Global and Domestic CO_2 Emissions Pathways: The 2014 Revision

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Systems Analysis Group, RITE

■ Introduction

The global CO_2 emissions pathways developed by RITE have been used by the Japanese government and many other organizations for policy making and evaluating counter measures against global warming as fundamental data. Recently, we reviewed the pathways based on the latest historical emissions and economic trends. The followings are our new pathways of energy-related CO_2 emissions up to 2050 by major region in the world.

■ The pathways of the global energy-related CO_2 emissions

Based on CO_2 emission statistics up to 2011, economic trends by region up to 2012 and the future economic growth outlook, CO_2 emissions are estimated using one of the most advanced assessment models in the world. The pathways in this paper are estimated under the current policy where measures against global warming will be continued (see Figure A-2 for the baseline scenario without any particular measures).

Figure 1 shows the global energy supplies. Fossil fuels (coal, petroleum, natural gas) which are an emission sources of CO2 are important energy, accounting for 82% of the total in 2012. In the future up to 2050 fossil fuels are projected to continue to be crucial and largely dominate energy supplies.

The global energy-related emissions in 2011 are 32.3 billon tons and with the fossil fuel supplies increased, emissions in 2020 are estimated 37.8 billion tons, and 56.3 billion tons in 2050 (Figure 2). The emissions in developed countries were significantly reduced temporarily, affected by global financial crisis but the global CO_2 emission trend is forecasted to continue to increase. The regional emission shares have significantly changed since 1990 and are estimated to change further toward 2050. The CO_2 emissions by country that belongs to Annex I will account for less than 40% of the global CO_2 emissions in 2020 (Figure 2). It should be noted that these estimates are close to the median values in the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5 2014) which includes a number of collected scenario studies of the world (see a comparison in Figure A-2). We can say that in the long-term significant emission reductions and promotion of effective emission reductions by major emitters are crucial to suppress the climate change. In addition, we can also say that deployment of Japan's variety of energy-efficient technologies and products would contribute to effective emission reductions in the world.

The main updated points of “Global CO2 Emissions pathways” published in August 2011 are the outlooks for nuclear power generation and fossil fuel prices (Ref. 2 is referred for nuclear power generation and Ref. 3 for fossil fuel prices.). Nuclear power generation has been revised downward from the August edition, 2011 and fossil fuel prices, particularly gas prices have been revised downward due to the effects of shale gas development in the United States.

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[1]Using DNE21 + model, we have estimated the marginal abatement cost of mitigation policy which would have conducted in 2010 and mitigation policy has been estimated to cost less than the marginal abatement cost after 2010. Marginal abatement costs of major countries (Japan, US, UK, France and Germany) have been estimated \$61/tCO2, \$15/tCO2, t \$28/tCO2, \$6/tCO2 and \$30/tCO2, respectively. The wind power and solar power generation which have been increasingly introduced by various policies are estimated to generate more electricity than that [4), 5)] at the latest since it is difficult to predict policy trends

Low gas prices would accelerate the replacement of the old low-efficient coal-fired power generation in the US by gas-fired power generation but conversely lower the incentives for energy efficiency improvement. Without any GHG mitigation policy, the global emissions in 2050 will be revised upward from 56.6 billion tons in the August edition 2011 to 60.5 billion tons (not including CO2 emissions from international aviation and international). However, with the effect of the current policy, emissions are estimated 56.3 billion tons which is slightly lower than that of the August 2011.

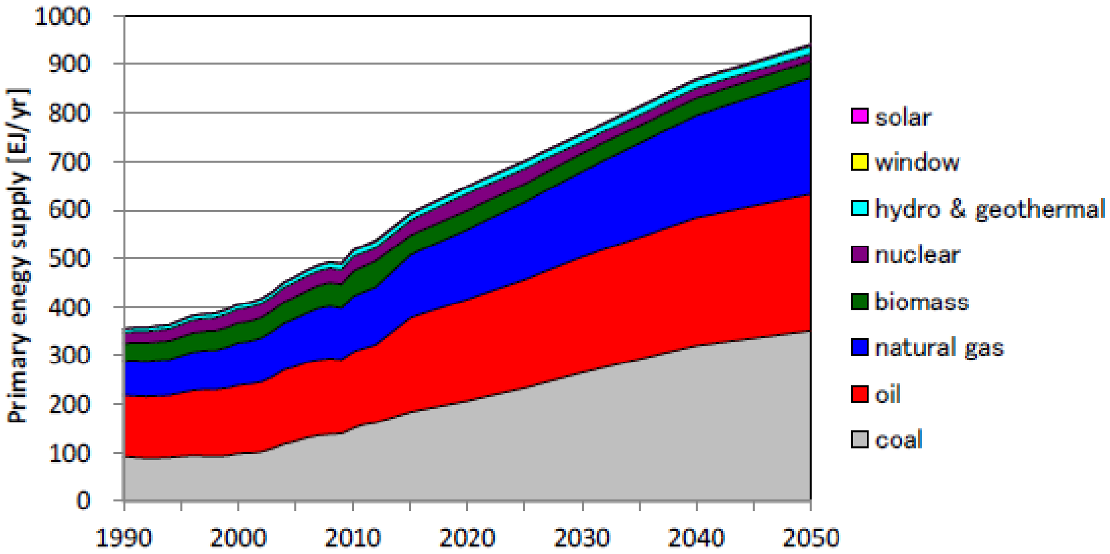

Figure.1 Pathways of the world total primary energy supply (IEA statistics[4), 5)] from 1990 to 2012)

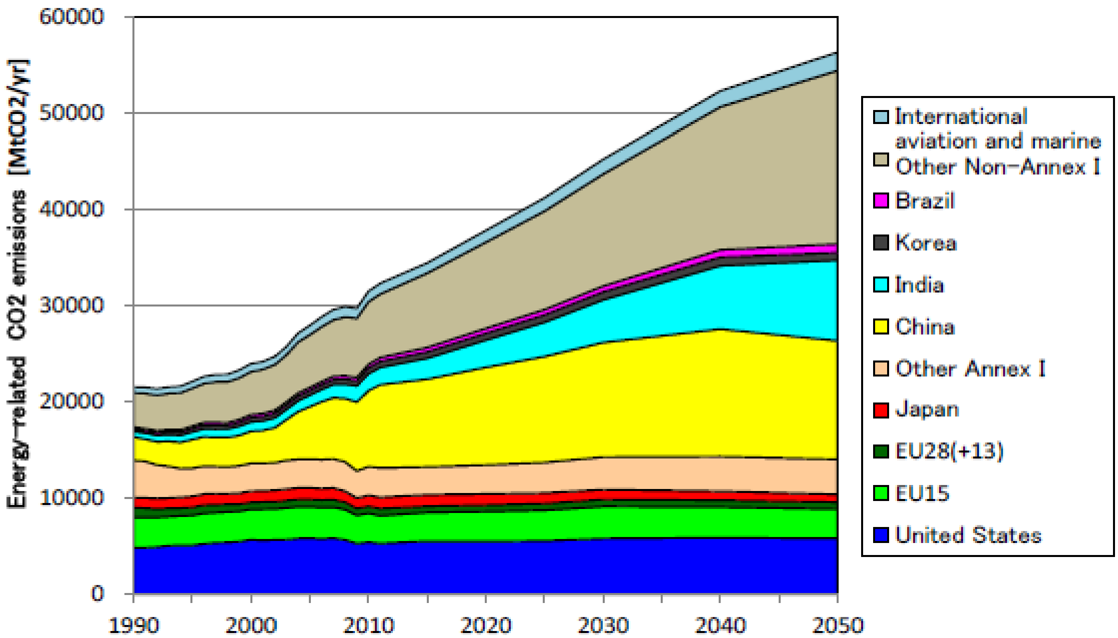

Figure.2 Pathways of energy-related CO2 emissions by the world major country and region (IEA statistics[6)] up to 2011)

