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GLOBAL GHG EMISSION SCENARIOS UNDER GHG CONCENTRATION STABILIZATION TARGETS

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Abstract

Stabilization scenario analysis revealed that when a low GHG stabilization level is set, the GHG emission peak needs to be reached as soon as possible and efforts should be made to reduce GHG emissions drastically by 2050 and thereafter. Furthermore, sensitivity analysis revealed two important results. First, the results of simulations using different discount rates for two different stabilization levels indicated that the more stringent the constraints, the more limited the choice of emission paths will be. In particular, to achieve a 2.0°C increase in the global mean temperature above the preindustrial level using 2-10% discount rates, a 15% emission range in 2020 and a 4% emission range in 2050 could be permitted for Kyoto Protocol gas. Second, the results of simulations using different climate sensitivities indicated that to achieve the goal of a 2.0°C global mean temperature increase with 50% or 66.6% probability, Kyoto Protocol gas emissions need to be reduced by 78% and 83%, respectively.

KEYWORDS: *GHG reduction policy, GHG stabilization scenario, integrated assessment model*

1. Introduction

In its Fourth Assessment Report (AR4), the Intergovernmental Panel on Climate Change (IPCC) presents new scientific findings that have emerged since the publication of the Third Assessment Report (TAR). Against the background of rising temperatures on a global scale attributable to increased greenhouse gas (GHG) emissions, it notes that many impacts of climate change have been reported. With the further progress of global warming from this point onward, significant impacts are projected in diverse areas including natural ecosystems, living environments, agriculture, water resources, and human health (IPCC, 2007a). There is an urgent need to reach an international consensus on climate stabilization levels and implement measures to avoid global warming impacts.

Discussions have started on how GHG emissions should be curbed after the first commitment

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period of the Kyoto Protocol (2008–2012). One of the points at issue is the setting of target levels for climatic stabilization such as the stabilization of GHG concentrations. However, the prospects for an international agreement on long-term GHG stabilization targets are unclear at present.

The United Nations Framework Convention on Climate Change 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" and states that this level "should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (United Nations, 1992). However, it has not been shown in specific terms at what level GHG concentrations need to be stabilized in order to achieve this objective. The European Union has proposed that global mean temperature increase should be limited to 2°C compared with that of pre-industrial condition as the "level that would prevent dangerous anthropogenic interference" (Commission of the European Communities, 2005), but an international consensus on this long-term target has not yet been realized.

At the G8 summit held in Heilingendamm, Germany, in June 2007, world leaders agreed to consider reducing GHG emissions to half of their present level by 2050. Preventing global warming and stabilizing the climate will require further reductions in GHGs even after achievement of the Kyoto Protocol targets. Experts were already aware of this before the Kyoto Protocol, but as the Protocol's first commitment period approaches, public awareness of the threat posed by global warming has risen, and on the international political stage where a post-Kyoto framework will have to be hammered out, world leaders now share a growing recognition of the need for further significant GHG emission reductions.

In this paper, we assess the timing of GHG reduction policies in the context of the relationship between the stabilization of GHG concentrations and economically efficient emission paths to realize these targets using the AIM/Impact[Policy] model, which is applied to the integrated assessment of global warming control targets.

2. Assessment of GHG reduction policies under long-term GHG stabilization targets

2.1 Objectives

In this paper, we examine policies for the long-term control of global warming under various stabilization constraints. Our aim is to demonstrate the plausibility of achieving stabilization targets by quantitatively analyzing GHG emission paths based on various scenarios and available or possible countermeasures. This type of analysis gives an idea of the climate stabilization levels under emission targets such as the GHG emission reduction by 2050 proposed at the G8 summit, and also shows the paths toward the target year and thereafter; that is, the required emission levels such as at 2020, 2100, and so forth if the target year is 2050.

2.2 Setting of GHG stabilization scenarios

One method of assessing stabilization targets is the scenario assessment, which analyzes temperature increase and the necessary volume of GHG reduction under GHG atmospheric concentration constraints. Many scenarios targeting carbon dioxide (CO_2) concentrations are assessed in the TAR (Houghton *et al.,* 1994; Wigley *et al.,* 1996; Swart *et al.,* 2002), while additional GHGs are included in the stabilization assessment in AR4 where GHGs are converted into CO_2 equivalent concentrations (De la Chesnaye, 2003; Meinshausen *et al.,* 2005; Hijioka *et al.,* 2006).

IPCC's AR4 summarizes the required emission levels for different categories of stabilization concentrations and the associated equilibrium global mean temperature increase using the "best estimate" of climate sensitivity. This helps us to grasp the relationship between the temperature increase when the GHG concentration is stabilized at a specific level and the reduction targets, such as the peaking period for CO_2 and other GHGs and the change in global CO_2 emissions in 2050, required to achieve such a stabilization level (IPCC, 2007b).

