# *SOCIOECONOMIC IMPACTS TO ACHIEVE A CERTAIN RADIATIVE FORCING LEVEL CONSDERING UNCERTAINTIES OF ESMS*

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## Overview

Several scenarios on climate change such as SRES (Special Report on Emissions Scenarios; Nakicenovic and Swart, 2000) and RCPs (Representative Concentration Pathways; van Vuuren, 2011) have been developed related to IPCC (Intergovernmental Panel on Climate Change). The latest scenario is the RCP scenarios, which were developed mainly for the next (5th) IPCC Assessment Report. In addition, new socioeconomic scenarios, named SSPs (Shared Socioeconomic Pathways), is now under development based on the RCPs. The RCP scenarios only define the four radiative forcing levels in 2100 (i.e. 2.6W/m$^2$, 4.5W/m$^2$, 6.0W/m$^2$, and 8.5W/m$^2$), while the four different integrated assessment modeling teams analyze different scenarios respectively by using their own models and own GHG concentration and emission pathways. On the other hand, various GHG concentration/emission pathways are possible to realize a certain radiative forcing level in 2100 (e.g. 6.0W/m$^2$). There have been several studies which compare socioeconomic (including energy) feasibility and impacts of certain GHG concentration scenarios (or radiative forcing scenarios) using multiple integrated assessment models (e.g. Clarke et al., 2009; Calvin et al., 2012). However, no studies have addressed an issue of uncertainties in ESMs (Earth System Models), although there still exist large uncertainties in this type of model.

The purpose of this study is to analyze socioeconomic (including energy) impacts to achieve a certain radiative forcing level based on multiple GHG emission pathways obtained from an earth system model of intermediate complexity considering uncertainties in existing ESMs (Figure 1) using a CGE (computable general equilibrium) model. The significance of this study is to combine studies of ESMs and a CGE model, and to clarify the meaning of the uncertainties seen in existing ESMs from socioeconomic aspects. Here, we use 4.5W/m$^2$, one of the four radiative forcing levels defined in the RCP scenarios (Thomson et al., 2011), for the analysis.

## Methods

The CGE model used in this study is a multi-regional and multi-sectoral, recursive dynamic, CGE model with 24 geographical regions each producing 21 types of economic goods and services (Masui et al, 2011; Matsumoto and Masui, 2011). In the model, electric power can be generated using thermal, hydro, and nuclear, as well as renewable energy. Also, CCS (carbon capture and storage) technology is considered. Each sector in the economy is represented by a nested constant elasticity of substitution (CES) production function. The time period of the model is 2001 (base year) to 2100.

The model is calibrated to reproduce economic and energy activity levels in the base year using GTAP6 for economic activity levels, the IEA energy balance tables for energy, and EDGAR 4.0 for GHG emissions. Future GDP values were taken from the Sustainability First scenario in UNEP/GEO3 and GEO4 of the United Nations Environmental Programme. Similarly, Future population growth rates were taken from the medium variant of the World Population Prospects of the United Nations. The rate of energy efficiency improvement is also set exogenous using the SRES B2 scenario (Nakicenovic and Swart, 2000).

The model is constrained to follow the global GHG emission pathways described above (see also Figure 1).

## Results

Here we show the results for the 5%, 50%, and 95% emission pathways (Figure 1).

The changes in GDP in the 21st century (Figure 2) indicate that world GDP will be $191 trillion (5%; 2000 constant US dollar), $207 trillion (50%), and $211 trillion (95%), respectively, in 2100. Changes in primary energy structure in the 21st century (Figure 3) indicate that the lower the GHG emissions to achieve 4.5W/m$^2$, the higher the percentages of biomass energy and the lower the percentages of fossil fuels (especially coal).

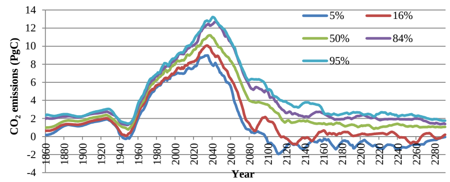


Figure 1 Emission pathways (Tachiiri et al., submitted)

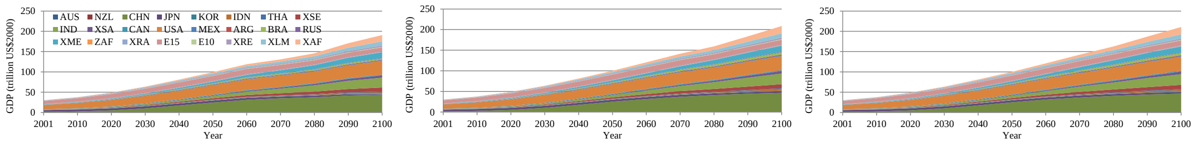


Figure 2 Changes in regional GDP (from left: 5%, 50%, and 95%)

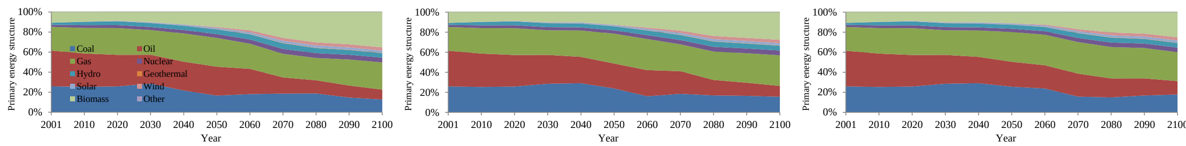


Figure 3 Changes in primary energy structure (from left: 5%, 50%, and 95%)

## Conclusions

The results suggest that the differences in GDP by emission pathway is relatively smaller than the differences (uncertainties) in the emission pathways. In this radiative forcing scenario, although GDP in the 5% pathway is 9.4% smaller than that in the 95% pathway, it increases over time as with the other emission pathways.

Primary energy demand in the 95% pathway is largest (801EJ in 2100), while that in the 5% pathway is slightly larger than that in the 50% pathway (788EJ and 787EJ in 2100 respectively), although the demand in the 50% pathway is larger before 2100. This result looks unusual, but can be interpreted that in order to achieve the negative emission in 2100 in the 5% pathway, use of biomass energy with CCS technology, which is the only possible method to realize negative emission in this model, is enhanced.

It is concluded that socioeconomic impacts caused by the uncertainties of ESMs are not small but relatively smaller than the differences in the emission pathways in the range of this study.

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