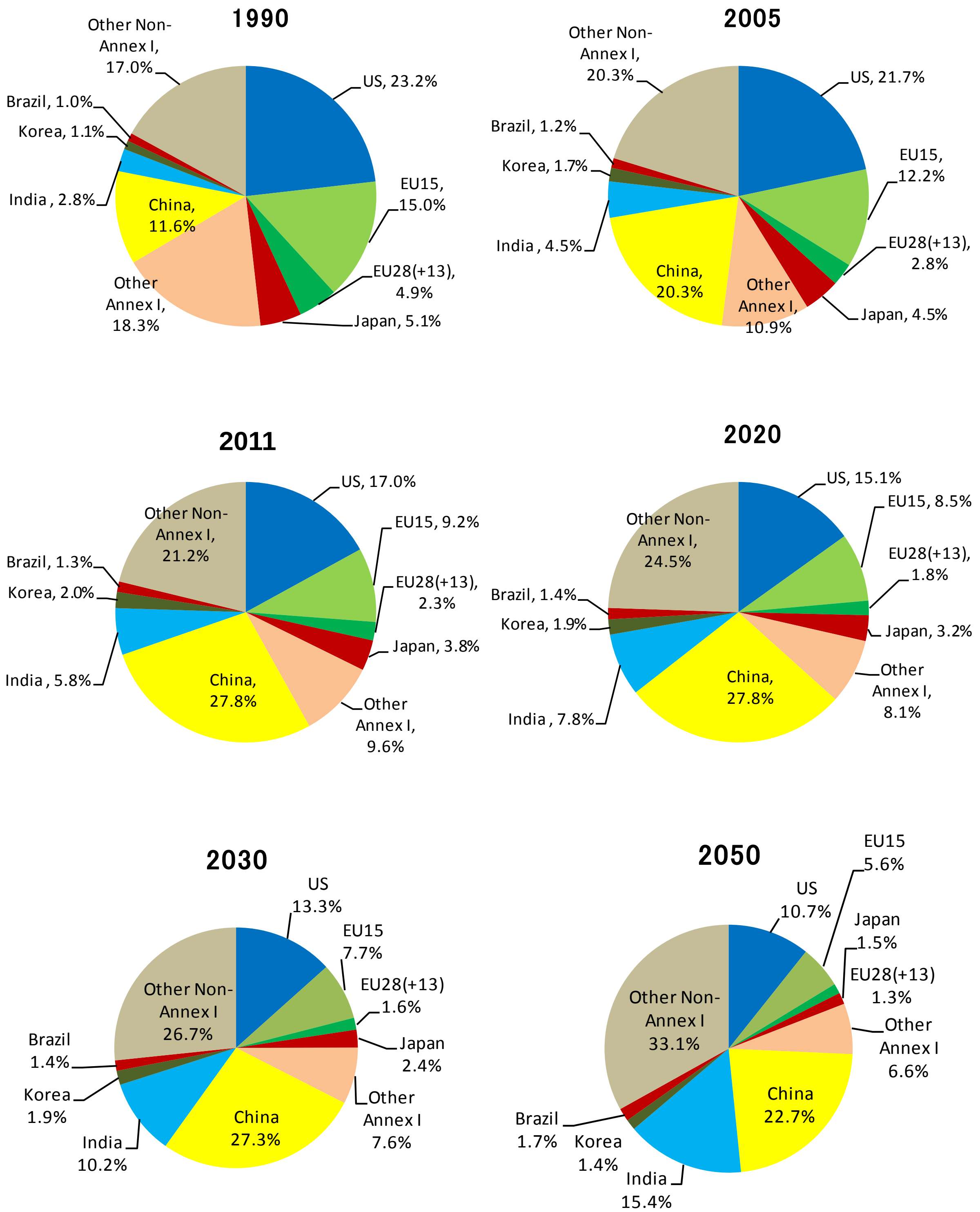

Figure 3 Regional shares in energy-related CO_2 emissions
(IEA statistics for 1990, 2005, 2011, RITE estimate for 2020, 2030, 2050)

Note) CO_2 emissions from international aviation and marine are not included.

■ Pathways of the global GHG emissions

Figure 4 shows the pathway of GHG emissions which include non energy-related CO2, N2O, CH4, F-gas under the Kyoto Protocol target, added to energy-related CO2. GHG emissions are estimated 53.9 billion tons in 2020 and 76.4 billion tons in 2050. The regional share in GHG emissions (Figure 5) increases more than the regional share in only energy-related CO2 emissions in other Non Annex I countries, so that the emission share in Annex I countries slightly decreases in 2020 (33%). This is due to more agriculture-related emissions of N2O and CH4 in other Non Annex I. Chinese emissions are estimated to peak in 2040 even under the current policy and mitigation. (Similarly, the emissions peak is around 2040 under baseline scenarios, as shown in Figure A-2.)

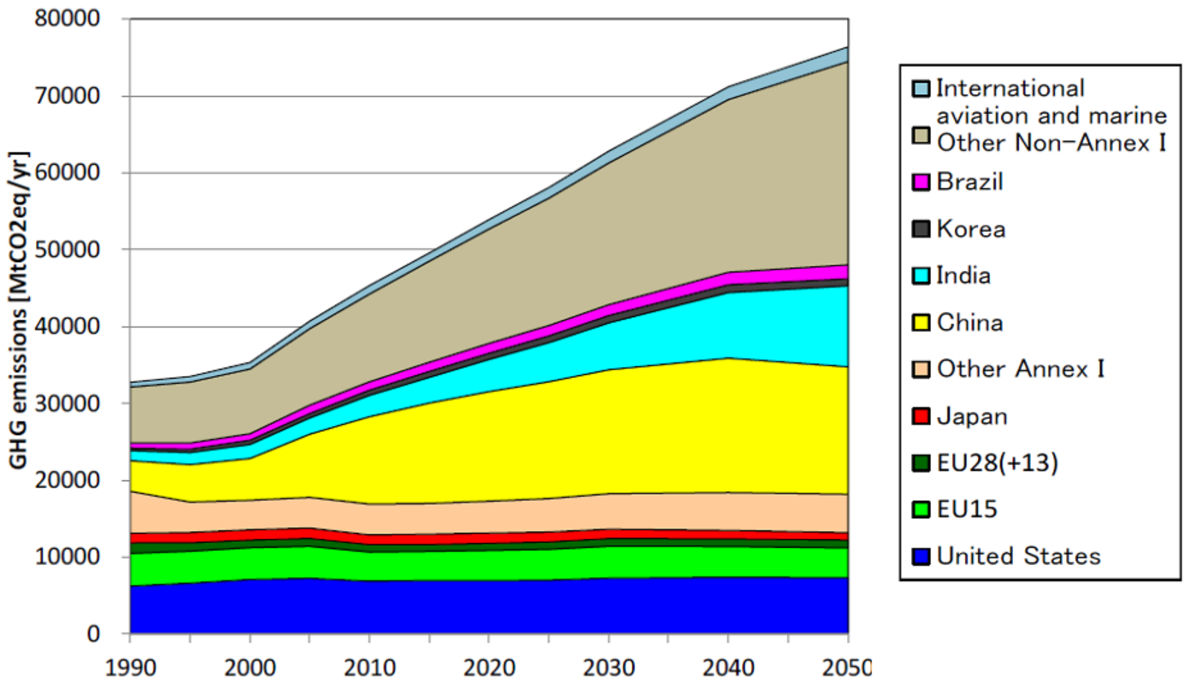

Figure 4 Pathways of GHG emissions by major country and region

(UNFCCC[7] for Annex-I, IEA statistics[6] for Non-Annex I up to 2010)

