization concentration target is established, the IPCC concludes that early reduction of CO₂ emissions and continued strengthening of reductions are necessary.

WRE profile scenarios, whose name was taken from the initials of authors Wigley, Richels and Edmonds, are also CO₂ concentration stabilization scenarios like those of the S profile. However, they describe economically efficient emission pathways, and compared with the S profile, CO₂ emissions continue on an upward trend for a time, followed by a drastic reduction, implemented at a certain stage. In the WRE scenarios, although there is room for further discussion on the setting of discount rates, technological innovations, energy-saving promotion effects, and so on, these scenarios indicate that it is possible for various different emission pathways to achieve the same concentration stabilization target.

2. Post-SRES (Swart et al., 2002) (Fig. 2)

Post-SRES CO₂ stabilization scenarios are mitigation scenarios formulated based on the Special Report on Emissions Scenarios (SRES) (Nakicenovic et al., 2000) released in 2000 by the IPCC. In the Post-SRES scenarios, atmospheric CO₂ stabilization concentrations are set at 450, 550, 650 and 750 ppm, and the timing and degree of the necessary mitigation measures are quantitatively shown under six future development assumptions described by the SRES (A1B, A1FI, A1T, A2, B1 and B2). Figure 2 shows anthropogenic CO₂ emission pathways according to future development pathways described by the SRES, and CO₂ emission pathways when CO₂ concentration targets are considered.
stabilization constraints are imposed. The CO2 emission pathways obtained when CO2 concentration stabilization constraints are imposed clearly show larger differentiations due more to the differences in constraints than to the differences in future world scenarios. On the other hand, when these results are compared with the case in which no concentration stabilization constraints are imposed, the amounts of reduction show large variations according to different future world trends, suggesting that the degree of difficulty of achieving climate stabilization will depend greatly on the circumstances in the future world.

(3) Equal Quantile Walk (EQW) (Meinshausen et al., 2004; Meinshausen, 2005) (Fig. 3)

In EQW, which is targeted at GHGs and aerosols, detailed studies are conducted on the relationships between stabilization concentrations and emission pathways. Figure 3 shows changes in GHG concentrations and emission pathways for three GHG stabilization concentration targets (GHG concentrations of 550, 475 and 400 ppm). In the case of the 550 ppm stabilization scenario, it is estimated that emissions in 2050 of the gases targeted for reduction under the Kyoto Protocol (hereafter referred as “Kyoto gases”) will need to be reduced by approximately 10% from the 1990 levels. In the case of the 475 ppm and 400 ppm (peak concentration 475 ppm) stabilization scenarios, on the other hand, a considerable reduction of approximately 50% in Kyoto gas emissions in 2050 compared to the 1990 levels is estimated to be necessary. Under these scenarios, CO2 emissions originating from land use change are assumed to have a negative value (i.e., they are absorption sources). Hence, when CO2 emissions originating from land use change have a high value, as in the present situation, even more severe reductions in emissions are found to be required. Moreover, studies of various mitigation measures under the 400 ppm GHG concentration stabilization target (peak concentration of 475 ppm) have concluded that considerable efforts will be required if mitigation is delayed.

Under the EQW approach, therefore, quantitative analyses of various GHG concentration stabilization targets have been conducted taking differences in reduction starting times into consideration in order to determine the future course that should be taken, particularly in terms of mitigation measures.

2.2 Stabilization concentrations and temperature rise

Meinshausen has studied the relationship between GHG stabilization concentrations and global mean temperature increases taking uncertainty into consideration (Meinshausen, 2005). The temperature rise at the time of GHG concentration stabilization is esti-
mated by Eq. (1) and (2) below:
\[ \Delta Q = \alpha^* \ln(C/C_0) \]  
\[ \Delta T = \Delta Q^*(\Delta T_{2xCO2}/\alpha^* \ln(2)) \]  
where \( \Delta Q \): radiative forcing, \( \alpha \): coefficient, \( C \): CO₂ equivalent concentration, \( C_0 \): CO₂ concentration prior to the industrial revolution, \( \Delta T \): global mean temperature increase (compared to that prior to the industrial revolution), and \( \Delta T_{2xCO2} \): climate sensitivity.