When making comparative studies, however, attention needs to be paid to the fact that assumptions differ for each case. In the past, analyses were conducted only on CO_2. In these CO_2 concentration stabilization scenarios, no stabilization constraints are imposed on the scenarios of GHGs other than CO_2, nor on aerosols that have a cooling effect, so the relationship between the global mean temperature and CO_2 stabilization concentration is not standardized among the scenarios. Hence, this point must be considered when establishing target values for the temperature increase using CO_2 concentration stabilization scenarios. Recent studies on the stabilization of concentrations have therefore included emissions of GHGs other than CO_2 as well as aerosols.

To study long-term targets, it is necessary to have an understanding of the "when," "where," and "how" of climate change impacts. In concrete terms, the following aspects of GHG stabilization scenarios must first be clarified: (1) targeted gases (gases that are the objective of the study concerned), (2) starting point of assessment (the time used as a base in discussions), (3) indicators for judgment of dangerous levels (which indicators are to be used in discussions), and (4) spatial scale of assessment (global or regional level).

2.3 Outline of AIM/Impact[Policy]

The AIM (Asia-Pacific Integrated Model) team has developed an integrated assessment model, AIM/Impact[Policy], for assessment of global warming control targets including the stabilization of GHG concentrations, global mean temperature increase, and so on, as well as economically efficient emission paths to realize these targets, and consequent impacts and risks of these targets (Hijioka *et al.,* 2006).

As shown in Figure 1, AIM/Impact[Policy] has two major parts: an impact projection part and an emissions projection part. The impact projection part shows the magnitude of the climate change impacts on several sectors by country under stabilization scenarios. The emissions projection part shows the global GHG emission paths and GHG reduction burdens by country and region under stabilization scenarios. In the present study, the energy economic model shown in Figure 1 was used for assessment of GHG reduction targets under long-term GHG stabilization constraints. This model projects global GHG emission paths under various stabilization scenarios. The projected global GHG emission paths are then used for the burden sharing scheme to project the reduction burdens by country. The global computable general equilibrium (CGE) model quantitatively assesses economic impacts by country and region resulting from the GHG reduction under stabilization scenarios as predicted in the burden sharing model.

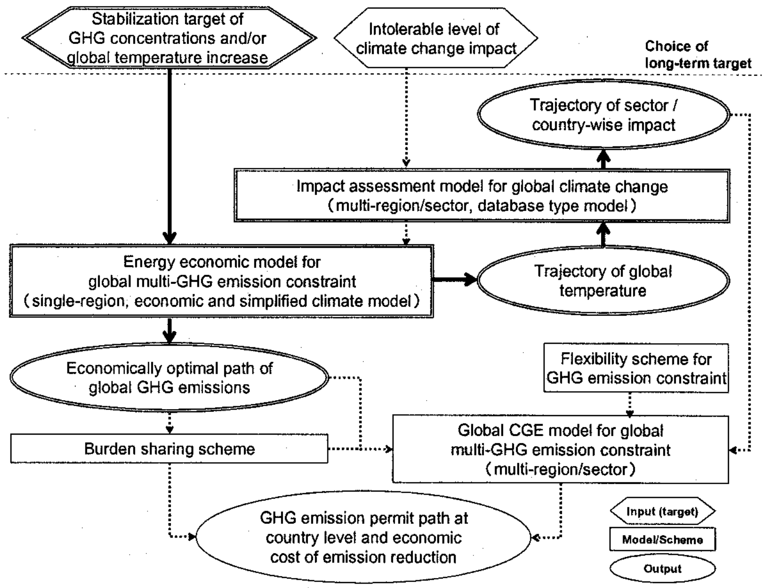

Figure 1. Structure of AIM/Impact[Policy]

The energy economic model adopts a dynamic and nonlinear optimization model to simultaneously predict very long-term economic activities and climate changes and to provide a framework for quantitatively assessing various climate change policies. The baseline year for the analysis period is 1990, and calculations are performed for every 10 years until the year 2300. The main driving forces in the model are population and technological improvement, assuming the four scenario trends given in the IPCC SRES (Nakicenovic *et al.*, 2000).

When policy targets are quantitatively assessed in the energy economic model, optimal paths of economic growth are identified under various constraints. Constraints that can be investigated are (1) GHG constraints, (2) global mean temperature constraints, (3) temperature change per decade constraints, and (4) sea level rise constraints. These constraints can be established simultaneously, and the times at which the restrictions are applied can also be set freely, from any given single point to multiple points in time.

