System Analysis Group

Analysis of International Emissions Reduction Regimes beyond the Kyoto Protocol

Even though the Kyoto Protocol is an historical first step toward the reduction of GHG emissions, its effectiveness is doubtful for the following reasons: no obligations on developing countries whose emissions are anticipated to rapidly and drastically increase; the withdrawal of the US, currently the world's largest emitter; and the existence of "hot air", which is a situation where a granted emission permit quota is larger than actual emissions, for Russia, Ukraine, etc. Since Japan ratified the Protocol, she must obey it and contribute to the reduction of the world's emissions. But it is also important to explore international emission reduction regimes beyond the Kyoto Protocol because some regimes might more effectively reduce world emissions and hold lower barriers for many countries to participate in. Thus, using a world energy model, we performed consistent and quantitative analyses and evaluations to provide useful data and information for such regime examination and exploration. This paper introduces our research activities and achievements.

1. Research objectives and overview

The objectives of this research are to obtain minimum cost emission reduction measures and their reduction costs/marginal reduction costs that correspond to various reduction targets for such countries of interest as Japan, the US, EU, China, India, etc. Goals also include computing and evaluating emission trades, the monetary flows accompanying the emission trades, and the evaluation of various reduction regimes using integrated indexes of reduction costs/marginal costs, per capita and per GDP emission amounts, and other indicators.

To achieve these objectives, we constructed a world energy system model, DNE21+, which has high regional resolution, and used it to obtain the minimum costs and the minimum cost reduction measures for reduction targets imposed on each country based on various views. After defining such indexes as "sovereignty," "burden," "their equities," and "capability of burden sharing," we compared and evaluated the reduction regimes using these indexes.

2. World energy model DNE21+

The DNE21+ model explores the world's minimum cost energy systems (energy flows, capacities of energy conversion facilities, etc.) for given final energy demands and given costs of conversion technologies for a reference case having no emission reduction constraints. It also explores minimum cost systems that satisfy the final energy demands that decrease depending on energy price hikes for emission constraint cases. The model's capability includes: 1) long-term analysis to the year 2050; 2) analysis of regional differences based on the world disaggregated into 77 regions; and 3) analysis of concrete technological measures of emission reduction.

3. Cost effective measures for CO_2 concentration stabilization at 550 ppm

A case study was conducted of the minimization of the world's total cost under a constraint of 550 ppm stabilization, which is an idealistic case.

(1) Analysis Outline

The DNE21+ model analyzed the cost to Japan and the world to achieve CO_2 concentration stabilization at 550 ppm and derived corresponding appropriate measures.

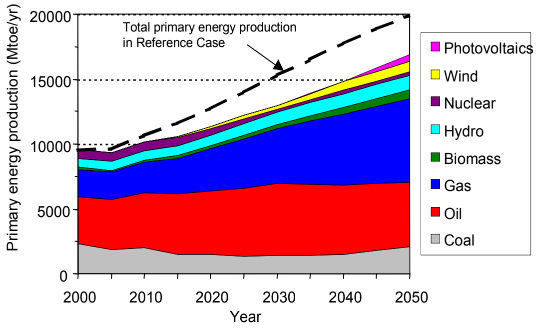
(2) Assumptions

Assumptions of future population, GDP, and final energy demands were determined based on the IPCC B2 scenario. The S550 IPCC WG1 emission scenario was adopted as an emission constraint scenario. The entire world was set to achieve targets in such a way that marginal CO_2 reduction cost is the same for all the regions, which is identical to the minimization of the world's total costs.

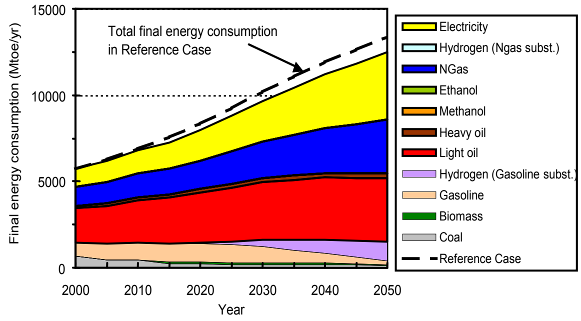
(3) Results

Figure 1 shows the optimum primary energy production and final energy consumption for the S550 achievement. Increases of wind and hydro power, photovoltaic introduction, energy savings in both primary and final energies and hydrogen usage for FCV in 2020 and thereafter were observed. The marginal cost of CO_2 emission reduction was computed to be 55 and 123 $/tC by 2020 and 2050, respectively. It was 135 $/tC by 2050 where FCV is unavailable, and

182 \$/tC where CCS technology is unavailable. This indicates that these technologies play an important role for 550 ppm stabilization.



(a) Primary energy production



(b)Final energy consumption

Fig. 1 Global primary energy production and final energy consumption for S550

4. Comparison and evaluation of various reduction regimes

(1) Outline

For each reduction regime, reduction cost, emission amount, and their per capita and per GDP values etc. are computed for each region using the model run results; the indexes introduced in (3) were quantitatively evaluated.

(2) Simulation cases

Six cases of reduction regimes were studied. In all the cases, S550 was assumed to be a constraint on the entire world.

(a) The marginal reduction cost is the same for all the regions, as treated in Section 3.

(b) Reduction targets are based on per capita emissions.

i. Per capita emissions of all the regions converge by 2050.

ii. Per capita emissions of all the regions decrease at the same rate.

(c) Reduction targets are based on per GDP emissions.

i. Per GDP emissions of all the regions converge by 2050.

ii. Per GDP emissions of all regions decrease at the same rate.

(d) Kyoto Protocol + UK proposed target

In 2003, the UK proposed the following target for Annex I countries to achieve 550 ppm stabilization: reduction of emissions by about 60% by 2050. Considering this proposal, the following emission reduction targets by region were assumed:

<2010> Except for the US, Annex I countries obey the Kyoto Protocol; the US achieves her own target of 18% reduction in GDP intensity in 10 years. An EU bubble or joint fulfillment of 15 countries is allowed.

<2015 and thereafter> Annex I countries achieve the target proposed by the UK (61% reduction by 2050 relative to 1990). The 27 EU countries are allowed to joint fulfillment. Non-Annex I countries must constrain their emissions so that the world's total emission does not exceed S550. Emission allotment among non-Annex I countries is proportional to their historical emissions in 1990.

(3) Results

Evaluations used the following indexes: "sovereignty," which consists of CO_2emission amounts and its ratio to the values of the year 2000; "equity in sovereignty," which consists of per capita and per GDP "sovereignty;" "burden," which consists of CO_2 reduction amount, reduction costs etc.; and "capability of burden sharing," which consists of per GDP "burden" and "equity in burden," which consists of per capita " burden." It was found that the (c) i case in Section 4. (2) is advantageous for Japan and the (b) ii case is advantageous for the US, and that the (b) i case of per capita emission convergence has the highest equity when it is assumed that the smaller the variations in the above indexes among countries are, the higher equity the regime can claim.

5. Future study

Such reduction regimes as participation timing of emission reduction varies depending on the countries, and a "bottom-up approach" is implemented to improve CO_2 intensity by sector, unlike a "top-down approach" of ceilings on emission amounts, are topics for future study.