Assessment of value of carbon price to achieve NDC of Japan using national scale CGE model

Maho Takimi[1], Toshihiko Masui[2]

Author Affiliations

1. Mizuho Information & Research Institute, Inc., 2-3 Kanda-Nishikicho, Chiyoda-ku, Tokyo 101-8443, Japan
2. Center for Social and Environmental Systems Research, National Institute for Environmental Studies (NIES), National Institute for Environmental Studies, 16–2 Onogawa, Tsukuba, Ibaraki 305–8506, Japan

Abstract

Japan has greenhouse gas reduction targets of 26% by 2030 compared to 2013 and 80% by 2050 compared to the present level. In order to achieve deep reductions in greenhouse gas emissions, carbon pricing is believed to be an efficient and effective measure. For analyzing options of different levels of carbon pricing, a computable general equilibrium (CGE) model for Japan was developed with detailed disaggregation of electricity sector. According to the analysis, the required carbon price for achieving reduction targets is much higher than currently introduced level. Deeper decarbonization of electricity is essential to meet the targets.

Keywords AIM/CGE, Carbon pricing, GHG emissions

1. Introduction

In 2015, Japan submitted its (I)NDC [1] to UNFCCC (United Nations Framework Convention on Climate Change) and committed to reduce greenhouse gas (GHG) emissions by 26% by FY 2030 compared to FY 2013. Japan also has a long-term GHG reduction target, in which it aims 80% reduction by 2050. For achieving the long-term targets, in particular, Japan needs to introduce additional measures including innovative technologies.

As an efficient and effective measure for driving innovation and contributing to GHG reduction, carbon pricing has been introduced widely across the world. Japan is also in discussion for a possible new carbon pricing scheme in light of the Paris Agreement and international momentum for climate action.

In this study, we developed a computable general equilibrium model (CGE model) for Japan with detailed disaggregation of electricity sector, which is seen to play a key role in decarbonization considering the amount and growth rate of CO_2 emissions from the sector, as shown in Fig. 1. This study also assesses the level of carbon pricing for meeting the GHG reduction targets in Japan for policy implications.

