# Discussions about the Role of Nuclear Power for Achieving the Paris Agreement in Japan

by

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**Abstract**

Japanese government determined its INDC of GHG emission reduction to the COP21 in 2015. Not only decreasing $CO_2$ emission, but also improving self-sufficiency rate of energy and lowering electricity costs for preserving international competitiveness of industry were placed as important issues for setting it. We discussed current status and the importance of nuclear power in that plan and evaluated the economic impacts by using our econometric models, if some portion of nuclear power will be substituted by other sources. The result shows that nuclear power is important for achieving the three issues at the same time, and non-negligible economic loss may happen if the use of nuclear power in the INDC target will not be achieved.

## 1 Introduction

Japanese government determined its INDC (Intended Nationally Determined Contribution) of GHG emission reduction to the COP21 in 2015. According to it, GHG emission should be controlled to 74% level of the year 2013 in 2030, including the removals by LULUCF. Energy-originated $CO_2$, which occupied 87.7% of total GHG emission weighted by the global warming factor in 2013 (MOE (2017)), should be controlled to 75% level of the year 2013 in 2030 (Government of Japan (2015)). It is quite difficult to achieve this target under current circumstances (nuclear, renewables, economic condition, etc.). Moreover, the Government is considering to determine the long-term pathways of GHG emission reduction in 2050. This paper discusses the issues/barriers to achieve this target focusing mainly on nuclear power with an evaluation of economic impacts using the econometric models developed by our organization.

## 2 The INDC target and surrounding situation

Figure 1 compares the past records and the target in 2030 of energy-originated $CO_2$ by sector. The industry sector has decreased its emission by 10% in last decade and additional reduction until 2030 is very small. On the other hand, the reduction in the commercial sector and the residential sector have not progressed at the same period and additional reduction is accounted to be more than 30% from the 2015 levels. As for transport, improvement of car fuel economy by efficiency standards and reduction of transportation demand by population decrease has been occurring and these movement is assumed to continue in future.

Decarbonization in power generation mix and promoting electrification in final energy use are quite important for emission reduction in the commercial sector and the residential sector, because low temperature energy services (heating and hot water) are mostly supplied by burning fossil fuels in these sectors (Figure 2) (IEEJ (2018)). Considerable $CO_2$ reduction could be achievable if these services will be supplied by using heat pump technology.

Figure 1: Past records and the INDC target of energy-originated $CO_2$ emission by sector in Japan

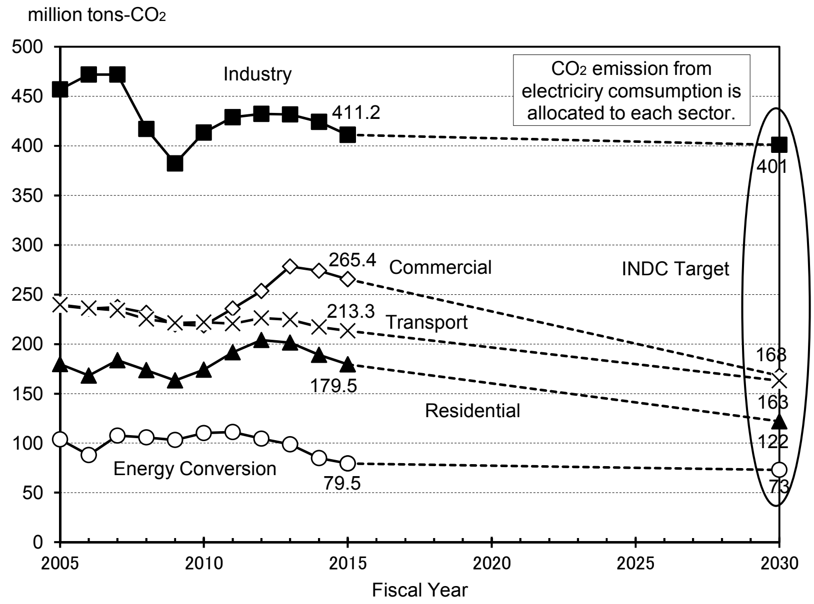
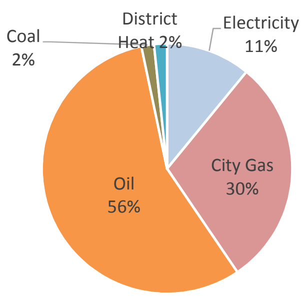
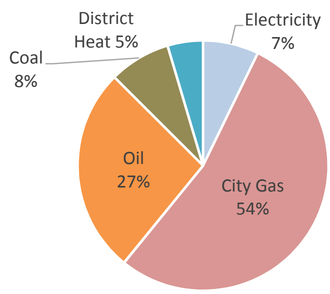


