

EMF 35 JMIP study: preliminary results and implications for Japan's climate change mitigation

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Abstract

The present study, Stanford Energy Modeling Forum (EMF) 35 Japan Model Intercomparison project (JMIP), employs five energy-economic and integrated assessment models to evaluate long-term climate change mitigation of Japan. Japan submitted its mid-century strategy last June to the Framework Convention on Climate

Change, but the submitted strategy has not yet gone through modeling analysis. Moreover, along with other countries, Japan is expected to update its policy pledges in 2020. This study contributes to the modeling analysis of the ongoing policy debate. A preliminary analysis has been reported by Sugiyama et al. (2019, <https://doi.org/10.1016/j.energy.2018.10.091>) and this study further extends it.

EMF 35 JMIP conducts a suite of sensitivity analysis on dimensions including emissions constraints, technology availability, and demand projections. The five participating models are: AIM/CGE, AIM/Enduse, DNE21, IEEJ, and TIMES-Japan. Four are bottom-up models, and one (AIM/CGE) is a computable general equilibrium model. We have harmonized GDP and population assumptions across models.

The overall results confirm that mitigation strategies that work in other jurisdictions are also applicable in Japan, including energy efficiency, electricity decarbonization, and electrification. We also find that absent structural changes in the economy, heavy industries will be one of the hardest to decarbonize.

Partly because of the challenges associated with industrial decarbonization, the marginal cost of abatement is higher than in the United States and comparable to that of Europe, as indicated by previous exercises of the EMF project. The challenge of industrial mitigation can be found in other Asian countries, particularly China and South Korea, and further investigation is warranted.

Keywords

Climate change mitigation, mid-century strategy, industrial mitigation, model intercomparison

1. Introduction

In June 2019, the Government of Japan submitted its mid-century strategy to the United Nations Framework Convention on Climate Change, as requested by the 2015 Paris Agreement (Government of Japan, 2019). The strategy stated the goal of reducing greenhouse gas emissions by 80% by 2050. It also stated that there should be a virtuous cycle between economic growth and environmental protection and emphasized the centrality of disruptive innovation to achieving the established goal.

Although the Government of Japan has not formally conducted quantitative analysis of the proposal, many papers already examined such long-term policy proposals, including economy-wide climate policies (e.g., Oshiro et al., 2018; Kato & Kurosawa, 2019; Fujimori et al., 2019; and references in Sugiyama et al., 2019) and power-sector policies that feature significant penetration of variable renewables (e.g., Komiyama & Fujii, 2015; Matsuo et al., 2018).

While these studies have advanced our understanding and are useful for informing policy, they have not analyzed all the relevant factors yet. One important factor that has not received enough attention is inter-model uncertainty among energy-economic and integrated assessment models. It has long been known that analyzing and presenting such uncertainty is crucial for informing climate policy debate (Krey, 2014).

The Stanford Energy Modeling Forum 35 Japan Model Intercomparison Project (JMIP) is tasked with analyzing climate policy for Japan with a multi-model framework. The present study extends a pilot study (Sugiyama et al., 2019) and explores policy uncertainties more fully.

2. Method

2.1. Models

Table 1 shows the models participating in the present study. Although this list does not cover all the models actively under development in Japan, it represents a broad and balanced set of models in this jurisdiction. There are, however, some issues. The list is dominated by partial equilibrium models, and no model developed by a team outside Japan is present.

Table 1. Models participating in the study.

Model	Institute	Equilibrium concept	Region	Temporal treatment
AIM/CGE[Japan]	Kyoto U / NIES	General	Japan	Myopic
AIM/Enduse[Japan]	Kyoto U / NIES	Partial	Japan	Myopic
DNE21	U Tokyo	Partial	World	Intertemporal
IEEJ	Institute of Energy Economics Japan	Partial	Japan	Intertemporal
TIMES-Japan	Institute of Applied Energy	Partial	Japan	Intertemporal

2.2. Scenarios

Regarding the input assumptions, we harmonize population and economic growth across models. The population data is from the National Institute of Population and Social Security Research (2017). We assume two GDP growth scenarios. The high

GDP growth scenario sets the growth rate by 2030 to those from the government's Long-Term Energy Outlook, and for 2030-2050, to levels from the Shared Socioeconomic Pathway (SSP) 2 (Dellink et al., 2017). Another scenario presumes the SSP 2 growth rate for the entire period (see LoDem below).