[1] (Intended) Nationally Determined Contributions

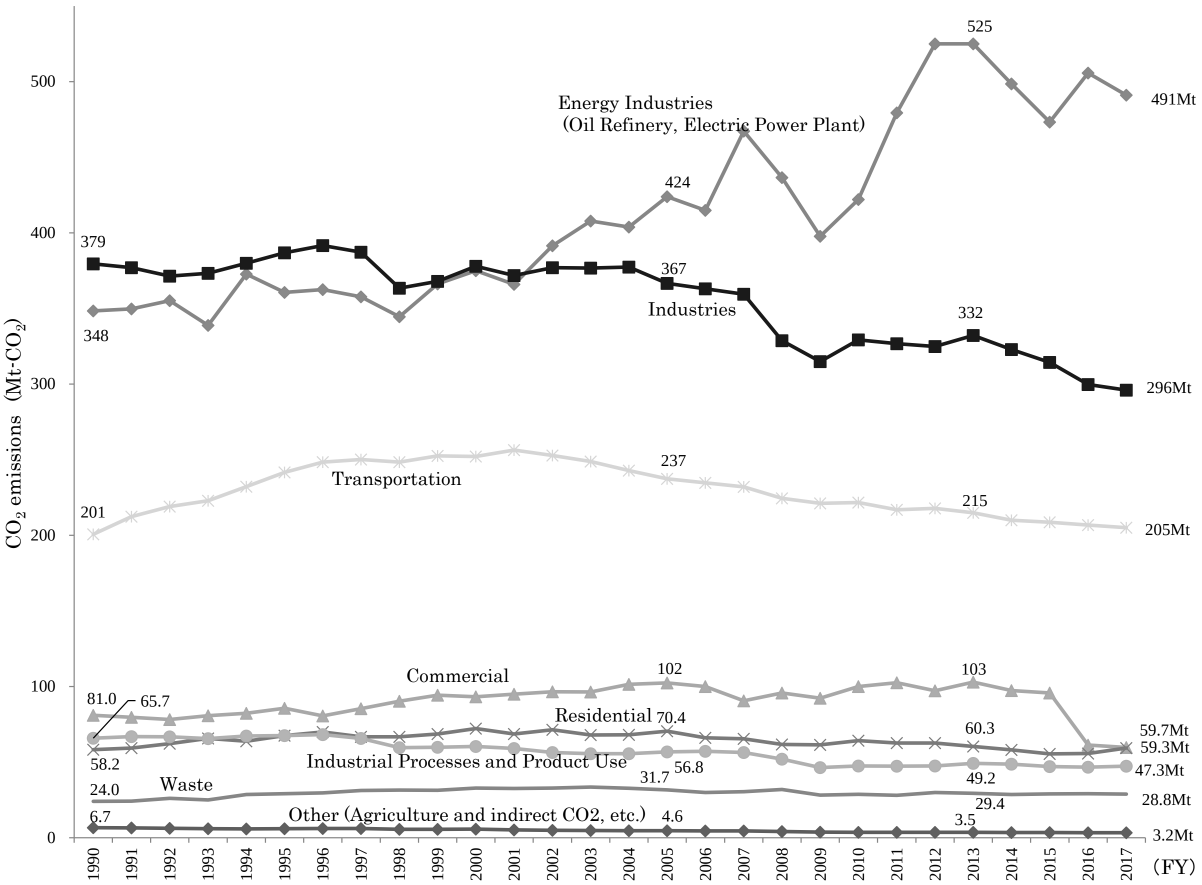

Fig. 1 CO_2 emissions by sector in Japan

Source: Greenhouse Gas Inventory Office of Japan (2019)

2. Methodology

2.1 Model Structure

The structure of the CGE model in this study is based on AIM/CGE [country], which was developed by the AIM (Asia-Pacific Integrated Model) Project Team. The extended version of this model has long been utilized for analyses of economic impacts of climate change mitigation in Japan. The AIM/CGE [country] applied to Japan is a recursive dynamic general equilibrium model and replicates the latest input-output table in Japan.

This model covers a larger number of sectors and commodities compared to previous studies (Table 1). It permits detailed analysis of production sectors, including the primary industry, manufacturing industry and service industry. It also distinguishes between the production activities using existing capital and new capital, which allows analyses of the technology improvements in the future.

The simulation period is from 2011, the latest available year of the IO table, to the year 2050.

Table 1. Sector and commodity classification

Paddy	Basic chemical	Heat supply
Other food crops	Plastic products	Water supply
Other crops	Specialty chemical products	Waste and recycling services
Livestock	Cement	Construction
Forestry	Iron and steel	Trade
Marine and fishery	Metal and non-metal products	Railway transport
Coal mining	Electric and electronic equipment	Road transport
Crude oil mining	Transport equipment	Other transportation and services
Natural gas mining	General machinery	Telecommunication, computer and information technologies services
Other mining	Other manufacture	Finance and insurance
Food, beverage and tobacco	Electricity (commodity)	Public administration
Textile and leather	Electricity (thermal power)	Real estate
Processed wood products	Electricity (hydro power, etc.)	Education and research
Pulp and paper products, and print	Electricity (nuclear power)	Health, medical and social security services
Petroleum refineries	Gas (Town gas)	Other services
Coal refinery		

Each production sector is assumed to maximize its profit according to a multi-nested production function as shown in Fig. 2, while households maximize their utility under income constraints.

GHG emissions from fossil fuel combustion and production activities, including CH_4, N_2O and F-gas, are treated in the model. When GHG emission reaches the level of the constraint, carbon price becomes positive and the prices of fossil fuels rise. The model is calibrated to trace the historical GHG emissions data of Japan.