As shown in Eq. (2), the global mean temperature increase is determined by radiative forcing and climate sensitivity. Climate sensitivity indicates long-term (equilibrium) variations in the global mean temperature when atmospheric CO₂ concentration doubles. The global mean temperature increase, a parameter that comprehensively indicates the uncertainty of physical processes and interactions contained in a climate model, is estimated at 1.7°C to 4.2°C in the IPCC’s Third Assessment Report (Cubacsch et al., 2001). With regard to the uncertainties in climate sensitivity, a probability density distribution approach has been proposed using various methods (Forest et al., 2002; Gregory et al., 2002; Kerr, 2004; Murphy et al., 2004; Wigley & Raper, 2001).

Using the probability density distribution function of climate sensitivity reported in the existing studies shown in Fig. 4, Meinshausen clarified the relationship between stabilization concentration (radiative forcing) and global mean temperature increase in terms of the probability of overshooting the target values for global mean temperature increase (1.5°C, 2.0°C, 2.5°C, 3.0°C and 4.0°C), with the temperature prior to the industrial revolution as the base (Fig. 5). According to Fig. 5, for example, it can be seen that in the case of 450 ppm GHG concentration stabilization, the probability of overshooting 2°C is 47% on average, with minimum and maximum values of 26% and 78%, respectively. In this way, Meinshausen has attempted to achieve analysis with a higher degree of reliability by using the probability distribution of climate sensitivity to express targeted GHG stabilization concentrations and the global mean temperature increase in terms of a range of probabilities.

### 2.3 Impact threshold values

Classifications such as the following have been proposed (Harasawa, 2005b) to define threshold values for the impacts of global warming.

**Type 1:** When the amount of damage shows linear or other smooth changes with the degree of climate change, this type of threshold value indicates a point at which such damage is judged to be impermissible by certain decision makers. The targeted sectors are WEHAB (water, energy, health, agriculture, biodiversity), and others. For example, permissible upper limits can be cited for populations at risk of food shortages, water shortages, health deterioration, etc., or permissible degree of reduction in biodiversity.

**Type 2:** This type of threshold value is directly connected to the main processes of the climate system itself, and indicates a point that should not be exceeded in order to maintain the stability of one of the processes. Examples that can be cited are a shutdown of thermohaline circulation, which would result in instability of the climate system; melting of the West Antarctic and Greenland ice sheets, which would cause an irreversible sea level rise; and melting of permafrost, which could lead to a sudden release of GHGs.

Since the impacts of global warming affect various fields, there have been many studies assessing individual sectors. There are far fewer studies, however, in which different sectors have been assessed in an integrated manner. Examples of studies that comprehensively summarize the results of research on global warming impacts in various sectors include those by Hitz & Smith (2004), Hare (2003), Parry et al. (2001) and Leemans & van Vliet (2004). Parry et al. summarized the relationship between temperature increase and CO₂ concentration, and risk populations (from hunger, malaria, flooding, water shortages) with the global mean temperature increase as the predictor.
variable, thereby providing knowledge for discussion of values at which the temperature increase should be stabilized (Fig. 6). From now on, it will be necessary to further refine global warming studies, taking uncertainty into consideration, and to integrate knowledge of impacts in various sectors, of which there have been many reports recently, so as to provide scientific information with high reliability for discussing climate stabilization targets.


3.1 AIM/Impact[Policy]

In the present study, we are developing AIM/Impact[Policy] (Hijioka, 2005), a policy support tool to assist in achieving climate stabilization targets by comprehensively analyzing and assessing GHG concentration stabilization and mitigation measures as well as impacts and risks under the targets (Fig. 7).

AIM/Impact[Policy] is being developed and applied in a study entitled “Comprehensive assessment of climate change impacts to determine the dangerous level of global warming and appropriate stabilization target of atmospheric GHG concentration” (hereafter referred to as “S-4”), which is a research topic of the Global Environmental Research Fund (GERF) of Japan’s Ministry of the Environment. The objective of S-4 is to promote comprehensive assessment of climate change impacts in Japan and the Asia region. The objective of the development of AIM/Impact[Policy] is to provide an integrated approach for the analysis of dangerous levels of global warming...
impacts by connecting the knowledge obtained from sectoral climate change impact studies with GHG stabilization targets.