We have two main scenarios:

- Baseline_Def: no climate policy assumed, with a default parameter setting for each model.
- 26by30+80by50_Def: each model imposes Japan's nationally determined contribution (26% emissions reduction by FY2030 relative to the FY2013 levels) and mid-century strategy (80% emissions reduction by 2050). The parameter setting follows the default configuration.

In addition, we analyze scenarios with varying policy stringency:

- 26by30+70by50_Def: As in the 26by30+80by50_Def scenario but with an emissions reduction goal of 70% by 2050;
- 26by30+90by50_Def: As in the 26by30+80by50_Def scenario but with an emissions reduction goal of 90% by 2050;
- 26by30+100by50_Def: As in the 26by30+80by50_Def scenario but with an emissions reduction goal of 100% by 2050;

We also perform the following sensitivity analyses:

- 26by30+80by50_NoNuc: No nuclear power is available.
- 26by30+80by50_NoCCS: No CCS (carbon capture and storage) is available.
- 26by30+80by50_LoDem: A lower level of GDP is assumed.

Some models cover multiple greenhouse gases, but this study focuses on carbon dioxide from energy usage.

3. Results

Figure 1 depicts the time series of CO₂ emissions for the main baseline and mitigation scenarios. The models exhibit a wide range of emissions in the baseline

scenario, justifying the necessity to investigate inter-model uncertainty. In the 26by30+80by50_Def scenario, models substantially reduce emissions, though the final levels in 2050 are somewhat different because of the differences in the emissions database used in each model.