Total investment in a given year is decided to meet the assumption of economic growth in the following year prior to calculating the equilibrium. Subsequently, allocation of total investment to each sector is computed internally to maximize social utility. The allocated investment becomes the new capital in a sector. In each sector, not only the production from the new capital but also that from the existing capital is assumed. The existing capital in a particular sector cannot be moved to another sector. Technology improvement of production sector is calculated according the increase of new capital.

Produced commodities are either supplied domestically or exported according to the small country assumption. In the domestic market, both domestic and imported goods are supplied as well. For the detailed model structure, refer to Masui et al. (2014).

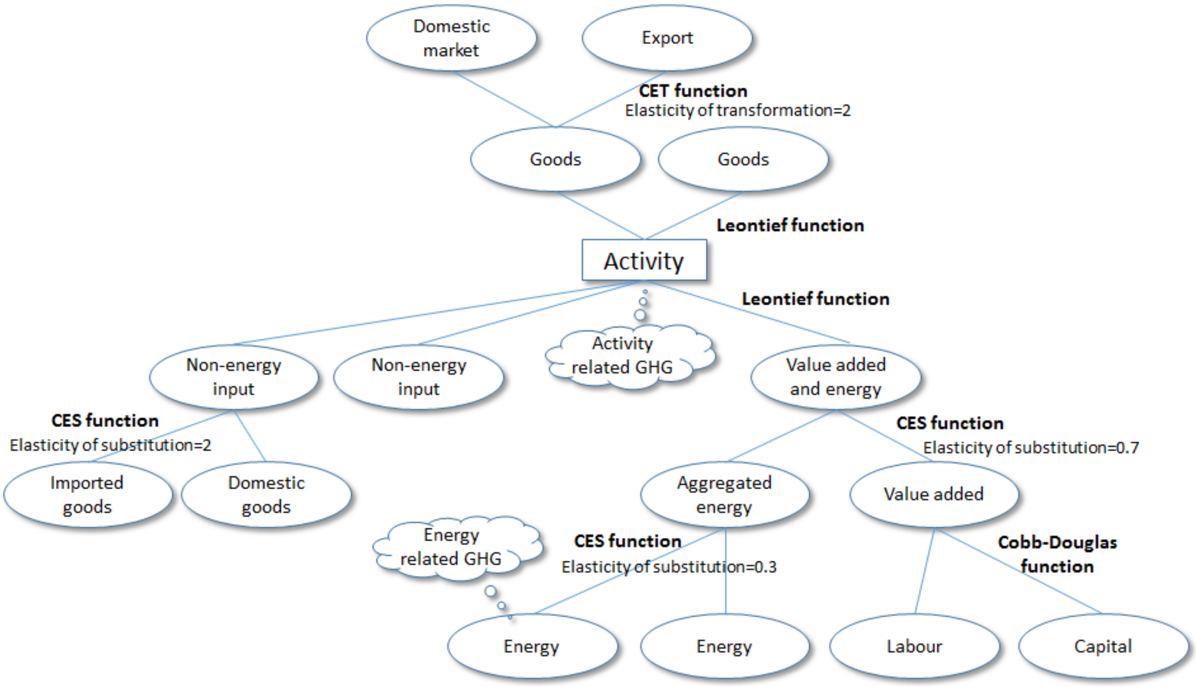

Fig. 2 Basic structure of production sector in AIM/CGE [country]

2.2 Future Scenarios

The assumption of socioeconomic indicators, such as population growth and GDP growth, are the main inputs to the simulation. Those are in line with government forecasts, as shown in Fig. 3 and Fig. 4. The simulation also follows the power generation mix of 2030 published in the Long-term Energy Supply and Demand Outlook by Ministry of Economy, Trade and Industry (METI) in 2015 (see Table 2).

