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

Scientifically and Economically Rational Scenarios for Reducing CO_2 Emissions

Background and Objective

While we do not have a clear outlook for the national energy policy, reduction of CO_2 emissions is a major international issue of some urgency. Although scientific findings on global warming, which form the basis of emissions reduction, include inevitable uncertainties, they should be appropriately updated in a rational plan of emissions reduction. Regarding low-carbon technologies, which can lead to emissions reduction, we need to select an appropriate direction for their development based on the latest technology trends and associated potential risks.

This study investigated in detail the limitations of global CO_2 emissions from a scientific viewpoint and provides a reasonable prospect of low-carbon transformation based on technology availability, and thus aims to contribute to the establishment of a long-term national energy policy. We also conducted an assessment of various risks regarding carbon dioxide capture and storage (CCS) to discuss the future adoption of CCS technology.

Main results

1 Explication of the latest findings of the Intergovernmental Panel on Climate Change (IPCC)

The IPCC Fifth Assessment Report (AR5) published in 2013–14 has updated the relationship between the risk level of climate change and the global temperature increase, which forms the basis of the long-term goal of emissions reduction of CO_2 and other gases. Generally speaking, the updated risk level is assessed with greater confidence and is higher than that of the Fourth Assessment Report released in 2007. We have investigated in detail this information and found that the AR5 updates are connected with its wider scope of risks and associated socio-economic factors in addition to new climate observations and projections (Fig. 1) (V14012). The dependency of the risk level on socio-economic factors implies that the restriction of CO_2 and other gases emissions could vary with the direction of global socio-economic development.

2 Improvements in our energy-economy-climate integrated assessment model

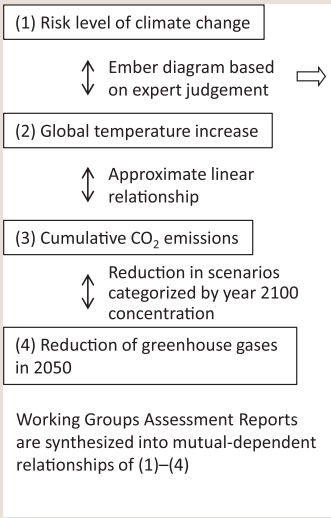
Arising from difficulty of substantial emissions reduction in the near future, long-term scenarios of reduction of CO_2 and other gases assessed in AR5 seriously consider technologies to realize negative emissions (net absorption) in the far future on a century time scale, such as power generation by biomass energy with CCS. To make a detailed investigation of future technology potential in tandem with the uncertainties of climate projection, we have improved our existing integrated assessment model and simple climate model*1. The improved integrated assessment model includes updated parameters, such as efficiencies and unit prices of power generation facilities, new energy pathways to deal with hydrogen and other innovative technologies, and an interface to be coupled with our existing biomass model (Fig. 2). The simple climate model has been improved to deal with the uncertainties of climate sensitivity*2 (Fig. 3). These models will be used for studies on feasible long-term (year 2050) goals to contribute to the establishment of a long-term national energy plan.

3 Elucidation of CCS technology and associated policy developments

We have surveyed recent CCS projects around the world. Regarding coal-fired power plants with CCS, although the Boundary Dam project in Canada has started operation in commercial use with financial support from the government under its CO_2 emissions regulation (implemented July, 2015), progress on a global scale is not observed (Table 1). Because CCS business entails uncertainty in regards to profitability, political or financial support from governments and mechanisms of cost compensation by selling captured CO_2 are essential for making CCS commercially viable. Meanwhile in our national circumstances, we have found that the public's awareness on current electricity generation mix and low carbon technologies such as CCS is low, and that there are various public opinions about the development of thermal and nuclear power generation. These findings imply the need for a broad social understanding about the domestic energy situation and the significance of climate change countermeasures in the discussion of CCS introduction.

*1 Model improvements were supported in part by the Program for Risk Information on Climate Change from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

*2 A physical parameter to quantify the temperature change by heating or cooling effects of various climate change factors. It is commonly defined as an increase in the global mean temperature due to doubling of the atmospheric CO_2 concentration. The temperature increase following doubled CO_2 concentration in the equilibrium state is different from that in a transient state, and two parameters termed equilibrium climate sensitivity and transient climate response are defined, respectively.