In the energy economic model, the per capita level of utility between different points in time is converted into current value by a discount rate, and it is presupposed that policies are adopted that will maximize the weighted aggregate by population.

The energy economic model consists of four modules, such as an economic/energy module, GHG emission module, climate module, and sea level rise module. The GHG emission module adopts CO_2, CH_4, N_2O, black carbon, and 26 types of chlorofluorocarbons (CFCs) as GHGs, and SO_2 and organic carbon, as cooling gases.

2.4 Business as usual scenarios

The AIM/Impact[Policy] model enables the running of simulations based on four SRES scenarios. For the period 1990–2100, the population, economic growth rate, types of energy consumption, rate of technological progress, rate of energy efficiency progress, and other parameters are assumed to follow the trends of parameters represented by the SRES A1, A2, B1, and B2 scenarios. For the period 2100 - 2300, the changes of parameters such as population, economic growth rate, rate of technological progress, rate of energy efficiency progress, are assumed based on the trend for the period 1990 - 2100. Note that the GHG emission and energy consumption figures for 1990 and 2000 used in this paper are based on the latest information rather than on the SRES figures.

Table 1 shows the preconditions for the scenarios and simulation results; namely, population, GDP, rate of technological progress, rate of energy efficiency progress, primary energy consumption, and secondary energy consumption. Figure 2 shows the time series of GHG emissions, GHG concentrations, global mean temperature increase, radiative forcing, and primary energy consumption.

Table 1. Preconditions for scenarios and BaU simulation results

	A1		A2		B1		B2	
	Population 1)	GDP 2)	Population 1)	GDP 2)	Population 1)	GDP 2)	Population 1)	GDP 2)
2050	8704	186.0	11296	115.3	8704	148.2	9367	108.7
2100	6516	490.5	15657	239.8	6515	256.0	10529	218.2
2200	3873	959.3	21943	338.1	3873	369.9	11564	383.0
2300	2962	1633.6	28985	399.4	2962	520.1	12431	564.3

	Rate of technological progress			
	A1	A2	B1	B2
2050	0.26	0.35	0.30	0.31
2100	0.20	0.35	0.27	0.28
2200	0.12	0.35	0.21	0.23
2300	0.07	0.35	0.16	0.19

	Rate of energy efficiency progress																			
	CH_4	N_2O	SO_2	BC	OC	CH_4	N_2O	SO_2	BC	OC	CH_4	N_2O	SO_2	BC	OC	CH_4	N_2O	SO_2	BC	OC
2050	0.21	0.18	0.42	0.32	0.32	0.43	0.40	0.55	0.73	0.73	0.27	0.25	0.49	0.46	0.46	0.34	0.30	0.65	0.55	0.55
2100	0.09	0.08	0.07	0.08	0.08	0.25	0.24	0.32	0.43	0.43	0.09	0.08	0.25	0.15	0.15	0.20	0.18	0.21	0.25	0.25
2200	0.03	0.03	0.01	0.01	0.01	0.15	0.14	0.15	0.15	0.15	0.03	0.03	0.10	0.01	0.01	0.09	0.08	0.06	0.05	0.05
2300	0.01	0.01	4.E-03	2.E-03	2.E-03	0.09	0.09	0.07	0.05	0.05	0.02	0.02	0.05	2.E-03	2.E-02	0.04	0.04	0.03	0.01	0.01

	Primary energy consumption (exaj)															
	COL	OIL	GAS	RNW	COL	OIL	GAS	RNW	COL	OIL	GAS	RNW	COL	OIL	GAS	RNW
2050	196.2	186.0	354.5	151.6	317.5	154.3	233.3	112.5	230.7	141.3	241.7	92.2	279.4	179.5	253.3	94.7
2100	88.8	108.3	439.3	295.6	735.3	81.1	342.5	159.9	85.3	106.6	135.2	134.1	248.2	105.8	321.9	183.4
2200	11.7	44.9	9.2	357.6	492.8	20.2	28.1	195.1	11.4	84.6	25.7	169.4	183.4	36.3	44.8	328.1
2300	1.5	18.6	0.1	419.6	330.3	5.0	0.2	230.3	1.5	67.2	4.9	204.7	135.6	12.7	0.3	472.7

	Secondary energy consumption (TKWh)			
	A1	A2	B1	B2
2050	8.6	4.0	4.9	3.9
2100	29.2	8.2	11.0	7.7
2200	62.6	15.0	18.1	17.5
2300	99.7	21.4	25.7	27.6