In establishing future targets for the global mean temperature, sea level rise, atmospheric GHG concentrations, and so on, AIM/Impact[Policy] functions to (1) project the optimal GHG emissions path and GHG reduction burden by region, and (2) show the scale of the impact of warming by country and sector under this GHG emissions path, and provide materials to investigate whether or not the established future targets are sufficient to avoid “dangerous impacts” (i.e., to determine the validity of future targets). This will be highly useful for formulating specific future targets for global warming response policies.

AIM/Impact[Policy] consists of multiple models. These are classified into models to simulate GHG emissions under the global warming control targets (an energy economic model, a burden sharing model to estimate the GHG reduction burden by country, and a global economic model to assess economic impacts resulting from the implementation of global warming response policies), and a model to simulate the global warming impact anticipated to occur under the global warming control targets (an impact assessment and adaptation model) (Fig. 7).

3.2 Outline of energy economic model

The energy economy model (Hijioka, 2005) contained in Fig. 7 is used to simulate the optimum GHG emission pathway in terms of economic efficiency for an assumed climate stabilization target, and to quantitatively assess the impacts of global climate change and sea level rise. This model consolidates the world into a single region, and consists of four basic modules (an economic/energy module, greenhouse gas emissions module, climate module and sea level rise module). It allows policy targets to be quantitatively assessed by identifying optimal paths of economic development under various constraints; namely, (1) GHG concentration constraints, (2) global mean temperature constraints, (3) temperature change rate constraints and (4) sea level constraints. These constraints can be set simultaneously, and the time that the constraints are applied can also be set freely, from a single point to multiple points in time.

In this model, in addition to changes in radiative forcing resulting from GHG and SO2 emissions, those due to ozone (stratospheric and tropospheric), variations in stratospheric water vapor, soot originating from fossil fuels, and soot originating from biomass combustion are also modeled. Values for GHG concentration are expressed by converting the sum of these radiative forcing values into CO2 concentration.

3.3 Outline of impact assessment and adaptation model

By quantitatively showing country-level and sector-level global warming impacts under the GHG concentration stabilization targets, the impact assessment and adaptation model provides materials to investigate whether or not the established future targets are sufficiently low to avoid “dangerous impacts” (i.e., to determine the validity of future targets).

![Fig. 7 Outline of AIM/Impact[Policy].](image-url)
In investigating the validity of future targets, a highly simplified impact cost estimation equation (e.g., an equation for estimating the global impact cost as a function of global mean temperature change) for endogenous use in the economic model is insufficient because it cannot grasp regional deviations in impacts and it has low accuracy in impact estimation. On the other hand, impact assessment models that segment the world into lattice points and give detailed estimates of the impact for each lattice point entail a large computational burden and are not suited to trial-and-error investigations of the validity of various future targets. In the present study, therefore, using existing detailed sector-level impact assessment models, we estimated the impact on each lattice point using sensitivity analysis with two climate factors, temperature and precipitation, and we spatially averaged them to prepare country-level and sector-level impact functions (the predictor variables were change in temperature and change in precipitation from the present conditions) to estimate the scale of the warming impact by country and sector.

Figure 8 gives an outline of the impact assessment and adaptation model used to assess sector-level impacts, with the global mean temperature estimated using the energy and economic model as input data.

### 3.3.1 Global mean temperature

Annual changes in global mean temperature (compared to the base year) are calculated using the climate module integrated into the energy economic model. As mentioned above, it is possible to set various stabilization concentration constraints. Moreover, it is possible for users to arbitrarily set the climate sensitivity, which has the greatest impact on the estimation of temperature rise.

#### 3.3.2 Country-level normal climate change database

Country-level normal climate change databases are prepared in order to estimate country-level climate changes. Here, General Circulation Model (GCM) experimental output is aggregated by country mean value according to the following equations, and the country mean values (spatial pattern) of climate change (temperature change and precipitation change) are stored as a table type database.

\[
\text{Country-level normal temperature change} \left( \frac{\degree C}{\degree C} \right) = \frac{(\text{Future average year country mean temperature} - \text{Present average year country mean temperature})}{(\text{Future average year global mean temperature} - \text{Present average year global mean temperature})} \tag{3}
\]

\[
\text{Country-level normal precipitation} \left( \% / \degree C \right) = \frac{(100 \times \text{Future average year country mean precipitation} / \text{Present average year country mean precipitation} - 100)}{\text{Future average year global mean temperature} - \text{Present average year global mean temperature}} \tag{4}
\]