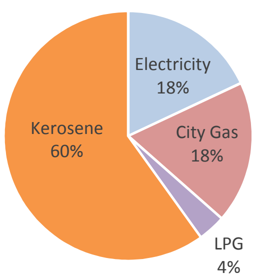

Figure 2: Estimated Composition for Low Temperature Energy Services in the Commercial and the Residential Sector in 2016



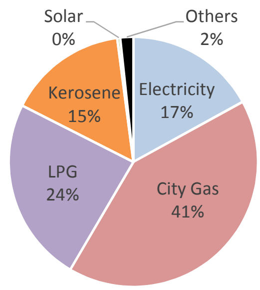

Commercial: Heating




Commercial: Hot Water

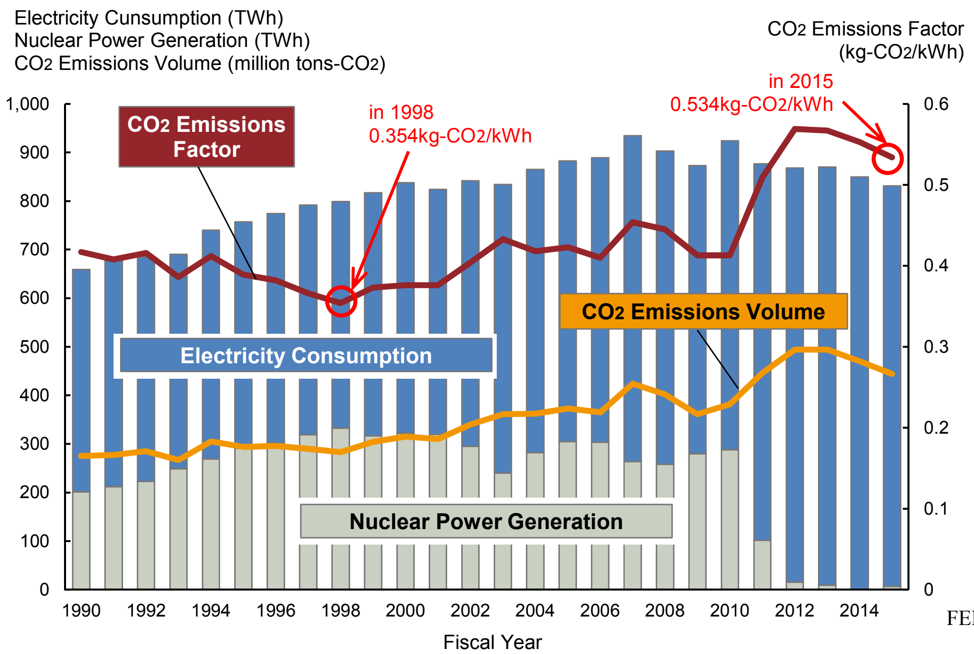



Residential: Heating




Residential: Hot Water

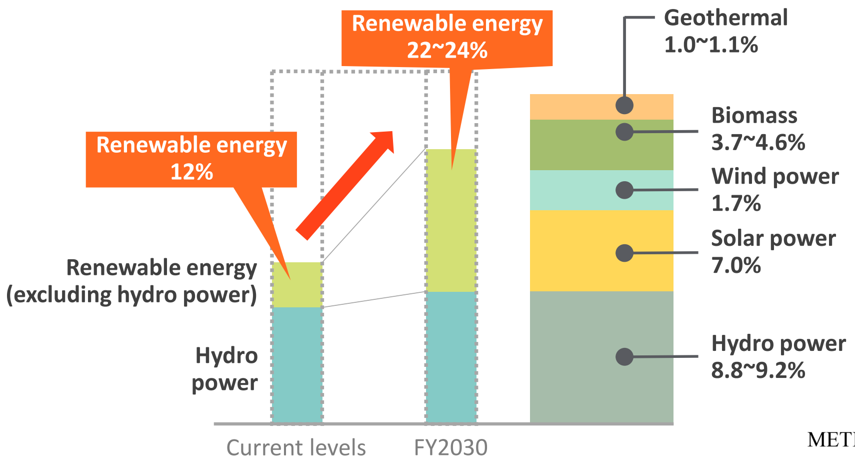
Figure 3: Historical Trends in $CO_2$ emissions from Power Generation in Japan