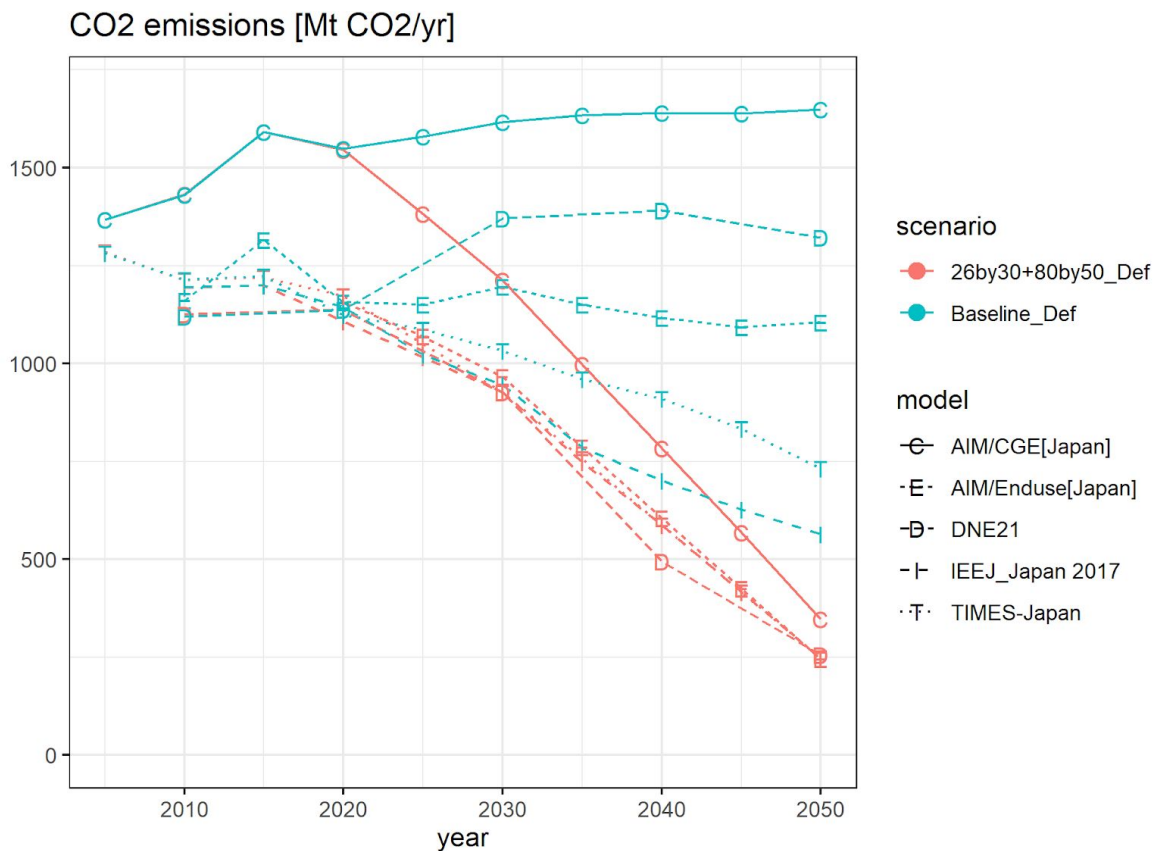


Figure 1. Time series of CO₂ emissions for the baseline (Baseline_Def) and mitigation (26by30+80by50_Def) scenarios.

The breakdown of CO₂ emissions by sector shows differences in the response of each sector (Figure 2). Partial equilibrium models demonstrate almost complete power-sector decarbonization by 2050, and they also display that the industry sector is hard to decarbonize. In the AIM/CGE model, the sector that is most difficult to mitigate is transportation.

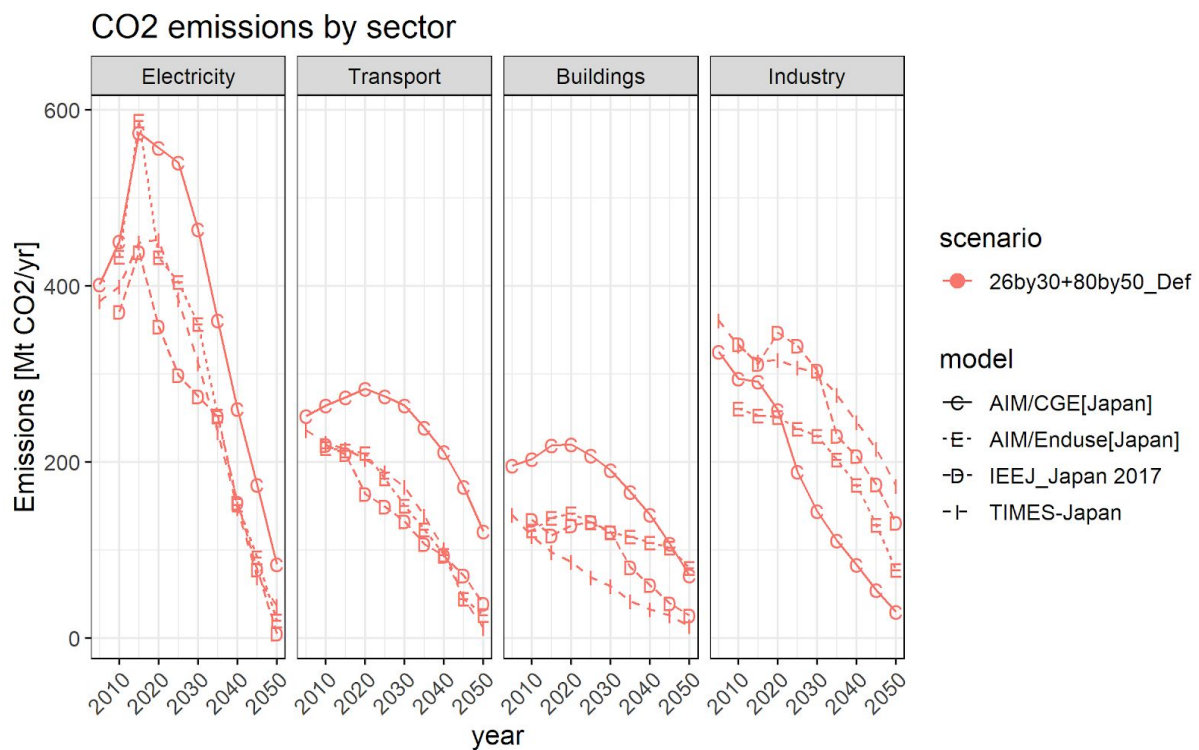


Figure 2. CO₂ emissions by sector in the main mitigation scenario (26b30+80by50_Def).