1) million people, 2) bil.$

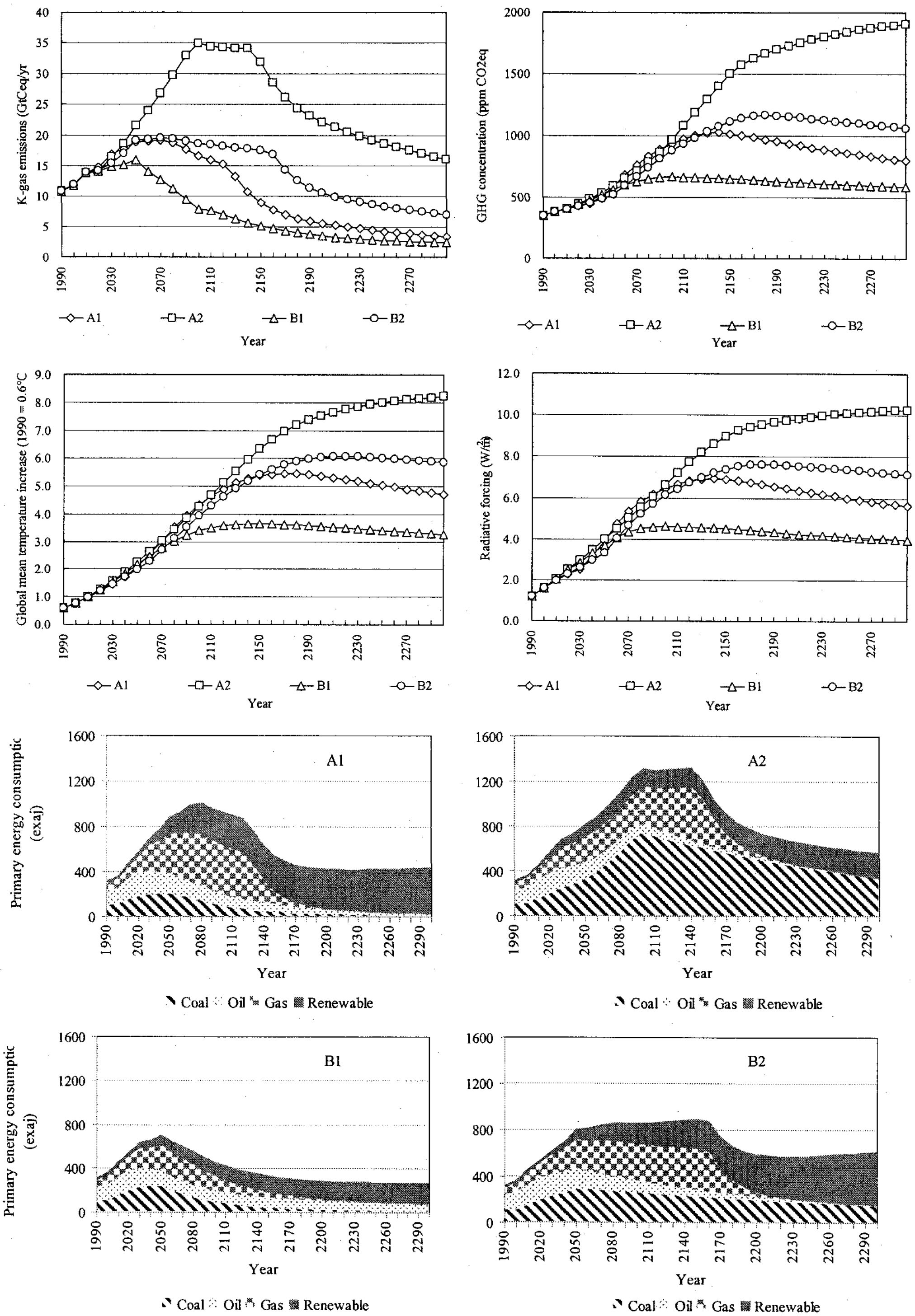

Figure 2. Time series of K-gas emissions, GHG concentrations, global mean temperature increase and radiative forcing, and primary energy consumption

Under the A1 scenario, emissions of the six gases covered by the Kyoto Protocol (K-gases) will peak in 2070 and then decrease, while GHG concentration will peak in 2140. The global mean temperature increase (above the preindustrial level) will reach 4.3°C by 2100 and peak in 2170 at 5.5°C, subsequently declining to 5.4°C by 2200 and 4.7°C by 2300. Looking at energy consumption, oil will be the major source of energy up to 2020, followed by natural gas from 2020 to 2130, and renewable energy beyond 2130.