FEPC (2017)

Figure 3 shows the historical trends in $CO_2$ emissions from power generation (FEPC (2017)). $CO_2$ emissions factor in 2015 was 0.534kg-$CO_2$/kWh and 29.3% larger than the 2010 level. This is mainly because of the operation stop of nuclear power plants since the Fukushima accident in 2011. The target of average $CO_2$ emissions factor of power generation in 2030 in the INDC is set to be 0.37kg-$CO_2$/kWh. Japanese government aims to increase the share of carbon-free electricity to 44% (nuclear 20-22%, renewables 22-24%) in 2030 to achieve this target (Government of Japan (2015), METI (2015)). It was ever achieved in 1998 as shown in Figure 3. The biggest difference in 1998 and 2030 is the composition; nuclear supplied 36.8% in 1998, but it is accounted to be only 20-22% in 2030. On the other hand, renewables should be increased from 12.2% in 2014 to 22-24% in 2030. It is not easy because hydro occupied more than half of renewables currently and most of the suitable sites were already developed. Instead, the rest of renewable (solar power, wind power, biomass and geothermal power) should be increased in large scale (Figure 4) (METI (2016a)).

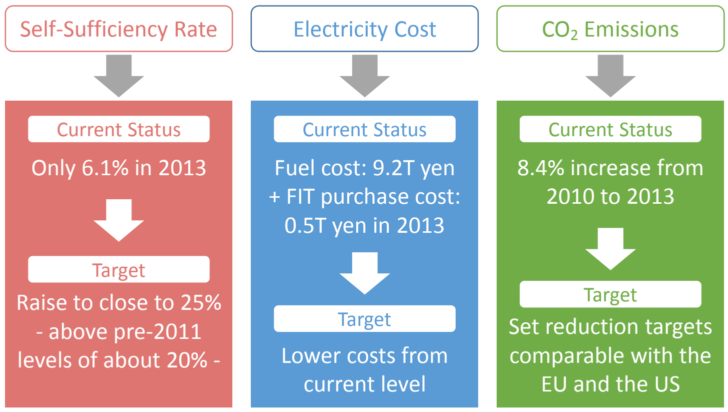
Figure 4: The INDC target of the share of renewable energy in power generation mix




METI (2016a)

Not only decreasing $CO_2$ emission, but also improving self-sufficiency rate of energy and lowering electricity cost for preserving international competitiveness of industry are important issues to make a long-term energy plan, because Japan relies on imports for the greater part of its energy resources (METI (2015)). Nuclear power was thought to be an ideal energy source to satisfy these issues before the Fukushima accident. At present, it is considered that no single energy source can satisfy all of them, because renewables are still expensive by the estimation of the governmental committee and connectable amount of variable renewable energy (VRE) to the grid is limited (Figure 5, Figure 6, and Table 1).

Figure 5: Three energy issues for setting the Japan's INDC

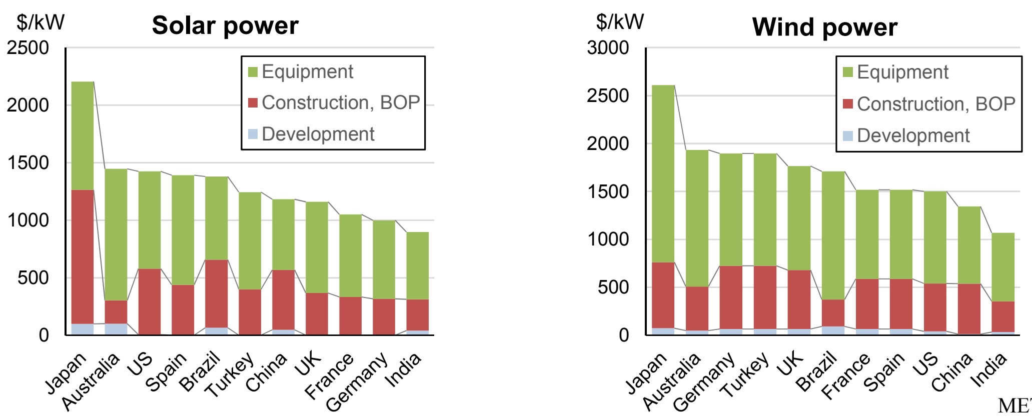



METI (2015)