Note) GHG emissions from LULUCF are not included

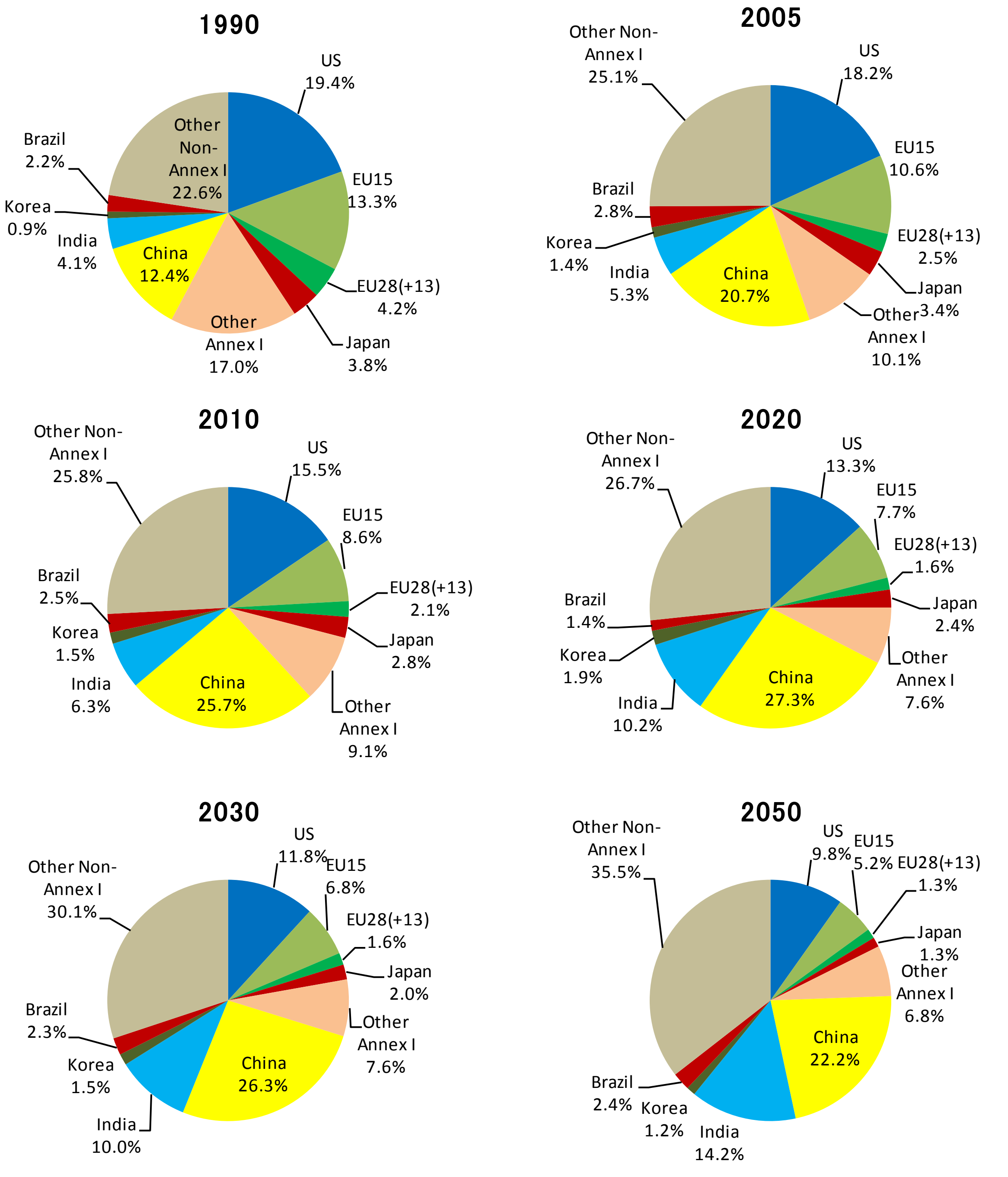

Figure 5 regional shares in GHG emissions
(UNFCCC[7] for 1990, 2005, 2010 Annex-I, IEA statistics[6] for 1990, 2005, 2010 Non-Annex-I, RITE estimate for 2020, 2030, 2050)

Note) CO2 emissions from international aviation and marine and LULUCF are not included.

Figure 6 and 7 show GHG emissions pathways per GDP and per capita. Emissions per GDP of Japan, EU15 and the United States are in a low level, which means that economic activities in those regions are less dependent on GHG emissions. Although the other countries are expected to improve in the future, emissions per GDP are estimated more than the status quo emissions of Japan, the United States and Europe even in 2050 (for example, China's emissions per GDP is as high as those of USA in 2000). On the other hand, emissions per capita of Annex I countries (the United States, EU and Japan) and other Annex I countries (Russia, etc.) in 1990 are high. However, emissions of the other countries has increased along with the economic development, and Korea’s emissions per capita has exceeded the EU15 and Japan level in 2000 and also in 2010 China’s emissions per capita were similar to the level of EU15 and Japan and are estimated to exceed in the near future. As emissions per capita are affected by various factors such as industrial structure and climate in each country, being equal is not necessarily equitable. However, in the ideal, it is considered desirable to be in a direction to converge to some extent.

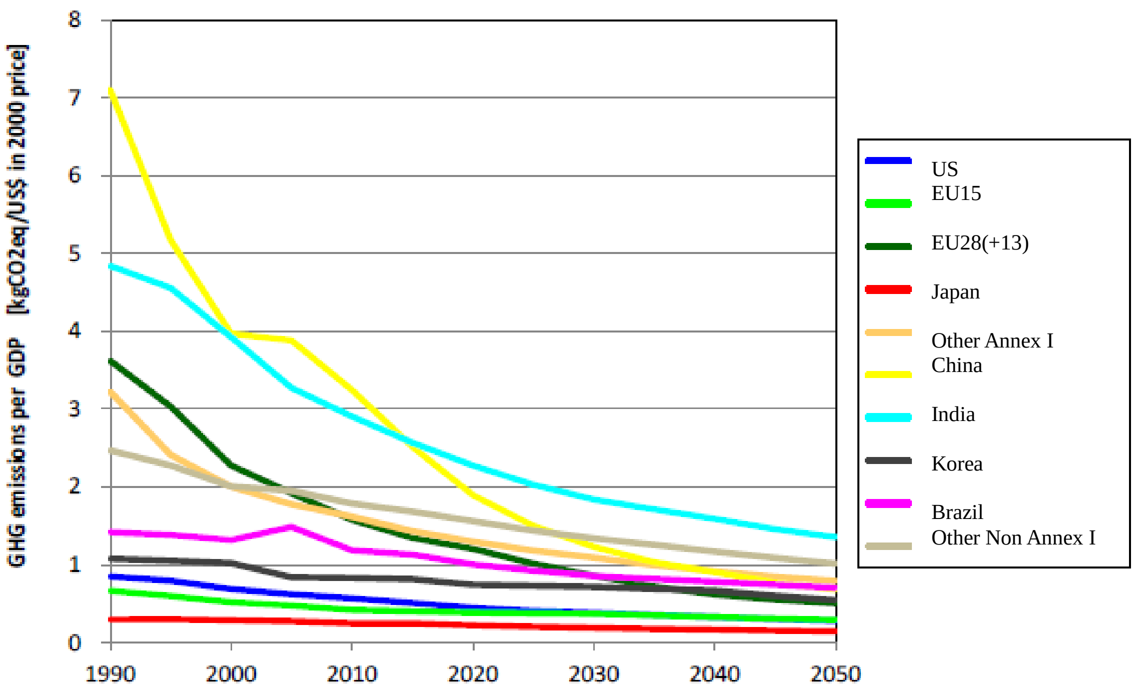

Figure 6 GHG emissions pathways per GDP by major country or region (UNFCCC[7]) for Annex I, IEA statistics[6]) for Non Annex I up to 2010)

Note) CO2 emissions from international aviation and marine and LULUCF are not included.

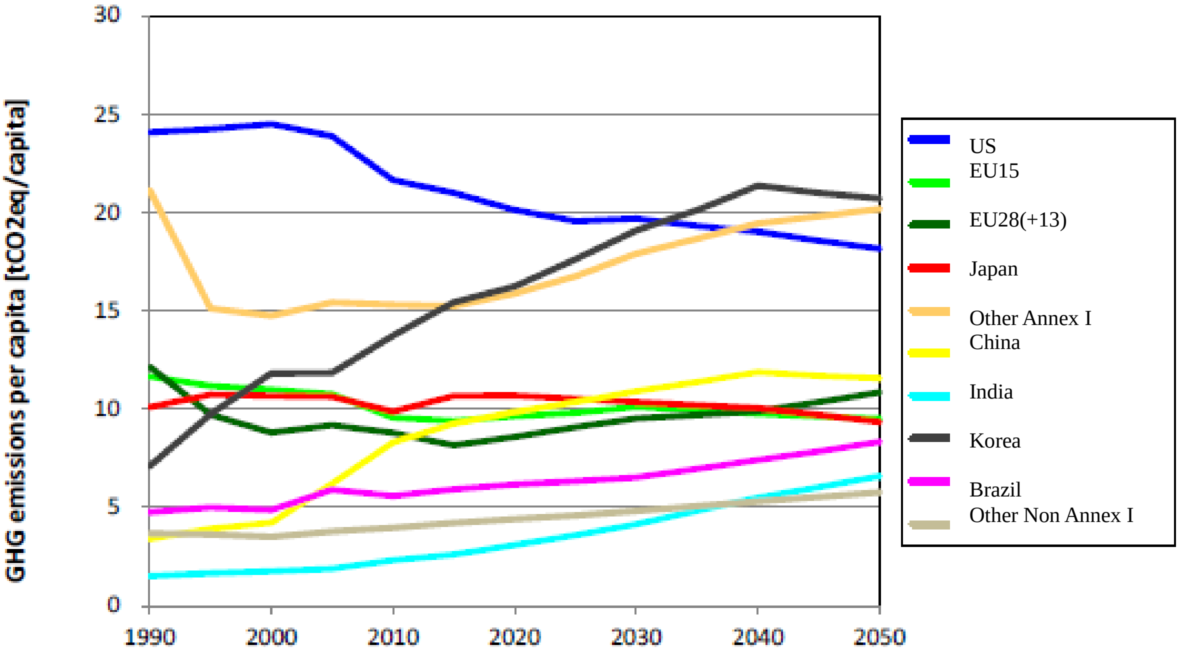

Figure 7 GHG emissions pathways per capita by major country or region (UNFCCC[7)] for Annex-I, IEA statistics[6)] for Non Annex-I up to 2010)

Note) CO2 emissions from international aviation and marine and LULUCF are not included.