Under the A2 scenario, GHG concentration will increase 5.5-fold over the 1990 level by 2300, and the global mean temperature will continue to rise until 2300 with the increase above the preindustrial level reaching 4.3°C by 2100, 7.5°C by 2200, and 8.2°C by 2300. Oil will be the major source of energy up to 2020, followed by coal beyond 2020.

Under the B1 scenario, K-gas emissions will start declining from 2050, which is earlier than in any of the other scenarios. GHG concentration will peak in 2100, then gradually decrease. The global mean temperature increase above the preindustrial level will reach 3.4°C by 2100 and peak in 2150 at 3.6°C, gradually declining after that.. As regards energy consumption, the contribution by renewable energy sources rises more rapidly than in any other scenario, reaching 30% by 2100 and about 45% by 2150.

Under the B2 scenario, K-gas emissions will peak around 2070 as in the case of A1, but will subsequently drop more gradually than in A1 up to 2160. GHG concentration will peak in 2180, and then drop gradually. In terms of energy consumption, petroleum will be the major source of energy up to 2020, followed by coal from 2020 to 2060, natural gas from 2070 to 2160, and renewable energy beyond 2160.

2.5 Stabilization scenarios

We analyzed GHG emission abatement policies under various constraints to consider when GHG emissions need to be reduced to achieve long-term climate stabilization. Constraint optimization calculations were carried out in which the GHG concentration and temperature increase did not exceed the constraints between the years 1990 and 2300. Table 2 shows the simulation results for radiative forcing; GHG concentration; temperature increase; peaking year for CO_2, GHG, and K-gas emissions; and changes in global CO_2, GHG, and K-gas emissions in 2050. As an example of stabilization characteristics, K-gas emissions, global mean temperature, primary energy consumption, and cumulative carbon capture and storage (CCS) under the B2T20 and B2G860 scenarios are shown in Figure 3.

Focusing on scenario-specific trends, the SRES A1 and B2 scenarios show almost the same trends of peaking of emissions and global emission changes in 2050. Refer to the G8 statement in Heilingendamm, achieving the target of halving emissions by 2050 (K-gases, compared with 1990 levels) would enable stabilization of the long-term temperature increase at around 2.4°C and of the GHG concentration at around 500 ppm CO_2eq. Furthermore, to achieve the above targets, the peaking year of CO_2, GHG, and K-gas emissions is projected to be 2010. These results suggest the need for a post-Kyoto framework aimed at further significant and urgent emission reductions. For example, under the B2T20 scenario, in which the temperature increase constraint is 2.0°C, all emissions - CO_2, GHG, and K-gas - need to be drastically reduced by 92%, 80%, and 78% respectively by 2050 compared with 1990 levels.

A comparison of the trends in temperature increase constraints and GHG concentration constraints shows that as the constraints become more stringent, the reduction in emissions by 2050 is more moderate under the temperature increase constraint than under the GHG concentration constraint. This is because with the temperature increase constraint, the GHG concentration stabilizes after overshooting the stabilized level. The peaking years show a steep shift, from 2010 under the A1G600 scenarios to 2040 under the A1G650 scenarios. These trends are because of the moderate changes in emissions between 2010 and 2050.

Table 2. Simulation results under constraints of temperature increase and GHG concentrations