The models confirm that emissions reduction in Japan is achieved through well-established strategies, including substantial energy efficiency improvement, rapid decarbonization of the power sector (which is accompanied with a larger installation of variable renewables), and end-use electrification. There are multiple futures of power mix. Some models feature a large deployment of nuclear while others emphasize renewables (Figure 3).

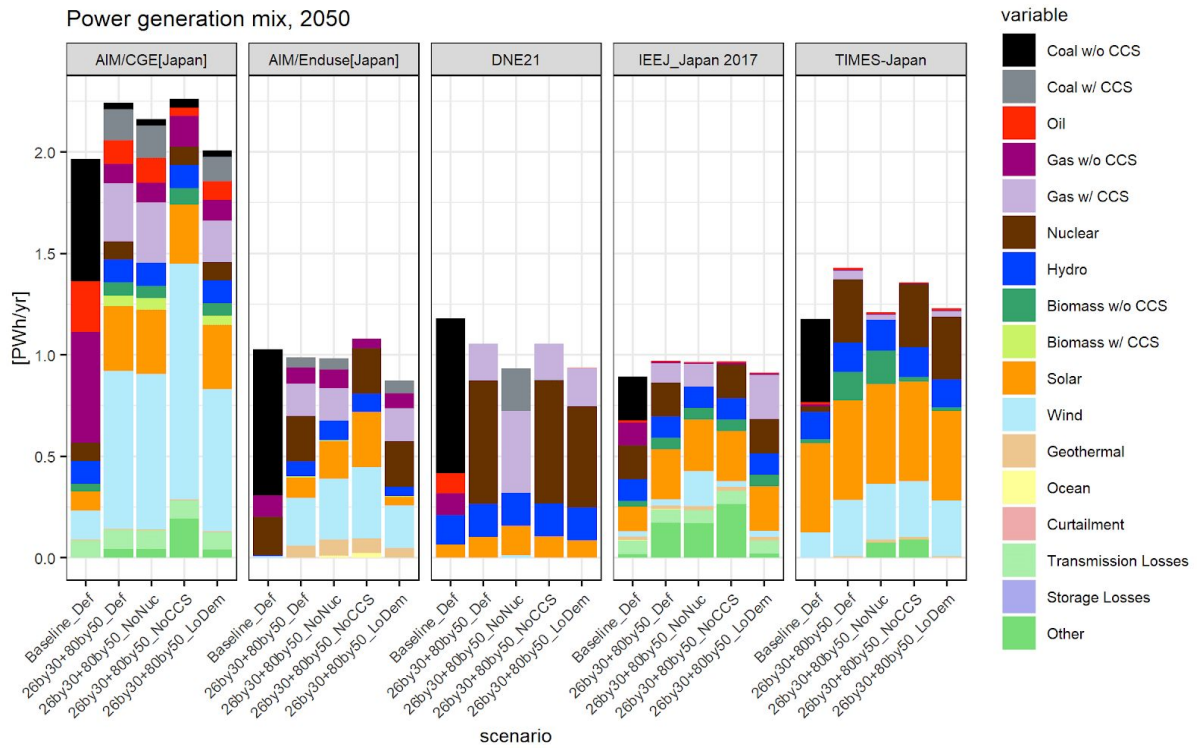


Figure 3. Power generation mix in 2050 for various scenarios.

Figure 4 compares marginal costs of abatement from this study against those reported by previous national EMF studies: EMF 24 for the United States (Clarke et al., 2014), and EMF 28 for the European Union (Knopf et al., 2013). The models show that the marginal cost of abatement in Japan is larger than in the United States and comparable to those in the European Union.