In light of the Long-term Low-carbon Vision published by the Global Environment Committee, Central Environment Council in 2017, which states that "*Low-carbon power sources (renewable energy, thermal power generation with CCS, and nuclear power) account for more than 90% of electricity generation*" in 2050, the maximum growth rate of renewable power generation until 2050 is assumed to follow that trend. Maximum capacities of thermal power without CCS (Carbon Capture and Storage) and nuclear power are assumed to continue at the same level as in 2030.

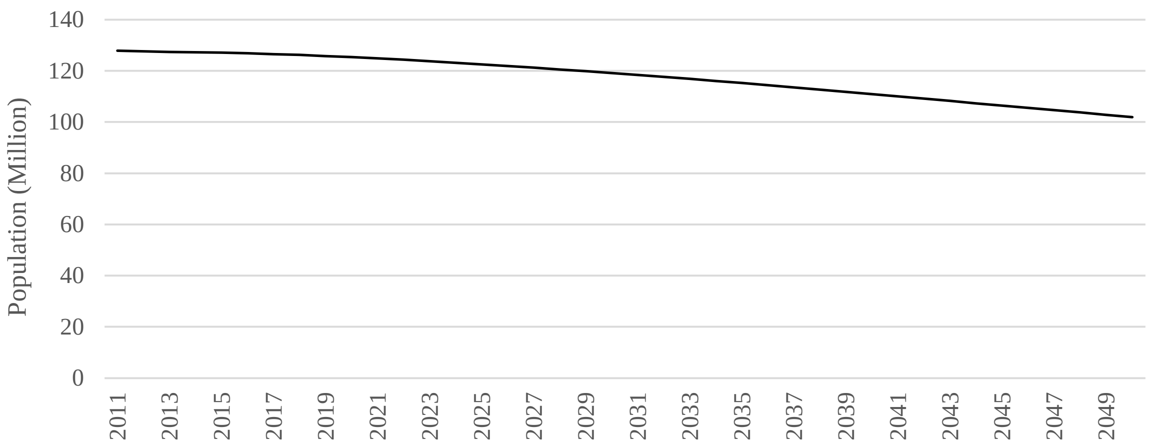

Fig. 3 Assumption of population

Source: National Institute of Population and Social Security Research (2017)

Fig. 4 Assumption of GDP growth

Source: METI (2015); Council on Economic and Fiscal Policy, Expert Panel, Committee for Japan's Future (2014)

Table 2. Assumption of power generation mix in 2030

	Power generation (100 GWh)	Share
Oil thermal power generation	315	3%
Coal thermal power generation	2,810	26%
Gas thermal power generation	2,845	27%
Nuclear power generation	2,317-2,168	22-20%
Renewable energy	2,366-2,515	22-24%
Total	10,650	100%

Source: METI (2015)

In this study, three future scenarios are assumed as shown in Fig. 5. The "reference scenario" assumes the energy efficiency improvements according to the description in the Long-term Energy Supply and Demand Outlook of METI without GHG constraints. In this outlook it is expected that from 2012 to 2030 energy efficiency in Japan is going to improve by 35%, which is almost equivalent to the improvements observed around the oil shocks in 1970s. The energy efficiency of new capital is assumed to improve by 2% each year throughout the simulation period. The energy efficiency of the household sector is also assumed based on the METI's outlook.

In the “NDC & 80% reduction scenario”, GHG emissions constraints aligned with Japan’s reduction targets of 2030 and 2050 are assumed. The “80% linear scenario” assumes that the GHG reduction starts promptly in 2014 and progresses linearly every year for achieving 2050 targets.

3. Results and Discussions

GHG emissions are expected to increase slightly over the simulation period in the "reference scenario". Both the "NDC & 80% scenario" and "80% linear scenario" meet the long-term reductions target, however their reduction speeds are different according to different assumptions.