Item	Description
Ember diagram	Five bars representing RFCs (the next item) with the scale of the temperature increase colored by gradation of white, yellow, red, and violet in order corresponding to four risk levels, provided to facilitate judgment about "dangerous anthropogenic interference" of the United Nations Framework Convention on Climate Change.
RFC (Reasons For Concern)	Five elements of climate change risks categorized from a cross-cutting perspective over different sectors and regions. RFC1: unique and threatened systems (sea ice, coral reef, etc.), RFC2: extreme weather events (heat wave, heavy rain, etc.), RFC3: the distribution of impacts (food and water security, etc.), RFC4: global aggregate impacts (economic loss, etc.), RFC5: large-scale singular events (melting ice sheet, etc.).
Climate change risks	Considered as results from the interaction of physical hazards and socio-economic factors. Risk levels are evaluated based on findings from the detection and attribution of associated impact considering the degree of confidence as well as documented criteria for key risks.
AR5 assessment	The risk levels assessed in AR5 are increased from those in the previous report as a whole except for RFC4. This update is connected with its wider scope of risks and associated socio-economic factors in addition to new climate observations and projections.

Fig. 1: Main points of AR5 (left) and assessment of climate change risks (right)

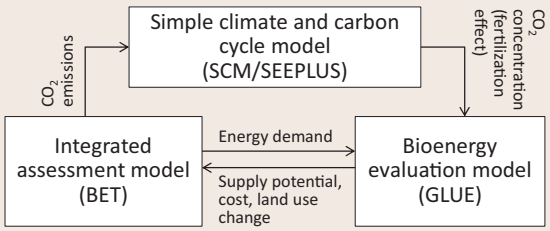


Fig. 2: Models for studies on CO_2 emissions reduction goals

Model names are shown in parentheses. SCM is a model to calculate the global mean temperature and CO_2 exchange between the atmosphere, ocean, and land, and SEEPLUS is a web-application to deal with SCM. BET is an integrated assessment model representing mutual dependency between energy, economy, and climate. GLUE is a model to calculate energy flow associated with biomass.

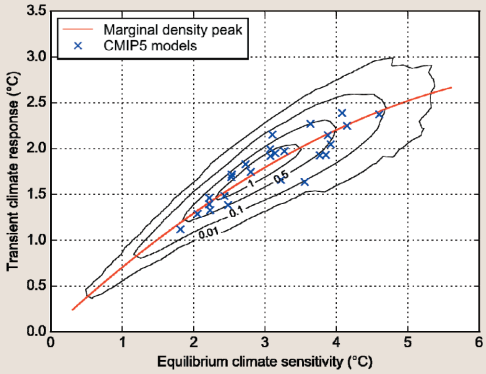


Fig. 3: Probability density of equilibrium climate sensitivity and transient climate response

This study considers the variation of multiple complex climate models (termed CMIP5 models, Fig. 3) assessed in AR5 and formulates uncertainties about climate response represented by the both sensitivity parameters. This formulation has been incorporated into SCM (Fig. 2), which enables evaluation of the temperature calculation in light of the uncertainty range of the CMIP5 models as well as AR5 assessment for climate sensitivity.

Table 1: Worldwide CCS projects suspended or delayed (2012–2013)

Project name	Country	Project phase	Reasons
< Cancelled project >			
PurGen One	USA	Just before final investment decision	Investment decision
Bełchatów	Poland		lack of finance
Taylorville Energy Center	USA		Changing economics and the lack of legislation
Tenaska Trailblazer Energy Center			
Cash Creek		Feasibility study	Changing of the plan to build a natural gas combined cycle facility
< On hold project >			
Swan Hill Synfuels	Canada	Just before final investment decision	Dependent on natural gas prices
Hydrogen Power Abu Dhabi	UAE		Prioritizing investment in other projects
Green Hydrogen	The Netherlands	Just before final investment decision	Submission not supported in the NER300's first round*
Eemshaven CCS			
Pegasus Rotterdam			
Southland Coal and Fertiliser	New Zealand		Prioritizing investment in other projects
Bulgaria	Bulgaria	Front-end engineering design study	Unspecified

*NER300 is one of the world's largest funding programmes for innovative low-carbon energy demonstration projects. It is conceived as a catalyst for the demonstration of environmentally-safe CCS and innovative renewable energy technologies on a commercial scale within the EU. It is funded from the sale of 300 million emission allowances from the New Entrants' Reserve set up for the third phase of the EU emissions trading system (EU ETS).