Priority Subjects — **Establishment of Optimal Risk Management**

Scientifically and Economically Rational Scenarios for Reducing CO_2 Emissions

Background and Objective

Although we do not have a clear outlook for the national energy policy, reduction of CO_2 emissions is a major international issue, as it was before the Great East Japan Earthquake. New scientific findings related toglobal warming, which form the basis of emissions reduction (including inevitable uncertainties) should be considered in a rational plan of emissions reduction. Based on the latest technology trends and their potential risks, we need to select an appropriate direction for development of low-carbon technology which can lead to emissions reduction.

This study synthesizes our knowledge of climate science and low-carbon technologies to forecast a long-term target of CO_2 emissions reduction while considering technology availability and economic feasibility. The study thus aims to contribute to the establishment of a long-term national energy policy. We also conduct a preliminary assessment of various risks regarding carbon capture and storage (CCS) to discuss the future adoption of CCS technology.

Main results

1 Implications of new findings from climate science for the long-term target

Regarding the Working Group I (climate science) contribution to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), published in September 2013, we have clarified and examined key issues from the perspective of long-term targets. This report shows, for the first time, an approximately linear relationship between the globally averaged temperature increase and cumulative CO_2 emissions since pre-industrial times, which has been confirmed in our climate model (Fig. 1). However, the proportional constant for the relationship between temperature increase and cumulative CO_2 emissions strongly depends on climate models, which means that the relationship between the climate stabilization target (the upper limit of the temperature increase) and cumulative CO_2 emissions is inconclusive.

2 Analysis of long-term CO_2 emissions targets using an integrated assessment model

Our integrated assessment model (named BET), referenced by the Working Group III (mitigation) contribution to the IPCC AR5, is a tool for evaluating economically optimal emission pathways while considering the cumulative CO_2 emissions targets under energy resource constraints and global scenarios of population and economy. Using this model, key mitigation characteristics for cumulative emissions that are compatible with the 2°C target* have been analyzed. The model results show that the target requires promotion of electrification and global deployment of technologies for biomass use combined with CCS, and that the emission pathways in 2050 are strongly affected by biomass resource constraints (Figures 2 and 3). Thus, the long-term CO_2 emissions reduction target should be continuously assessed with sufficient flexibility along with the development of low-carbon technologies as well as findings from climate science.

3 Comparison of potential risks to the environment and human health induced by low-carbon technologies

The introduction of CCS in coal-fired power plants in Japan will continue to be discussed in the future, therefore the role of CCS in low-carbon technologies should be clarified. Considering this, we have developed a life cycle assessment method for power generation technologies in terms of the risks they pose to the environment and human health, and conducted an assessment of coal-fired plants with CCS, photovoltaic, and geothermal power generation (Fig. 4). The results show different characteristics for each technology: for example, the introduction of CCS leads to an increase in the environmental load relative to conventional coal-fired power generation, for all the impact categories except global warming. Considering the wide range of risks to the environment and human health, the introduction of low-carbon technologies should be examined more carefully.

* This is the target that limits the global average temperature increase to 2°C relative to pre-industrial levels. It was documented in the agreements (Cancun Agreements in 2010) in the Conference of Parties to the United Nations Framework Convention on Climate Change. 2°C is considered as an aspiration goal rather than an obligation.

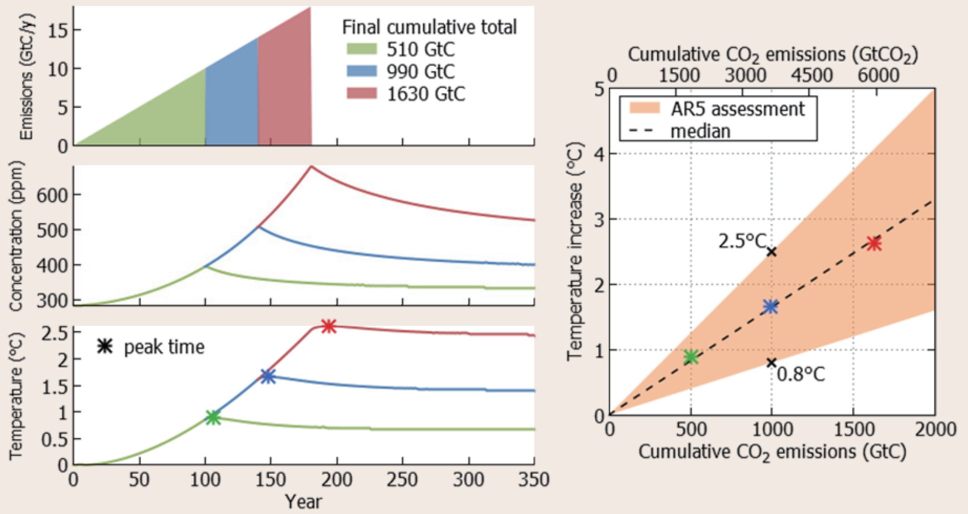

Fig.1: Relationship between the cumulative global CO_2 emissions and global average temperature increase