■ Pathways of Japan's energy-related CO2 and GHG emissions

Figure 8 shows Japan's primary energy supply pathways (CO2 emissions pathways under the current policy and mitigation to be continued (footnote 1)). For the current situation as of November 10, 2014 the government has stopped nuclear power generation. The government is assumed to restart nuclear plants sequentially and all of the nuclear power plants to meet the '40 standard (154 billion kWh/yr) in 2030. Thereafter up to 2050 it is assumed that nuclear power plants continue to generate the same amount electricity as in 2030. It should be noted that the current policy pathways of IEA WEO2013[3)] show 174 billion kWh/yr power generation of nuclear power in 2030, which is the higher level than RITE estimates. In this case, GHG emissions are expected to peak in 2015 and decline (Figure 9). The Figure shows 2% GHG emission reductions in 2020, 10% GHG reductions in 2030 and 30% reductions in 2050 compared to 2005. The current policy pathways of IEA WEO2013[3)] show 1078 million tons of energy-related CO2 emissions in 2030, while RITE estimates 1038 million ton emissions. There can be seen no big differences between the two.

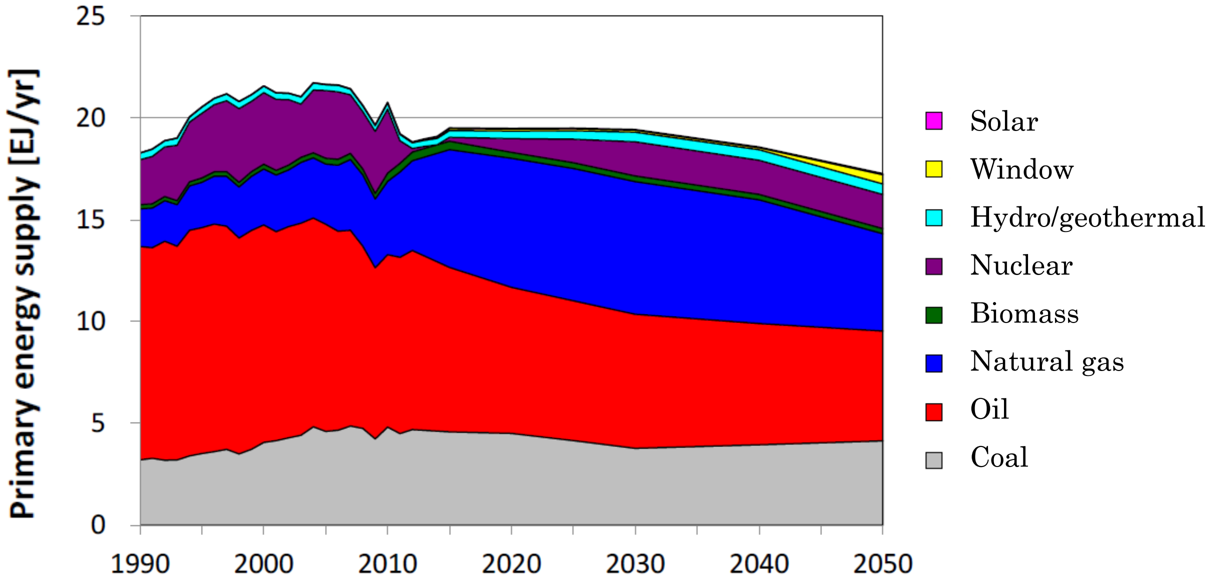

Figure 8 Japan's primary energy supply pathways (IEA statistics[4]) up to 2012)

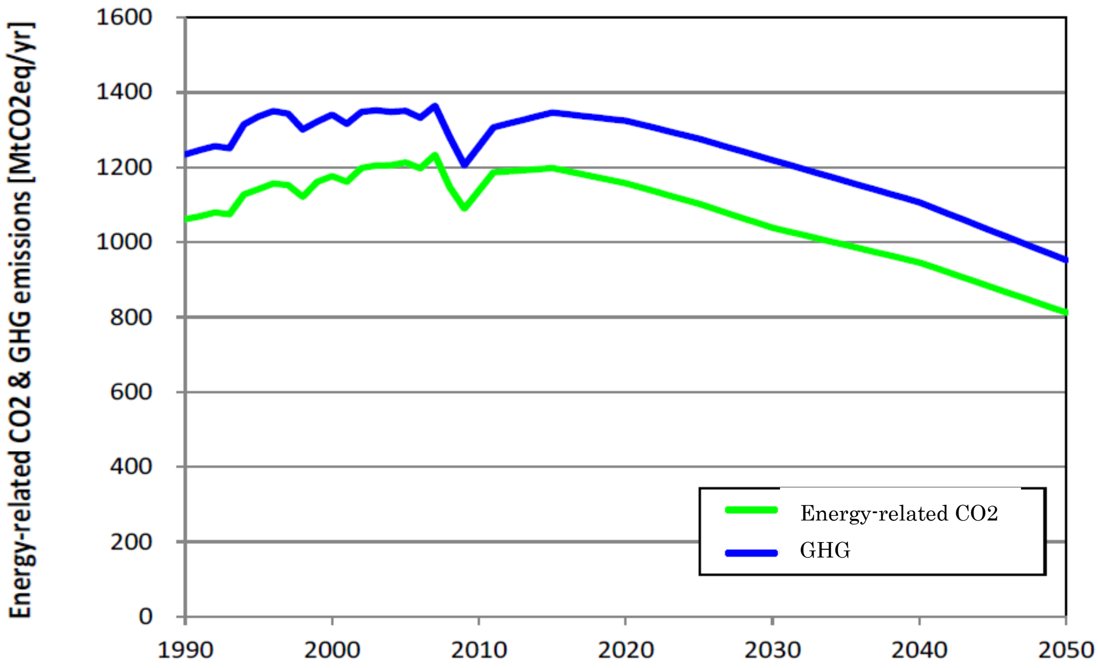

Figure 9 Japan's energy-related CO2 and GHG emissions pathways
(IEA statistics[6]) for energy-related CO2 up to 2011 and UNFCCC[7]) for GHG up to 2011)

■ Methodology and key assumptions to estimate the global CO2 emissions pathways

The world's energy-related CO2 emissions pathways are estimated using the assessment model for global warming, DNE21+[1)] developed by RITE. In this model, the world is divided into small regions and many mitigation technologies are bottom-upped. Energy use and CO_2 emissions that are consistent with economic and production activities are evaluated over the time period up to 2050 with this model.

To estimate CO2 emissions pathways, UN, World Population Prospects: The 2012 Revision[8)] is utilized for statistics and UN, World Population Prospects: The 2008 Revision (medium variant)[9)] for assumption of the future population trajectory. (Figure 10 shows the world population will reach 9.1 billion in 2050.) As to the GDP trajectory assumption, we estimated the trajectory based on the most recent economic situation, including the world economic crisis after the Lehman Shock. (Figure 11 and 12. The world average of real GDP growth rate from 2010 to 2020 is 3.1% per annum, from 2020 to 2050, 2.4%. The Japanese average of real GDP from 2010 to 2020 is 1.7%, from 2020 to 2030 0.8%, and from 2030 to 2050 0.1%.) The IEA statistics are used for historical energy-related CO_2 emissions. The pathway is assumed the current policies to be continued up to 2050 and drastic reduction in CO_2 emissions can be achieved in the future with the world efforts to cut emissions.