SRES	Scenario[1]	Constraint[2]	Radiative forcing[3]	Concentration GHG[4]	GMTI[5]	Peaking year			Changes in global emissions in 2050 (% of 1990 emissions)		
						CO_2	GHG	K-gas[6]	CO_2	GHG	K-gas[6]
			W/m^2	ppm	℃	Year	Year	Year	%	%	%
A1	A1T20	T	2.47	444	2.00	2010	2010	2010	9	21	23
	A1T22	T	2.72	465	2.20	2010	2010	2010	15	28	31
	A1T24	T	2.97	488	2.40	2010	2010	2010	30	42	47
	A1T26	T	3.21	511	2.60	2010	2010	2010	44	54	60
	A1T28	T	3.46	535	2.80	2010	2010	2010	57	64	72
	A1T30	T	3.71	560	3.00	2010	2010	2010	73	76	85
	A1T32	T	3.96	586	3.20	2010	2010	2010	85	84	95
	A1G455	C	2.60	455	2.10	2010	2010	2010	9	22	24
	A1G480	C	2.88	480	2.33	2010	2010	2010	19	32	36
	A1G490	C	2.99	490	2.42	2010	2010	2010	28	39	44
	A1G500	C	3.10	500	2.51	2010	2010	2010	34	44	49
	A1G535	C	3.46	535	2.80	2010	2010	2010	53	59	67
	A1G550	C	3.61	550	2.92	2010	2010	2010	63	68	76
	A1G590	C	3.99	590	3.23	2010	2010	2010	78	79	89
	A1G600	C	4.08	600	3.30	2010	2010	2010	87	86	96
	A1G650	C	4.51	650	3.65	2010	2040	2040	99	94	106
	A1G710	C	4.98	710	4.03	2020	2020	2040	125	113	127
	A1G860	C	6.00	860	4.86	2070	2070	2070	161	140	157
B2	B2T20	T	2.47	444	2.00	2010	2010	2010	8	20	22
	B2T22	T	2.72	465	2.20	2010	2010	2010	27	38	42
	B2T24	T	2.97	488	2.40	2010	2010	2010	43	52	58
	B2T26	T	3.21	511	2.60	2010	2010	2010	58	64	72
	B2T28	T	3.46	535	2.80	2010	2010	2010	62	68	76
	B2T30	T	3.71	560	3.00	2010	2010	2010	75	77	86
	B2T32	T	3.96	586	3.20	2010	2010	2010	92	88	99
	B2G455	C	2.60	455	2.10	2010	2010	2010	14	25	28
	B2G480	C	2.88	480	2.33	2010	2010	2010	34	44	49
	B2G490	C	2.99	490	2.42	2010	2010	2010	41	50	56
	B2G500	C	3.10	500	2.51	2010	2010	2010	43	51	57
	B2G535	C	3.46	535	2.80	2010	2010	2010	57	64	71
	B2G550	C	3.61	550	2.92	2010	2010	2010	68	71	80
	B2G590	C	3.99	590	3.23	2010	2020	2020	88	85	96
	B2G600	C	4.08	600	3.30	2010	2020	2020	90	87	97
	B2G650	C	4.51	650	3.65	2030	2030	2030	113	104	117
	B2G710	C	4.98	710	4.03	2050	2050	2050	164	139	157
	B2G860	C	6.00	860	4.86	2050	2060	2060	180	155	175

1) Climate sensitivity, 3.0℃; Discount rate. 4%, 2) T: Constraint of temperature increase; C: Constraint of GHG concentration increase. 3) Radiative force accompanying GHG and SO_2 emissions, due to ozone (stratosphere, troposphere), vapor, soot from fossil fuels, and soot from burning biomass. 4) Converting radiative forcings of GHG and aerosol to CO_2-equivalent concentrations. 5) GMTI: Global mean temperature increase compared with preindustrial level. 6) Six classes of gases specified in the Kyoto Protocol

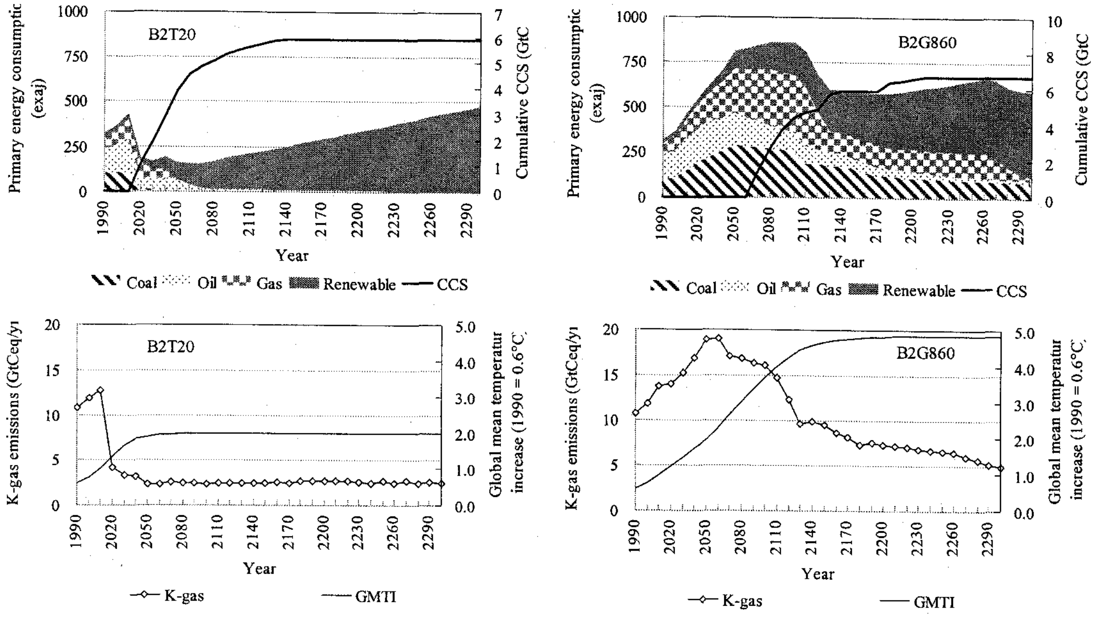

Figure 3. Time series of K-gas emissions, global mean temperature increase, primary energy consumption and cumulative CCS under B2T20 and B2G860 scenarios