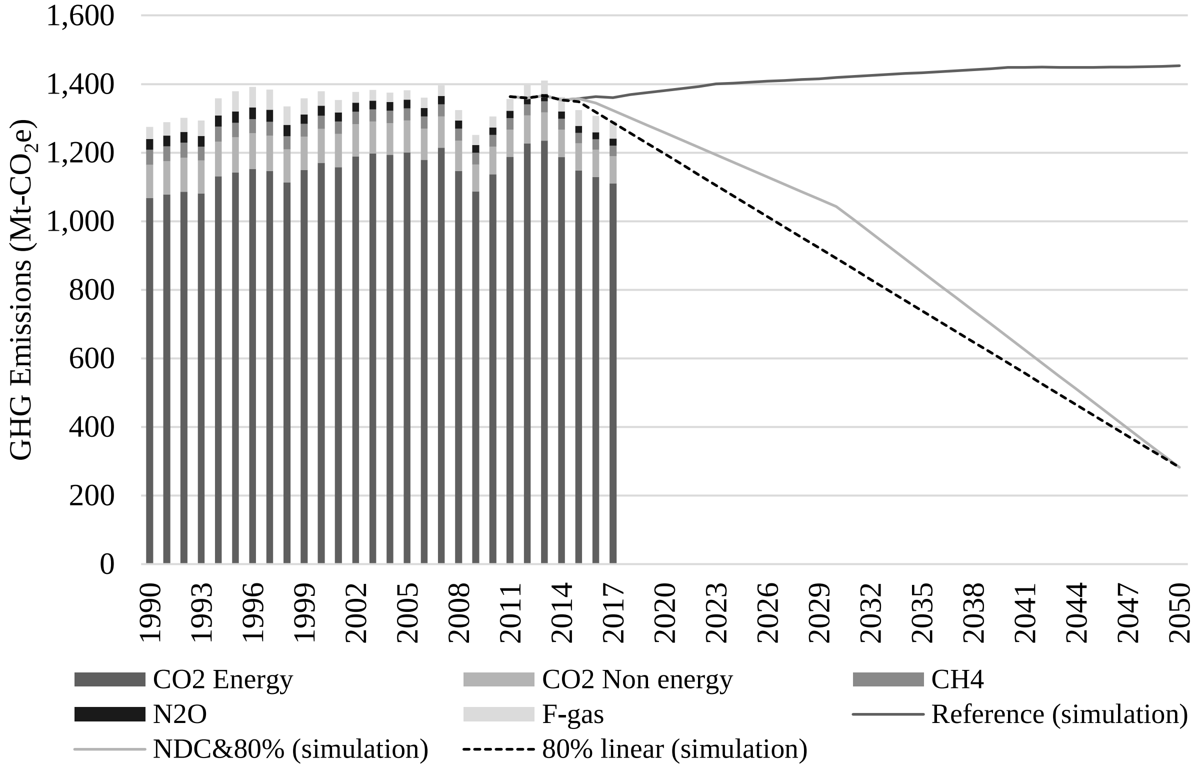

Fig. 5 GHG emissions estimated by AIM/CGE [country] Japan

Compared to the reference scenario, mitigation costs of two reduction scenarios are estimated as in Table 3. The carbon price in 2030 of the "NDC and 80% reduction scenario" is 9,000 JPY/tCO_2e (81.5 USD/tCO_2e)[2] and the estimated GDP loss is 0.3%. In the simulation of the "80% linear scenario", carbon price of 11,000 JPY/tCO2e (99.6 USD/tCO_2e) and GDP loss

[2] Exchange rate: 110.4 JPY/USD (2018 average rate of Mizuho Bank)

of 0.4 % is estimated.