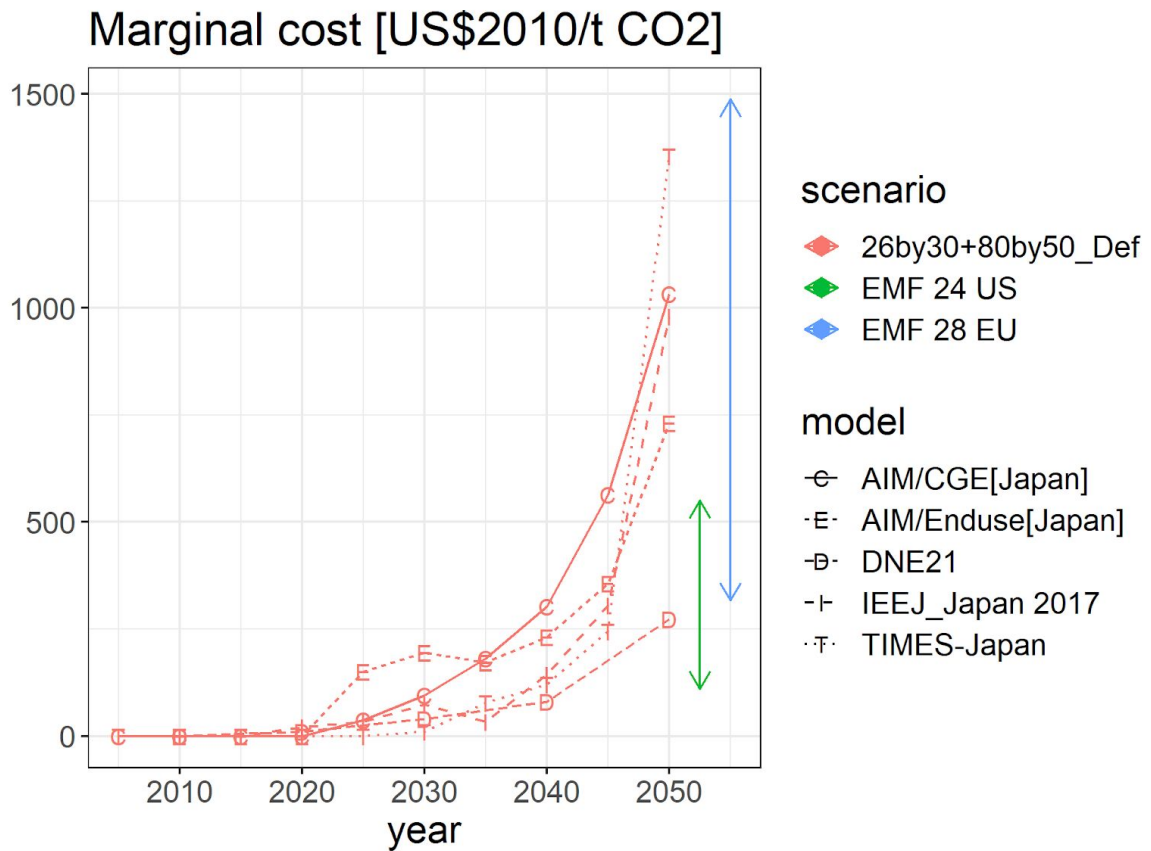


Figure 4. Comparison of marginal costs of abatement in the three regions: European Union, the United States, and Japan.

Next, we perform sensitivity analysis on policy stringency. Table 2 summarizes the feasibility assessment. Only three models exhibit feasible solutions for the 90% emissions reduction, and only two for the 100% reduction.

Table 2. Matrix of feasibility across scenarios. Feasible scenarios are marked with a cross.

Scenario name	2050 target	AIM/CGE	AIM/Enduse	DNE21	IEEJ	TIMES
Policy-70by2050	70%	X	X	X	X	X
Policy	80%	X	X	X	X	X
Policy-90by2050	90%	X	X	X		
Policy-100by2050	100%	X		X		

Finally, we present the cost metrics for various scenarios (Figure 5). Going beyond the current policy target of 80% emissions reduction by 2050 could increase both the average and marginal costs substantially. In terms of technology and demand sensitivity analyses, the availability of CCS options is one important factor to contain the costs low.

