Is it possible to reduce carbon dioxide without nuclear in Japan? – Analysis by JMRT (Japan Multi-regional Transmission) Model

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Overview

Among the energy issues facing Japan, energy independence and carbon emissions are two important policy targets. Japan imports most of its fossil fuels, and its energy self-sufficiency rate is a mere 4% (18% if nuclear power is included). The Japanese government aims to increase the self-sufficiency rate from the current 18% (including nuclear) to as much as 40%, while at the same time its GHG mitigation targets are 25% below 1990 levels by 2020 and 80% by 2050. Before the earthquake of 11th March, 2011, nuclear was expected to play a major role in achieving energy self-sufficiency and meeting carbon mitigation targets by increasing the availability factor. After the earthquake and the accidents at the Fukushima Dai-ichi nuclear power station, nuclear has become an unacceptable option. At present, only two nuclear power stations are operating to meet peak summer demand in the Kansai area. The Japanese government is now reviewing safety standards for nuclear power stations, but it is very unclear when other nuclear power stations will be put back into operation. This study aims to illustrate how to reduce CO2 emissions under a no-nuclear condition and with the consideration of 1) grid expansion between electricity grids and 2) timing of denuclearization.

Methodology

Japan has 10 electricity grids, with weak connections between them. In addition, two different electricity frequencies are used (50Hz and 60Hz) and frequency converters are used to convert one frequency to the other. Our model focuses mainly on electricity supply, with data on existing power stations and pumped storage included in the model. The model assumes conventional power stations and renewables as new technologies,. Each year is divided into four seasons (Spring, Summer, Autumn, and Winter) and each day is divided into three periods (Day, Peak and Night). The MOE's renewable potential GIS data contain geological, capacity, and cost information: For example, on-shore wind turbine GIS data includes location (latitude and longitude), wind-speed, distance from road, and distance from electricity-grid on a 1 km^2 mesh. From these data, we calculate capacity, availability factor, investment, and operational and maintenance (O&M) cost and create a new data set. In most technology models, the energy conversion process is represented in some detail, but location differences are not considered in this model. For TIMES, we make clusters categorised by investment cost and availability factor, and these clusters are applied to each prefecture. The upper limit of capacity installed in each cluster is applied based on the GIS dataset.

Table 1 Simulation Scenario

Scenario	Grid Expansion	Denuclearization			CO2 Target*
		in 2012	in 2022	no new nuke	
Base				✓	
CO2_NoGE_NoNew				✓	✓
CO2_GE_NoNew	✓			✓	✓
CO2_NoGE_NoNuke12		✓			✓
CO2_NoGE_NoNuke22			✓		✓

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(*) 25% and 80% reduction below 1990 level by 2020 and 2050, respectively

Key Findings

The weak connections between Japan's 10 grids create a location gap between high renewable potential regions and huge electricity consumption regions. Expanding grid-connections between grids makes it easier to access cheaper renewable sources and the system cost is expected to decrease between 2009 and 2050 from US$6,113,877M in the CO2_NoGE_NoNew case to US$6,091,642M in CO2_GE_NoNew. It is very uncertain how many nuclear power stations will go back into operation. The timing of denuclearisation will affect the structure of electricity in 2020. Carbon reduction targets will be met by both shifting to low carbon sources, for example, from coal to LNG, and by expanding renewable sources. Electricity shortages resulting from shutting down nuclear stations will be supplied by both thermal power stations and renewables; this means that shutting down nuclear in 2012 will require additional capacity from thermal power stations and expensive renewables, which are expected to decrease in price, but are currently a very expensive option compared to conventional power stations. The shares of LNG power stations and renewables in 2020 will be 62.8% and 30.1%, respectively, in CO2_NoGE_NoNuke12 and 46.1% and 21.0%, respectively, in CO2_NoGE_NoNew. Furthermore, denuclearisation under carbon constraints will lead to Japan's increased dependence on middle-eastern energy sources. As a result, the system costs of CO2_GE_NoNuke12, CO2_NoGE_NoNuke22 and CO2_NoGE_NoNew are US$6,338,231M, US$6,172,377M and US$6,091,642M, respectively.

Table 2 the Structure of Electricity Generation

	2010	2020		2050	
		CO2_NoGE_NoNuke12	CO2_NoGE_NoNew	CO2_NoGE_NoNuke12	CO2_NoGE_NoNew
Coal	27.4%	7.1%	13.2%	1.4%	2.6%
Oil	8.7%	0.0%	0.0%	0.0%	0.0%
LNG	27.5%	62.8%	46.1%	27.2%	24.3%
Nuclear	25.9%	0.0%	19.7%	0.0%	0.0%
Hydro	10.5%	8.4%	8.4%	11.5%	11.5%
Small Hydro		4.2%	2.9%	5.6%	4.0%
Solar		1.9%	0.8%	25.2%	28.3%
Wind Offshore		1.6%	0.0%	16.8%	17.4%
Wind Onshore		10.5%	8.1%	10.8%	11.9%
Biomass		2.2%	0.4%	0.0%	0.0%
Geothermal		1.4%	0.3%	1.6%	0.0%
Renewables		30.1%	21.0%	71.5%	73.1%

References

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