Here, the years 2071 to 2100 are used for the future average years, the base years (1961 to 1990) are used for the present average years, and the average is adopted when there are multiple emission scenario calculation results from the same GCM.
3.3.3 Country-level climate scenarios

The climate scenarios of targeted countries are prepared using the stored country-level normal climate change database. This involves preparing country-level annual mean temperature scenarios using a country-level pattern scaling method. Specifically, an arbitrary GCM is selected from the spatial pattern of the GCM (country-level mean climate change) contained in the country-level normal climate change database, and future country-level annual mean temperature scenarios and country-level annual mean precipitation scenarios are calculated using the following equations:

Country-level annual mean temperature [°C] =
Global temperature change × Country-level normal temperature change + Country-level base year annual mean temperature

Country-level annual mean precipitation [mm] =
(Global temperature change × Country-level normal precipitation change / 100 + 1.0) × Country-level base year annual precipitation

3.3.4 Sector-level country-mean potential impact database

Detailed impact assessments which place a large calculation burden on the computer are not carried out in AIM/Impact[Policy]. Rather, the results of assessments performed outside the tool are stored as a database. The impact assessment results are stored after converting presently observed climate data into units of 0.5°C for mean temperature and 5% for precipitation using an already developed impact assessment model, then impact estimation is performed by sensitivity analysis of the mesh that is created. The results are aggregated by country-mean values, and input into the database. This database can also contain knowledge obtained by other impact studies.

3.3.5 Sector-level potential impact

The sector-level potential impact is estimated by interpolation, combining the country-level climate change (annual mean temperature change and annual precipitation change) with the sector-level country-mean potential impact database. The impact estimated here is not a risk estimation taking adaptation into consideration, but the physical potential impact to be used as material for damage estimation.

3.3.6 Adaptive capacity

Although cumulative assessment of the cost-effectiveness of individual adaptation measures would be an ideal method of studying adaptive capacity, in order to study the effects of introducing individual adaptation measures – where localized effects are seen in many cases – on a global scale or at the regional or country levels, enormous amounts of data and detailed case studies become necessary. At the first step of the development process, therefore, this problem is handled by dealing with adaptive capacity in simple terms. Concretely, by combining socioeconomic factors, a parameter to determine adaptive capacity is incorporated into a function for estimating sector-level impact risk (described below), providing a mechanism that allows users to determine the relationship between socioeconomic scenarios and adaptive capacity. As regards the socioeconomic factors to be combined, different factors are used according to the sector.

3.3.7 Sector-level impact risk

Sector-level impact risk can be obtained using a function with potential impact and adaptive capacity as variables. For impact risk, we are planning to prepare various physical quantities, risk indexes for performing integrated assessment, and economic losses by sector.

3.3.8 Comprehensive judgment of global warming impact

It is difficult to summarize the risk of impacts in various sectors and express the degree of impact in terms of a single numerical index. Indicating the degree of impact in each sector in the form of a graphic chart in both a sector-parallel and time-series manner can therefore assist comprehensive judgment. Moreover, a comprehensive judgment criteria module is being developed. This module judges whether or not the sector-level impact risk set by the user can be avoided under various emission and socioeconomic scenarios and levels of adaptive capacity.

3.4 Global warming impact assessment using GHG concentration stabilization scenarios

We performed calculations under business as usual (BaU) conditions and the following two constraints to assess the impacts of global warming under GHG stabilization conditions.

- BaU: Business as usual
- GHG-475 ppm: a 475 ppm cap on total GHG concentration
- GHG-550 ppm: a 550 ppm cap on total GHG concentration

Constraints were calculated so that GHG concentrations not exceeding the constraint could be maintained from 1990 to 2200. The SRES B2 scenario prepared by IPCC was used for estimating figures on future population and future economic development. A discount rate of 4%, an annual reduction ratio of GHG emissions/primary energy supply of 0.85, and a climate sensitivity of 2.6°C were applied. Figure 9 shows the results obtained.