2.6 Uncertainty analysis

(1) Uncertainty analysis of discount rate on emission paths

In Table 2, we show a single emissions trajectory for a single stabilization scenario. However, from an economic perspective, one can conceive of many different GHG emission reduction paths for achieving the same stabilization scenario, from those involving early reduction efforts sustained over the long term, to others that seek to implement drastic reductions at a later date after letting events take their course to a certain extent. With AIM/Impact[Policy], the optimum timing for emission reduction is determined on the premise that resources will be distributed in a way that maximizes the population-weighted sum, with the inter-temporal per capita utility function being converted into present value using a discount rate.

To consider the degree to which the discount rate impacts on the emission reduction path, in Figure 4 we show the emission paths for discount rates of 2%, 4%, 6%, 8%, and 10% per year between the years 1990 and 2150, using the B2 temperature increase stabilization scenarios shown in Table 2.

Using the B2T20 scenario based on B2 with the constraint of a 2.0°C global mean temperature increase, which is the most stringent constraint in Table 2, 2020 emissions show a decrease compared with the 1990 levels of between 65% for the 2% discount rate and 50% for the 10% discount rate, while 2050 emissions show a decrease compared with the 1990 levels of between 75% for the 2% discount rate and 79% for the 10% discount rate. On the other hand, in the case of the B2T30 scenario, which features moderate constraints including a 3.0°C increase in global mean temperature, emissions show a much wider variance, from a 33% decrease for the 2% discount rate to a 27% increase for the 10% discount rate in 2020, and from a 26% decrease for the 2% discount rate to an 5% increase for the 10% discount rate in 2050. Summarizing the above sensitivity analysis, to achieve a global mean temperature increase of 2.0°C, a 15% range of emission changes compared with 1990 levels in 2020 and a 4% range in 2050 could be permitted. On the other hand, to achieve a global mean temperature increase of 3.0°C, a 60% range of emission changes compared with 1990 levels in 2020 and a 31% range in 2050 could be permitted. These results indicate that the more stringent the constraints, the more limited the choice of emission paths will be.

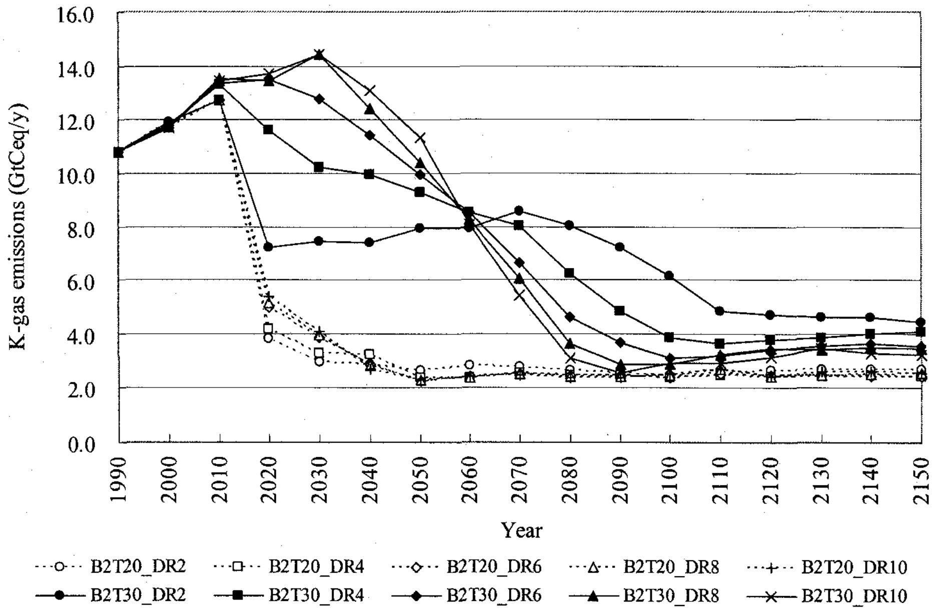

Figure 4. K-gas emission paths for discount rates of 2%, 4%, 6%, 8%, and 10%, using the B2T20 and B2T30 stabilization scenarios

(2) Uncertainty analysis of climate sensitivity

The IPCC AR4 states that climate sensitivity is likely to be in the range of 2-4.5°C, with a best estimate of 3°C. Table 4 shows GHG stabilization levels and temperature increase probabilities when "likely" is interpreted as 66.6% and "best" as 50%, and the climate sensitivity probability distribution is posited to be lognormal.