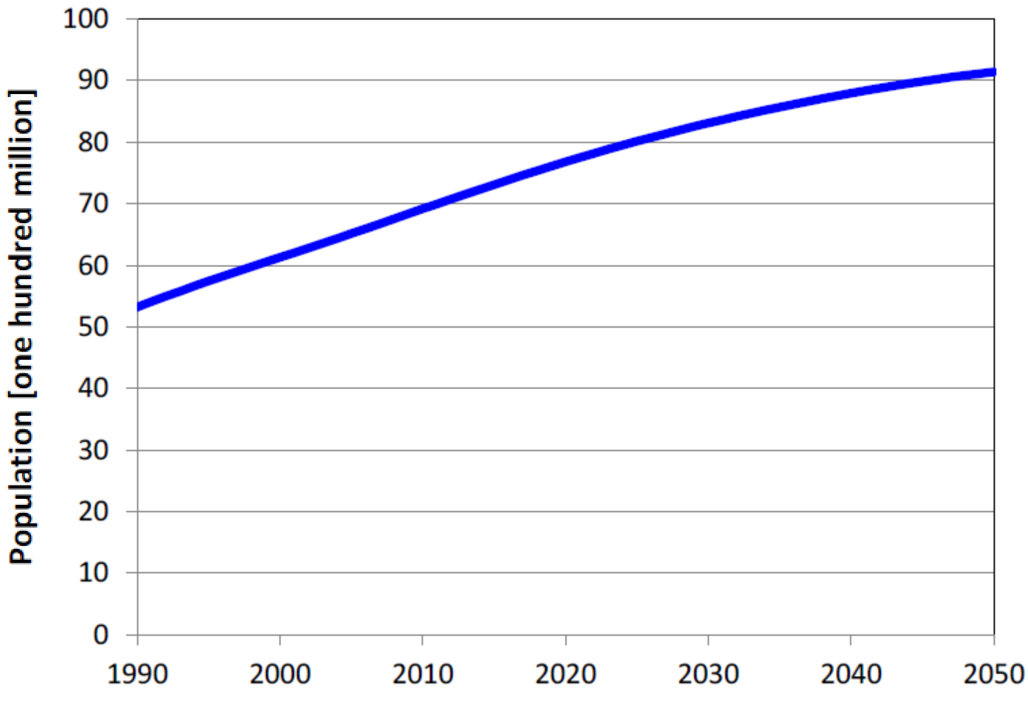

Figure 10 World population projections

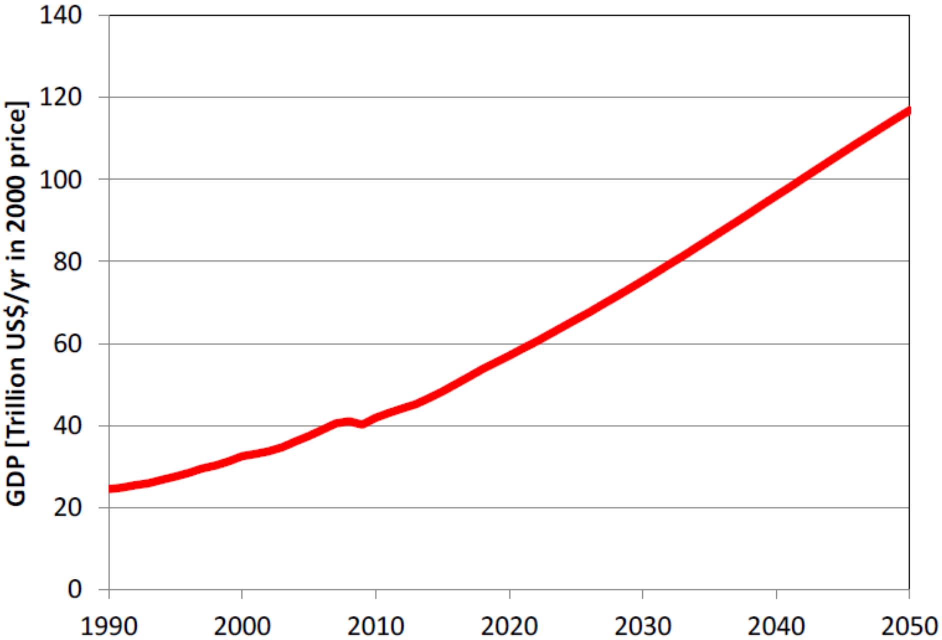

Figure 11 World GDP projections (Market exchange rates (MER) conversion)

Note) Shown in the 2000 real price (2000 exchange rate)

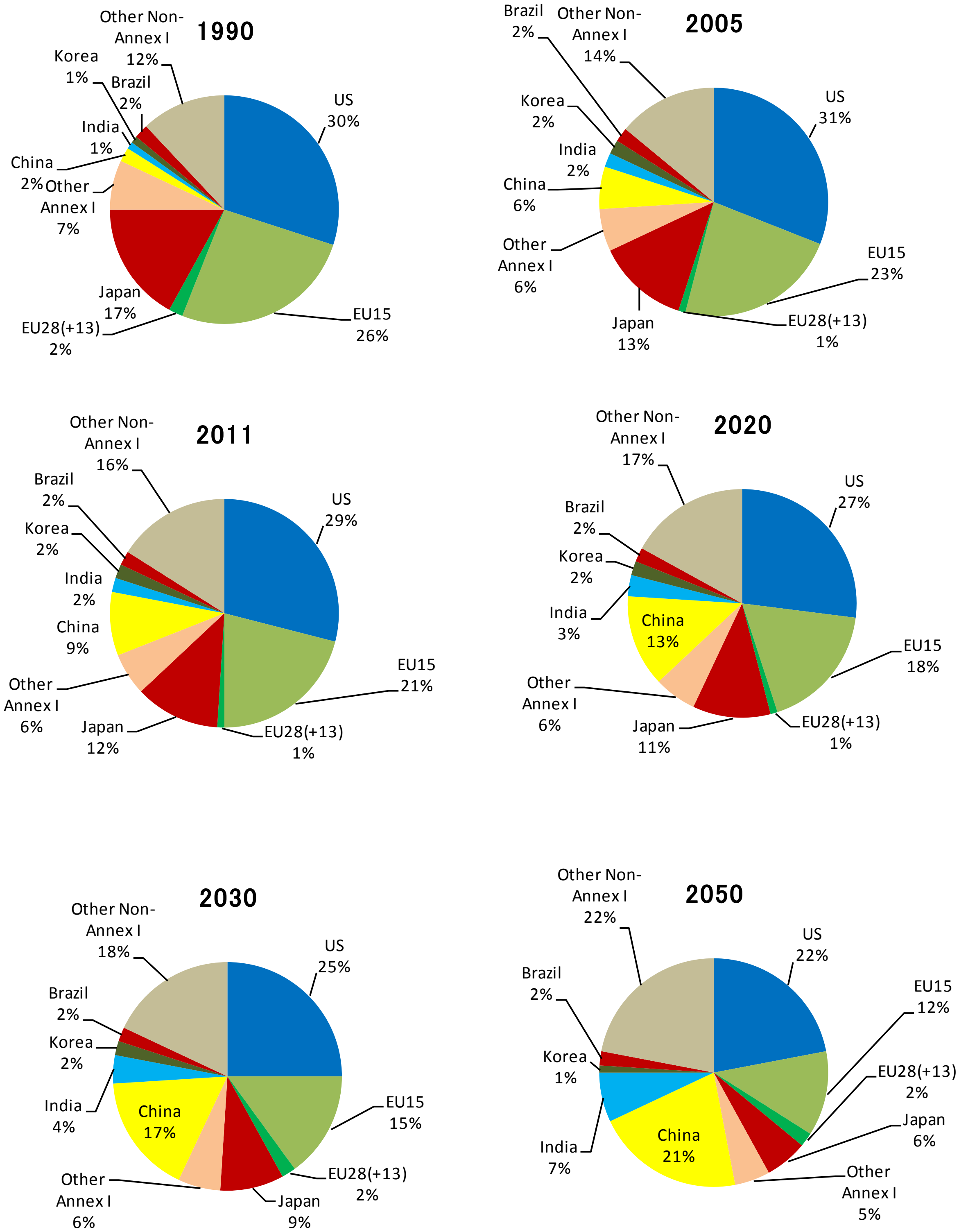

Figure 12 Regional share of GDP (Market exchange rates (MER) conversion)

■ Reference to this paper

If this pathway of CO_2 emissions is to be cited in any work, please notice us at the address below in advance.