There exists a carbon tax (Tax for Climate Change Mitigation) in Japan since 2012, however, our results suggest that the current tax rate, 289 JPY/tCO_2 (2.62 USD/tCO_2e), is significantly lower than the required level for achieving the reduction targets in 2030. Although the simulation results indicate a range of carbon prices according to the reduction speeds, they are consistent with the conclusion of the High-Level Commission on Carbon Prices of CPLC (Carbon Pricing Leadership Coalition) (2017), *"explicit carbon-price level consistent with achieving the Paris temperature target is at least US$40–80/tCO2 by 2020 and US$50–100/tCO2 by 2030, provided a supportive policy environment is in place"*.

Table 3. Estimated carbon prices in 2030

Reduction scenarios	Carbon price (Unit: JPY/tCO_2e)	GDP loss (w.r.t. reference)
NDC & 80% reduction	9,000	0.3%
80% linear	11,000	0.4%

Fig. 6 shows the share of thermal power without CCS in the mitigation scenarios. It is indicated that decarbonization of electricity sector is essential under mitigation scenarios and thermal power generation without CCS has to be reduced significantly from late 2030s onwards. It should be noted that this estiamtion does not account for back-up thermal power generation potentially required for growth of renewable power.

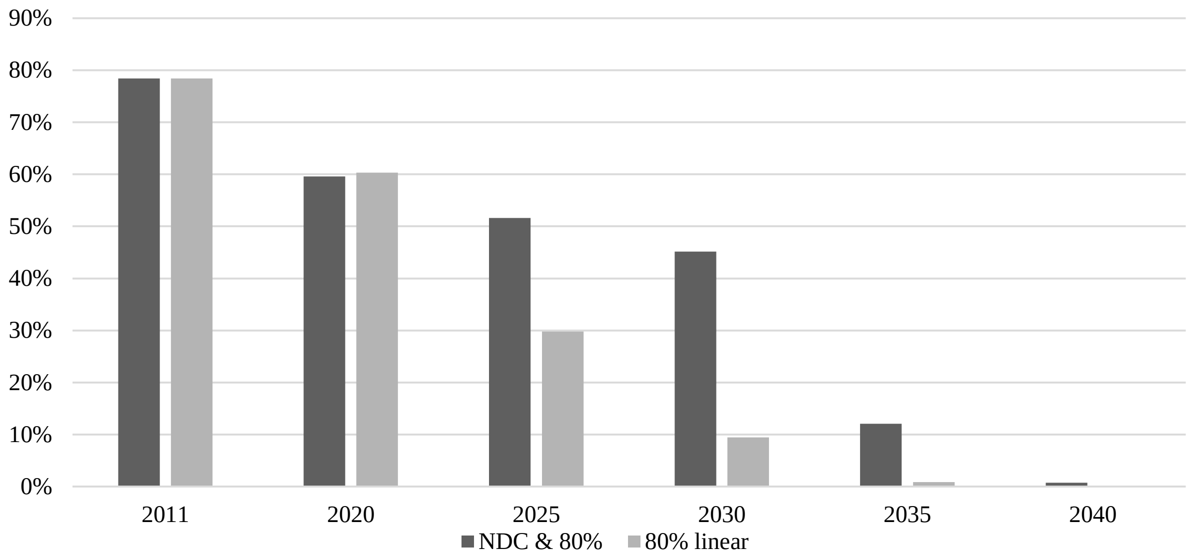

Fig. 6 Share of thermal power without CCS estimated by AIM/CGE [county] Japan

4. Conclusion

In this study we developed a computable general equilibrium (CGE) model for Japan, reflecting the latest input-output table, for analyzing the GHG mitigation scenarios and their economic impacts. The simulation results suggest that for meeting Japan's GHG reduction targets, higher carbon prices than the currently introduced level must be in place. In addition, under GHG mitigation scenarios, thermal power generation without CCS has to be reduced significantly from late 2030s onwards for decarbonizing the electricity sector.

This study does not encompass disruptive innovations such as CCS or social and economic transitions Japan is going to face in the future, including aging society, rapid globalization and so forth. A more detailed simulation and analysis needs to be conducted in the future.

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