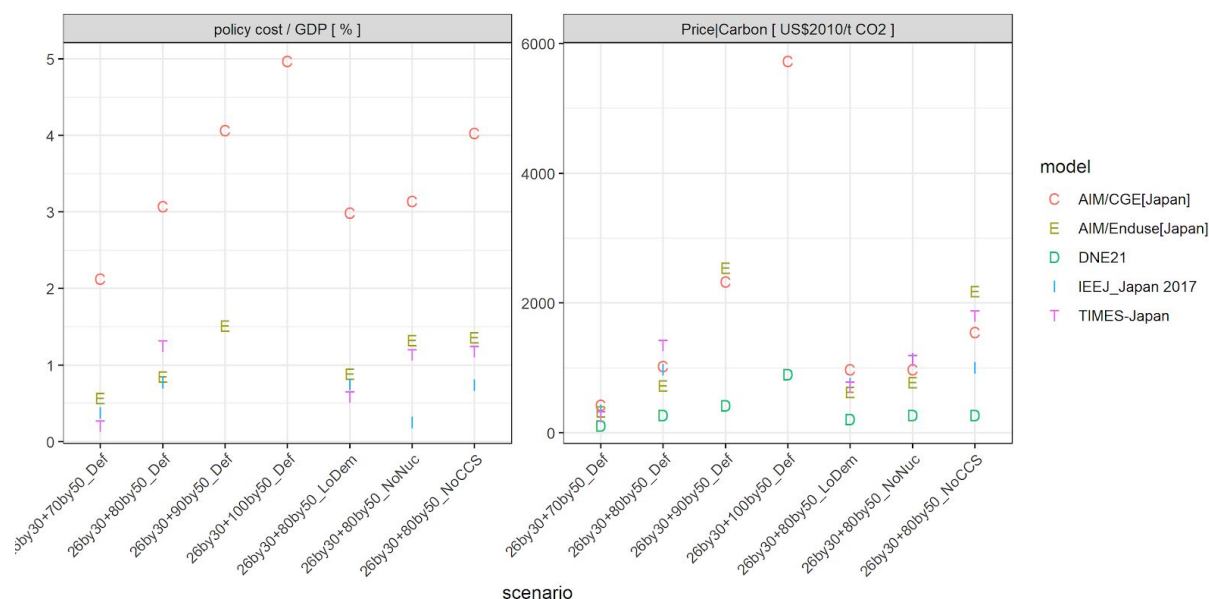


Figure 5. The loss of GDP (gross domestic product) and the additional total energy system cost per GDP (left) and the marginal costs of abatement (right) in 2050 for various scenarios.

4. Discussion and Conclusions

Under the assumptions of the prevailing socio-economic conditions and technology development trajectories, the marginal costs of abatement in Japan are comparable to or higher than those in the European Union and the United States. Some models exhibit infeasibility for more stringent policy scenarios, and the costs sharply increase beyond the 80% emissions reduction target. This suggests that Japan should consider emissions trading (Article 6 of the Paris Agreement; Fujimori et al., 2016) to contain mitigation costs.

Our study comes with many limitations. Chief among them is the non-participation of modeling teams outside Japan. It would be useful to compare the results from global modeling teams and national teams. Oshiro et al. (2019) conducted such an analysis but focused on emissions constraints in the form of a carbon budget, not emissions pathways. Extending this kind of work would shed more light on the determinant of emissions reduction costs in Japan.

The present study identified the industry sector as an important sector for mitigation. Now that the global community agreed on containing global warming below 1.5 or 2.0 degrees, the world must achieve net-zero CO₂ emissions in this century. This implies that reducing Japanese industrial emissions through the “hollowing out” of industries is not an option. Rather, Japan should pursue efforts to reduce emissions jointly with countries that have a large presence of heavy industries such as China and South Korea. This signifies another fruitful avenue for further research.

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