■ Pathway update

Let us note that this paper may be occasionally updated without notice so that the latest information on historical emissions, economic trends and energy prices can be reflected in the pathway.

■ Reference

1) RITE, 2009; 'RITE GHG Mitigation Assessment Model' (http://www.rite.or.jp/Japanese/labo/sysken/about-global-warming/download-data/RITE_GHGMitigationAssessmentModel_20090529.pdf)
2) IAEA, 2013; Energy, Electricity and Nuclear Power Estimates for the Period up to 2050 (2013 Edition), IAEA.
3) IEA, 2013; World Energy Outlook 2013, OECD/IEA.
4) IEA, 2014; Energy Balances of OECD Countries, OECD/IEA.
5) IEA, 2014; Energy Balances of Non-OECD Countries, OECD/IEA.
6) IEA, 2013; CO2 emissions from fuel combustion, OECD/IEA.
7) UNFCCC, GHG data from UNFCCC, http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php (access on October 3, 2014)
8) UN, 2012; World Population Prospects: The 2012 Revision
9) UN, 2008; World Population Prospects: The 2008 Revision

Contact to:

Kohko Tokushige, Fuminori Sano, Keigo Akimoto
Systems Analysis Group
Research Institute of Innovative Technology for the Earth (RITE)
9-2 Kizugawadai, Kizugawa-shi Kyoto 619-0292 JAPAN
PHONE: +81-774-75-2304 FAX: +81-774-75-2317 E-mail: sysinfo@rite.or.jp

Appendix 1 Outline of GHG mitigation model of RITE

The model consists of 3 modules: Key Assessment Model DNE21+, for energy-related CO_2; Non-energy CO_2 emission scenario, that assumes specific non-energy CO_2 emissions independent of mitigation levels of energy-related CO_2 emissions; 3 Non-CO_2 GHG Assessment Model, for mitigation of the 5 kinds of greenhouse gas emissions (Figure A-1).

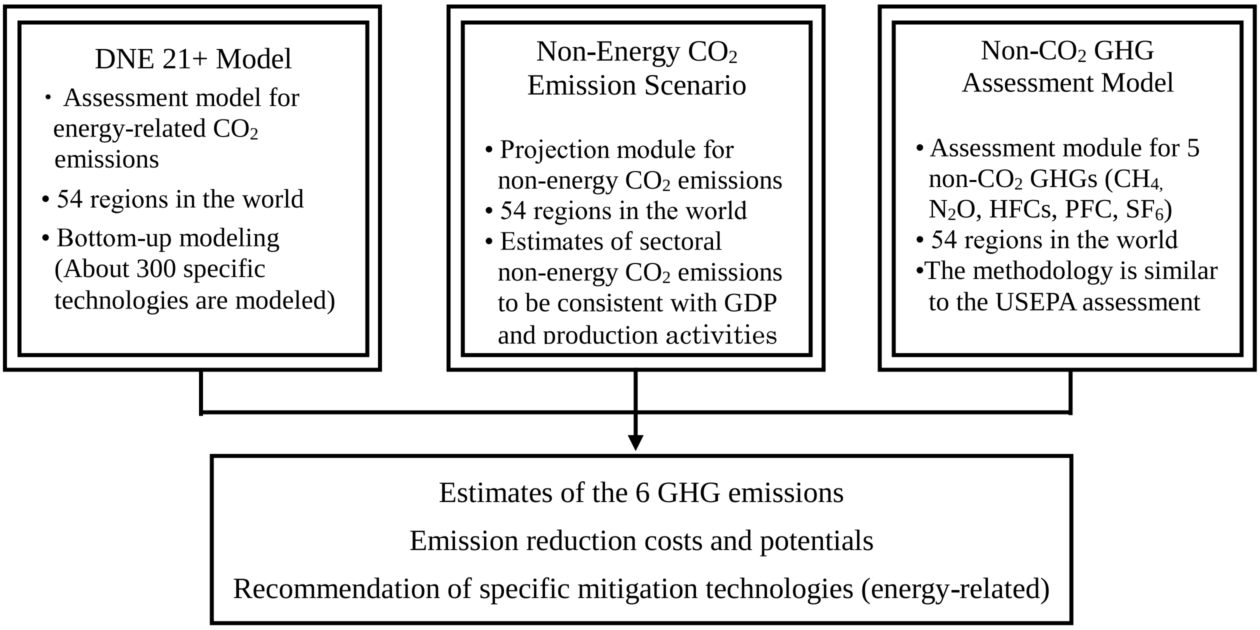

Figure A-1 Outline of GHG mitigation model

DNE21+ model is an optimization type liner programming model, minimizing the total worldwide energy system costs over all the assessment period (up to 2050). Figure A-2 shows outline of energy flows in DNE21+ model. The energy supply sectors are connected to the energy end-use sectors, energy export/import are considered, and the lifetimes of facilities are taken into account, so that assessments are made while maintaining complete consistency across the energy supply & demand sides. Based on the population and GDP scenarios developed by RITE, service demand scenarios (e.g., the production amount of crude steel in Iron & Steel sector, the traffic amount in the transportation sector) are bottom-upped for major energy-consuming sectors (energy-intensive industrial sectors, road transportation sectors and some equipments in residential & commercial sectors), and other remaining sectors are top-downed and their energy demands are exogenously assumed. The model solves the best mix of technologies to meet these demand scenarios. Here, costs and energy efficiencies of individual technologies used in both the energy supply sectors and the end-use sectors are explicitly modeled. So, detail evaluation of technologies is conducted and this is one of the salient features of our model. As another feature of the model, the fine regional segregation (the world is divided into 54 regions in country level.) is noted because it enables to analyze with regional differences in consideration (e.g., potentials of renewable energy).

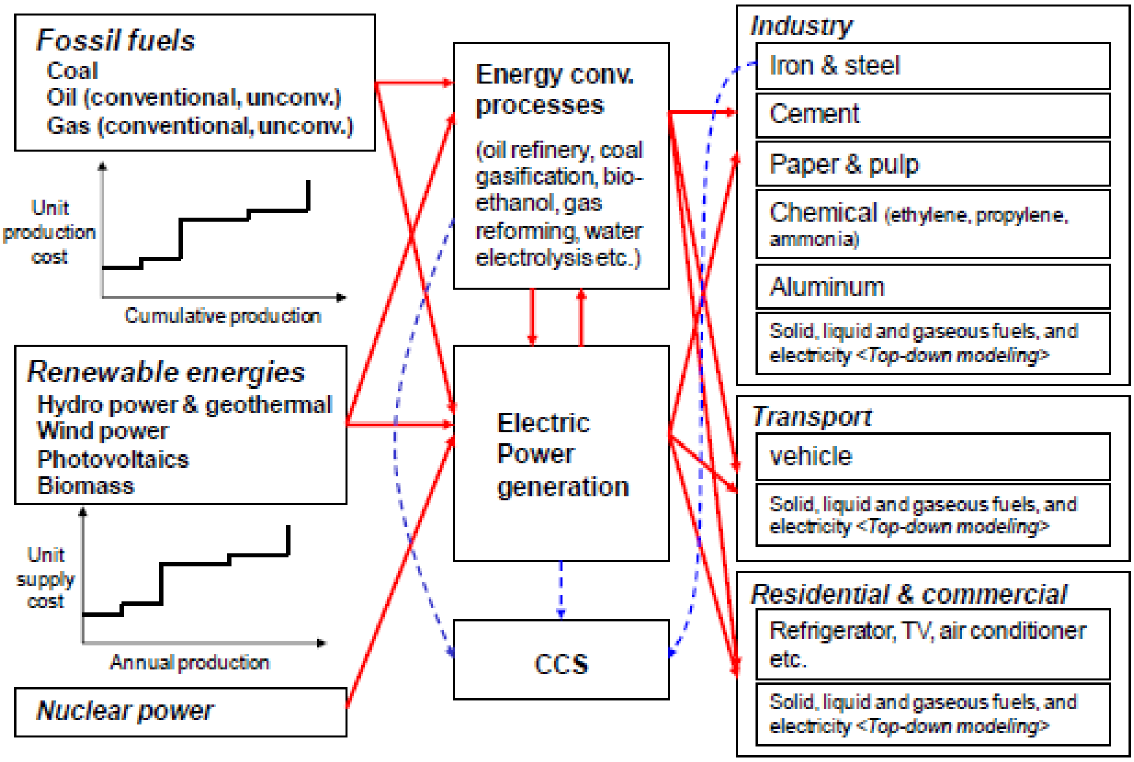

Figure A-2 Outline of energy flows in DNE21+ model

For non-energy CO2 emission, one specific scenario is developed based on historical data of UNFCCC and IEA and the cement production scenario which is used in DNE21+ model.