Figure 5 shows the relationship between the GHG emissions reduction rate and temperature increase nonexceedance probability. If K-gas emissions are reduced by 78%, 42%, or 24% by 2050, there is a 50% probability that the temperature increase can be kept within 2.0°C, 2.4°C, and 2.6°C, respectively, compared with the preindustrial level. If we set the goal of achieving a 66.6% probability that the temperature increase can be kept within 2.0°C, 2.4°C, or 2.8°C, K-gas emissions should be 83%, 79%, and 47%, respectively.

Determination of the probabilities of achieving reduction targets in this way provides important information for arriving at a consensus on stabilization targets.

Table 4. GHG stabilization levels and temperature increase probabilities

Stabilization level (ppm)[1)]	Very unlikely below[2)]	Best estimate[3)]	Very unlikely above[4)]
350	0.6	1.0	1.7
400	0.9	1.6	2.7
450	1.2	2.1	3.6
475	1.4	2.3	4.0
500	1.5	2.5	4.3
510	1.5	2.6	4.5
550	1.7	3.0	5.0
600	2.0	3.3	5.7
650	2.2	3.7	6.3

1) CO_2 equivalent concentration. 2) Probability less than the value is 10%,
3) Mode of the probability distribution. 4) Probability greater than the value is 10%

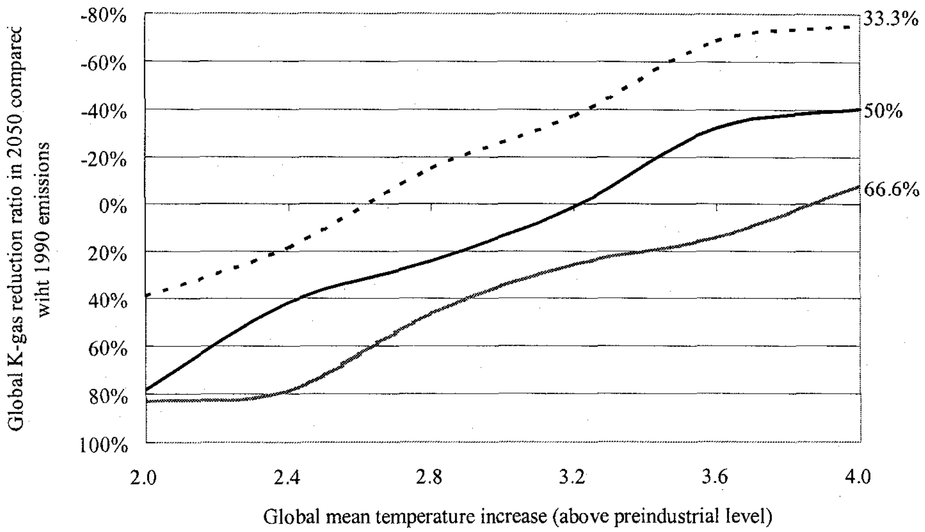

Figure 5. Relationship between K-gas emission reduction rate in 2050 and temperature increase nonexceedance probability under temperature increase constraints (SRES B2, 4% discount rate)

4. Conclusions

In this paper, using AIM/Impact[Policy], which is an integrated assessment model to analyze global warming control targets, we have assessed the timing of GHG reduction policies in the context of the relationship between the stabilization of GHG concentrations and economically efficient emission paths to realize these targets. Stabilization scenario analysis revealed that when a low GHG stabilization level is set, the GHG emission peak needs to be reached as soon as possible and efforts should be made to reduce GHG emissions drastically by 2050 and thereafter. Furthermore, sensitivity analysis revealed two important results. First, the results of simulations using different discount rates for two different stabilization levels indicated that the more stringent the constraints, the more limited the choice of emission paths will be. Second, the results of simulations using different climate sensitivities indicated that to achieve the goal of a 2.0°C global mean temperature increase with 50% or 66.6% probability, Kyoto Protocol gas emissions need to be reduced by 78% and 83% respectively.

The simulation results reported in this paper provide important information on the relationship between long-term stabilization levels and peaking timing, reduction targets, emission path choices, and probabilities, to assist in arriving at a consensus on stabilization targets.

Global warming is predicted to have serious impacts worldwide in many different fields, and there is a high likelihood that these impacts will be long term. The results of this study point clearly to the need to start reducing GHG emissions as soon as possible if the impacts of global warming are to be kept to a minimum. Given that the impacts of global warming are already beginning to manifest, and that humanity cannot avoid suffering the consequences to a certain degree, it is vital that concrete targets be set and shared worldwide, and that people throughout the world contribute to the effort to achieve these targets.

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