In the BaU case, GHG emissions would continue to increase until 2050 (Fig. 9 (a)), and by 2150 GHG concentrations (Fig. 9 (b)) would have increased to approximately three times the 1990 level. The global mean temperature (Fig. 9 (c)) would rise 3.5°C by 2100 and 4.5°C by 2150, and would also continue to increase thereafter. Judging from the projected temperature change in 2150, when the GHG concentration constraint is 550 ppm, the increase (2.5°C) exceeds the 2°C level seen in the case of the 475 ppm constraint. Focusing on GHG emissions (Fig. 9 (a)), in the
the first half of the 21st century is projected to be
GHG of 475 ppm case, however, the situation in
ate decreasing trend continues from 2040 onward. In
GHG of 550 ppm case than in the BaU case, a moder-
verse impact of decreased productivity is less in the
most 25% by the end of the century. Although the ad-
case, with the level of decrease expected to reach al-
potential productivity gradually progresses in the BaU
latter half of the 21st century, however, the decrease in
BaU case in the first half of the 21st century. In the
very slight decrease is seen in all cases including the
India) is examined in comparison with the aver-
level, indicating an urgent need for a full-scale reduc-
GHG emissions after 2010 are consistently lower than the 1990 level when the GHG concentration is capped at 475 ppm, confirming the need for a strict emissions control policy.

As shown in Fig. 9(d), the projected rises in sea
level in the case of GHG of 475 ppm are 0.16 m by
2100 and 0.22 m by 2150. These rises are respectively
0.64 and 0.55 times those projected for the BaU sce-
nario. Under the condition of GHG of 550 ppm, on the
other hand, the rise in sea level by 2150 is 0.26 m,
about 1.2 times that projected in the case of GHG of
475 ppm. Since the sea level continues to show a
rising tendency even after the GHG concentration is
stabilized, a more severe constraint can be inferred
when considering the stabilization target in terms of
sea level rise.

When the change in potential rice productivity
(India) is examined in comparison with the aver-
age-year conditions from 1961 to 1990 (Fig. 9(e)), a
very slight decrease is seen in all cases including the
BaU case in the first half of the 21st century. In the
latter half of the 21st century, however, the decrease in
potential productivity gradually progresses in the BaU
case, with the level of decrease expected to reach al-
most 25% by the end of the century. Although the ad-
verse impact of decreased productivity is less in the
GHG of 550 ppm case than in the BaU case, a moder-
ate decreasing trend continues from 2040 onward. In
the GHG of 475 ppm case, however, the situation in
the first half of the 21st century is projected to be
virtually maintained in the years after 2040. With re-
gard to the potential productivity of wheat in India
(Fig. 9(f)), a decreasing tendency during the 21st cen-
tury cannot be avoided even in the case of GHG of
475 ppm, but the rate of decrease is gentle compared
to the BaU case.

To summarize the analysis results, temperature
rises and adverse impacts are mitigated in the cases of
GHG of 475 ppm and GHG of 550 ppm in comparison
with the BaU case. However, even in the case of GHG
of 475 ppm, which requires severe reductions in emis-
ions (approximately 10% reduction in 2020 and 50%
reduction in 2050 compared to 1990), climate change
impacts cannot be avoided. Measures against global
warming integrating both mitigation and adaptation
measures are therefore essential.

4. Conclusion

In this paper, we have summarized the existing
GHG stabilization scenarios and reported the results
of analyses of global mean temperature increase and
GHG emission pathways as well as global warming
impacts under GHG concentration stabilization con-
straints using the AIM/Impact[Policy] policy support
tool. Our results indicate that (1) a GHG concentra-
tion stabilization target not exceeding 475 ppm is nec-
essary to limit the rise in global mean temperature to
2°C compared to the level prior to the industrial revo-
lution, requiring a significant reduction in emissions at
an early stage; and (2) global warming impacts cannot
be avoided even if GHG concentrations are stabilized
at 475 ppm or less, making global warming response
measures integrating both mitigation and adaptation

Fig. 9 Effects of two GHG concentration constraints on (a) GHG emissions, (b) GHG concentrations, (c) Global mean temperature increase, (d) Sea level rise, (e) Change in potential rice productivity (India), and (f) Change in potential wheat productivity (India).
measures essential.

As regards future tasks, integrated studies taking uncertainty into consideration need to be promoted in the areas of stabilization targets, mitigation measures to achieve the targets, and adaptation measures to reduce impacts and risks under the targets.

References


(http://sres.ciesin.columbia.edu/final_data.html.)


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