The Non-CO2 GHG model has been developed based on the studies by US EPA with some adjustments by latest historical data. The regional baseline emissions (emissions without GHG mitigation policy) were estimated for five gases: CH4 in seven sectors, N2O in six sectors, HFCs in one sector, PFC in one sector and SF6 in one sector. The emission reduction is calculated by using elasticity representing the relationship between non-CO2 GHG mitigation ratio relative to the baseline emissions and marginal abatement costs based on the database for emission reduction amounts and reduction costs of individual measures in non-CO2 GHG mitigation. So, the model is not a direct bottom-up model; however, marginal costs and potentials of non-CO2 GHG mitigation are eventually based on the bottom-up analysis of the US EPA.

This is the model outline. More information is available in reference[1].

Appendix 2 The pathways of energy-related CO2 and GHG emissions in the baseline scenario

Figure A-3 shows the pathways of global energy-related CO2 emissions without mitigation policy (the baseline scenario) and with continuous current mitigation policy in this paper (the current policies and mitigation). In the continuous current mitigation policy scenario, CO2 emissions are estimated 37.8 billion tons in 2020 and 56.3 billion tons in 2050, while in the baseline scenario, emissions are estimated 40.1 billion tons in 2020 and 62.5 billion tons in 2050 (38.8 billion and 60.5 billion tons excluding aviation and international shipping, respectively), which has been revised upward from the baseline scenario in the August 2011 edition. Figure A-4 shows the CO2 emissions in the baseline scenarios organized by IPCC AR5. The median value in 2050 under the standard assumptions of the model (Default) is estimated about 60 billion tons, which two of our scenarios are close to.

Figure A-5 shows the pathways of global GHG emissions without mitigation policy (the baseline scenario) and with continuous current mitigation policy in this paper (the current policies and mitigation), as Figure A-3. In the future baseline scenario, emissions are estimated 56.2 billion tons in 2020 and 82.6 billion tons in 2050. Appendix Figure A-6 shows GHG emissions in the baseline scenario organized by the IPCC AR5. The median value in 2050 is estimated about 80 billion tons, which are close to RITE estimates as energy-related CO2.

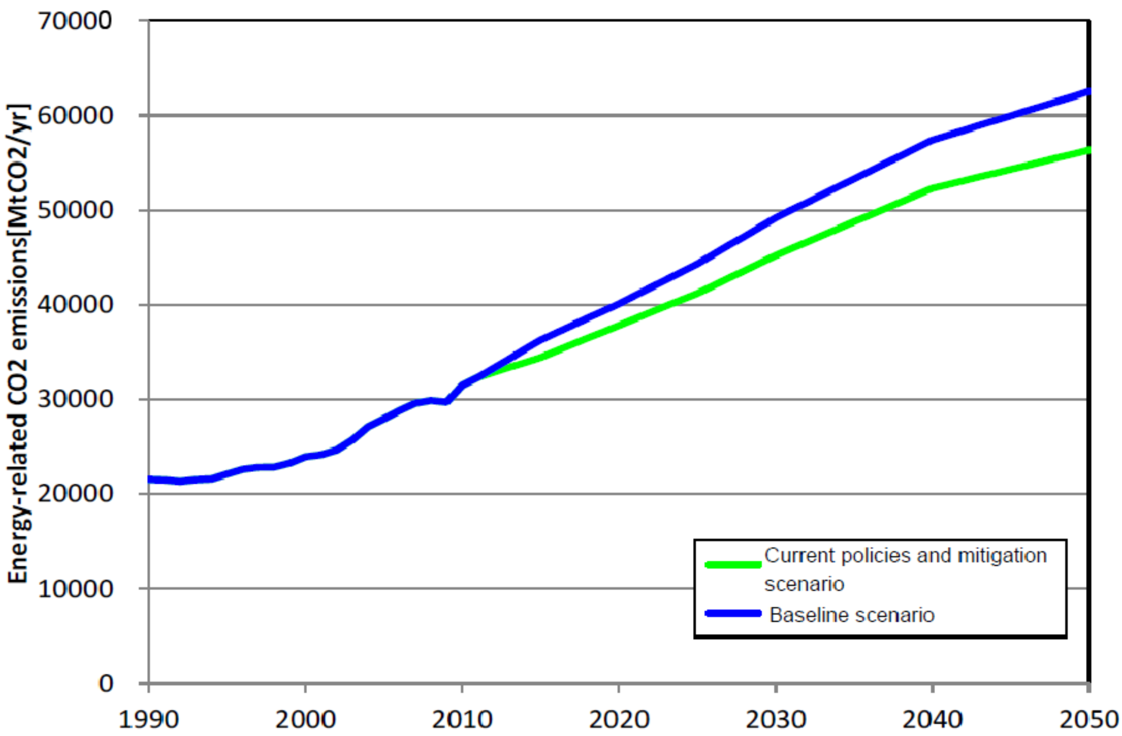

Figure A-3 Energy-related global CO2 emissions in the baseline and the current policies and mitigation (IEA statistics[6]) up to 2011)

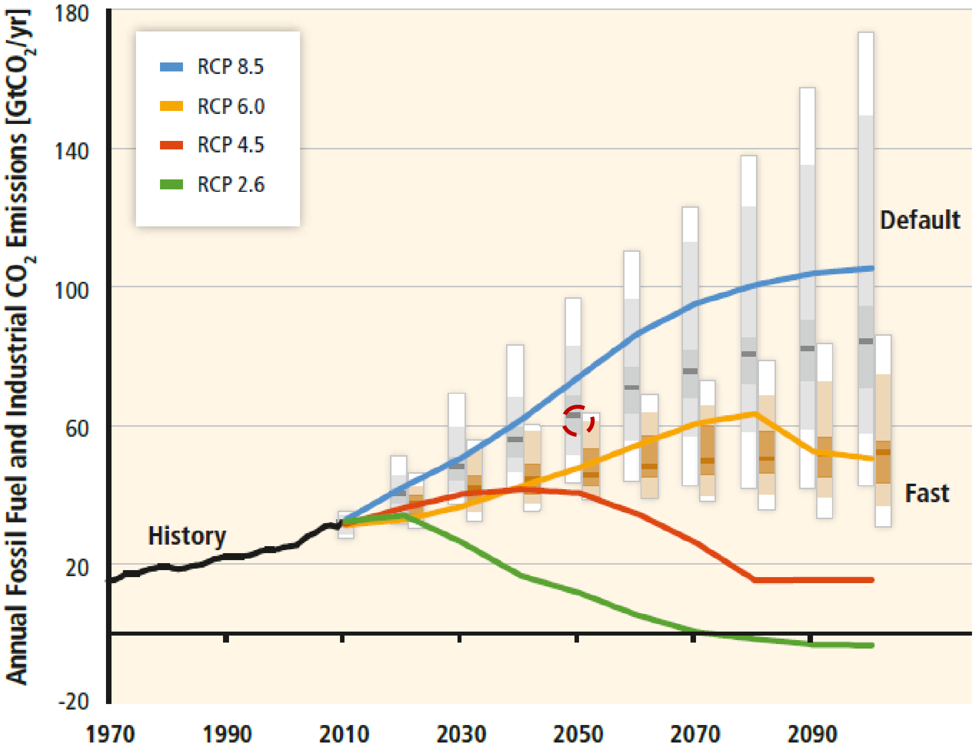

Figure A-4 CO2 emissions in baseline scenarios organized by IPCC AR5 WGIII
Note) Default (grey range) shows the standard assumptions of models used for projections.
Fast (gold range) shows the substantial improvement of energy intensity. The red circle shows RITE estimate.