Results from the computation of the CO_2 concentration and temperature increase for increased emissions when the annual emissions increase by 0.1 GtC consecutively for 100, 140, and 180 years, followed by zero emissions. The IPCC Fifth Assessment Report (AR5) assesses 0.8 to 2.5°C for the temperature increase per 1000 GtC with 66% probability (color-shaded region in the right panel). The dotted line in the right panel indicates the upper limit of the emissions for achieving a given temperature target with 50% probability. Emissions in $GtCO_2$ are 3.67 times higher than in GtC (the amount of carbon alone).

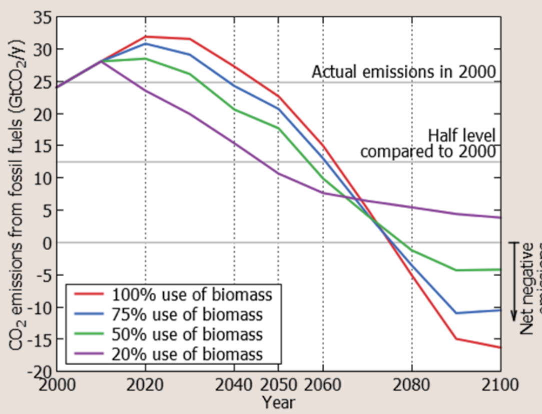

Fig. 2: CO_2 emissions pathways from fossil fuels compatible with the 2°C target

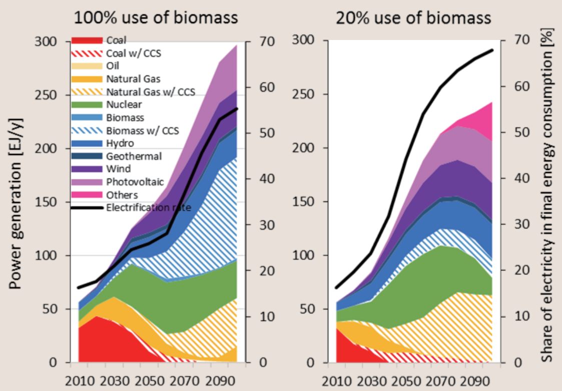

Fig. 3: Transition of the global power generation mix (left axis) and electrification rates (right axis) compatible with the 2°C target (EJ=10^{18}J)

Fig. 2 shows the CO_2 emissions pathway scenarios that enable us to achieve the 2°C target computed with four different constraints for available biomass resources. As shown in Fig. 3, an increase in electrification rates is necessary in all scenarios. In addition, net negative emissions in the future require not only innovative technologies, such as heat pumps, electric vehicles, and hybrid freight vehicles, but also CO_2 removal technologies, such as biomass use combined with CCS.

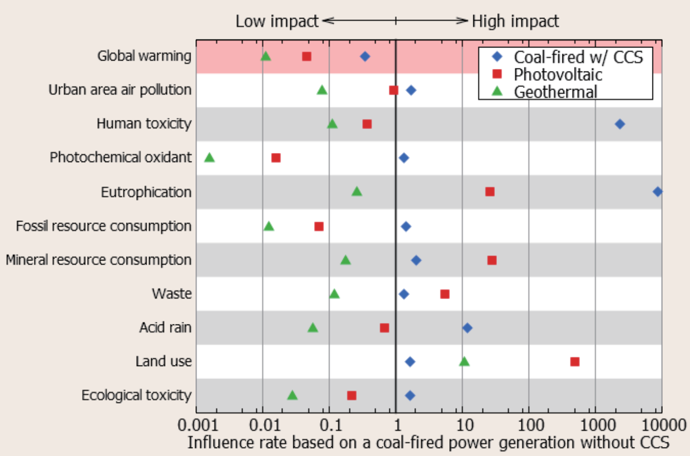

Fig. 4: Comparison of categorized environmental and health impacts throughout the life cycle of low-carbon power generation plants

The assessment results show the environmental impacts for each technology relative to conventional coal-fired power generation. The introduction of CCS in coal-fired plants increases the environmental impact in all the categories except global warming. The impact of photovoltaic power generation is noticeable in the category of mineral resource consumption among others, which is caused by manufacturing of solar panels. The impact of geothermal power generation is relatively low except in the category of land use.