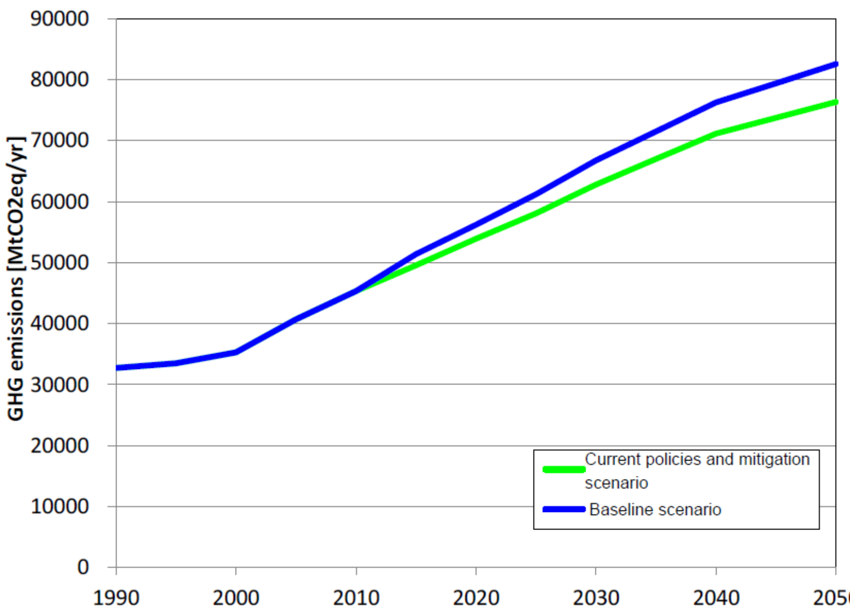

Figure A-5 Global GHG emissions in the baseline and the continuous current mitigation policy scenarios (Annex-I: UNFCCC[7)], Non Annex-I: IEA statistics[6)] up to 2010)

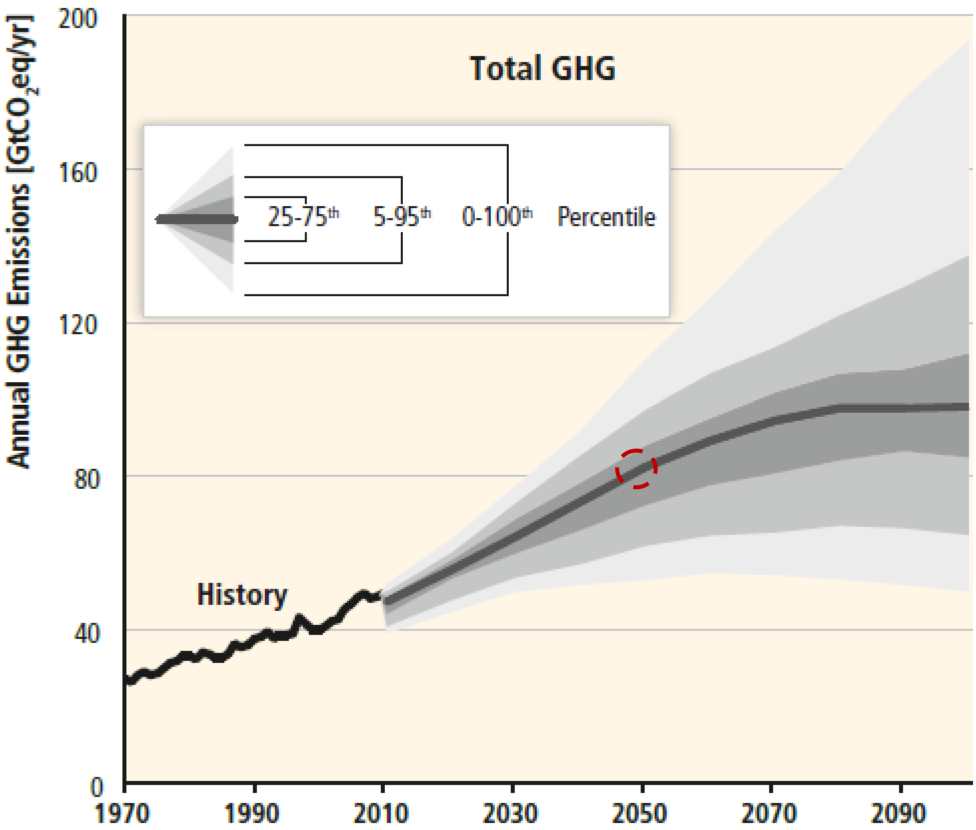

Figure A-6 GHG emissions pathways by IPCC AR5 WGIII

Note) The red circle shows RITE estimate.

Figure A-7 shows the trajectories of energy consumption per GDP (energy intensity) and CO2 emissions per energy consumption (CO2 intensity) whose values are normalized to 1 in the year 2010. Energy intensity is projected to improve in the future though the current situation has been stagnant due to the rapid development of China from 2000 up to now. In addition, as to CO2 intensity major changes cannot be seen as energy intensity because increase of fossil fuel consumption is larger than that of nuclear power and renewable energy, as shown in this paper so that in the future up to 2050 CO2 intensity is estimated rather worse than in 2010. These levels are consistent with the median estimates organized by IPCC (Fig.8).

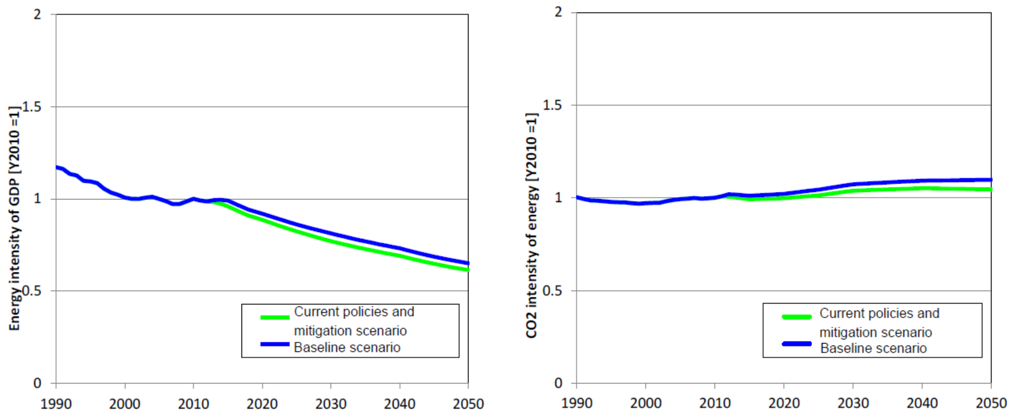

Figure A-7 Trajectories of the global energy intensity of GDP and CO2 intensity of energy in a continuous mitigation policy scenarios and baseline scenarios (IEA statistics[4), 5), 6)] up to 2011)

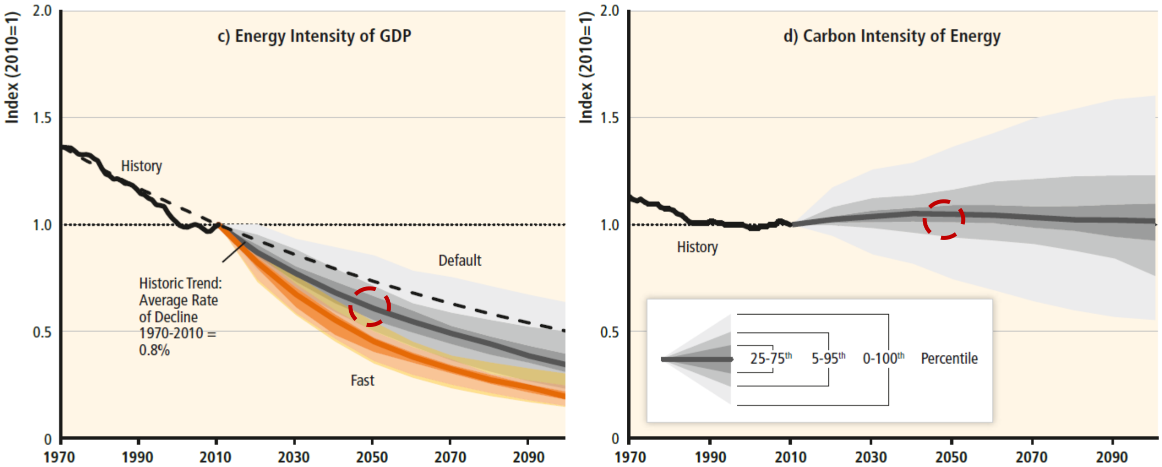

Figure A-8 Trajectories of the global energy intensity of GDP and CO2 intensity of energy organized by IPCC AR5 WGIII

Note) Default (grey range) shows the standard assumptions of models used for projections.
Fast (gold range) shows the substantial improvement of energy intensity. The red circle shows RITE estimate.