Table 1: Characteristics of energy sources for important policy issues in Japan

| Issue | Nuclear | Coal | LNG | Oil | Hydro | Other renewables |
|---|---|---|---|---|---|---|
| Improve self-sufficiency | Relatively favorable | Relatively favorable | Not favorable | Not favorable | Favorable | Favorable |
| Lower electricity cost (estimated cost in 2030) | Relatively favorable (10.1~¥/kWh) | Relatively favorable (12.3¥/kWh) | Not favorable (13.7¥/kWh) | Not favorable (30.6~43.4 ¥/kWh) | Favorable (large scale) (11.0¥/kWh) | Not favorable (16.9~29.4 ¥/kWh) |
| Decrease $CO_2$ emission | Favorable | Not favorable | Relatively favorable | Not favorable | Favorable | Favorable |
| Remarks | Lowering as much as possible | Development of next-generation, efficient technologies is important for $CO_2$ emission decrease | | Costly but important for balancing | Limited sites of development domestically | Additional cost is required for grid connection |

Figure 6: Comparison of capital costs of solar and wind power between Japan and other countries



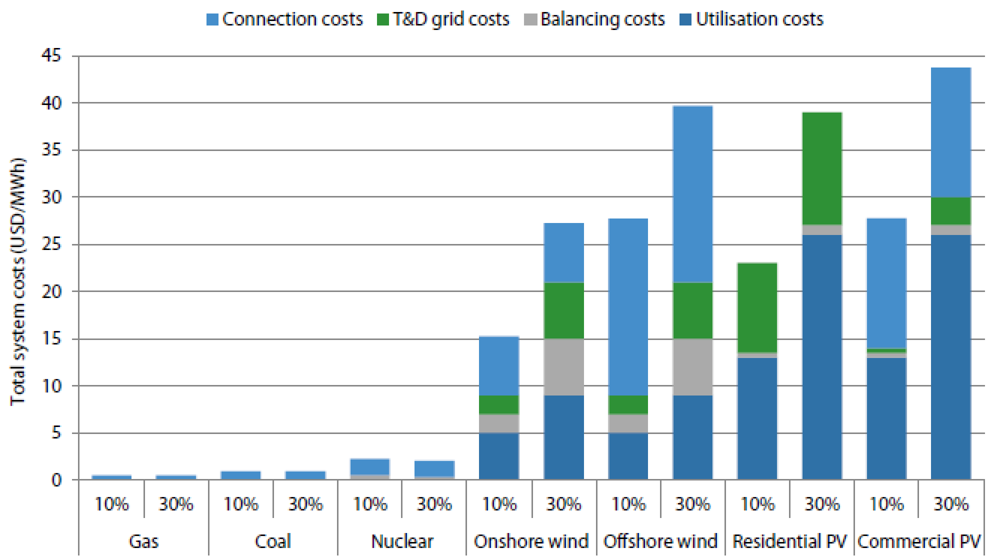

METI (2016b)

For VREs, we should take grid costs and connection costs in to account for proper comparison of power source. Their costs are classified by OECD/NEA as follows (OECD/NEA (2018)):

- Utilisation costs are related to the variability of VRE output, and they are able to demonstrate that in the presence of VRE generation it is generally more expensive to provide the residual load. The overall system thus becomes more expensive even if the plant-level costs of VRE are comparable to those of dispatchable technologies.
- Balancing costs are related to the uncertainty of power production due to unforeseen plant outages or to forecasting errors in relation to production. Unforeseen plant outages or forecasting errors related to electricity generation require that a higher amount of spinning reserves be carried out. Uncertainties in VRE power production may also lead to an increase in ramping and cycling of conventional power plants, to inefficiencies in plant scheduling and, overall, to higher costs for the system.
- Grid and connection costs reflect the effects on the transmission and distribution grid infrastructure due to the locational constraint of generation plants. While all generation plants may have some siting restrictions, the impacts are more significant for VRE. Because of their geographic location constraint, it could be necessary to build new transmission lines or to increase the capacity of existing infrastructure (grid reinforcement) in order to transport the electricity from centres of production to load Also, high shares of distributed PV resources may require sizeable investment into the distribution network, in particular to allow the inflow of electricity from the producer to the grid when the electricity generated exceeds demand. Connection costs (i.e. the costs of connecting the power plant to the nearest connecting point of the transmission grid) can also be significant, especially if distant resources have to be connected, as is sometimes the case for offshore wind.

Unfortunately, comprehensive analysis of these costs is not available for Japan. According to OECD/NEA study, these costs are estimated to be $15-$43/MWh (about 1.7-4.7 ¥/kWh) for VREs and not negligible (OECD/NEA (2018)).

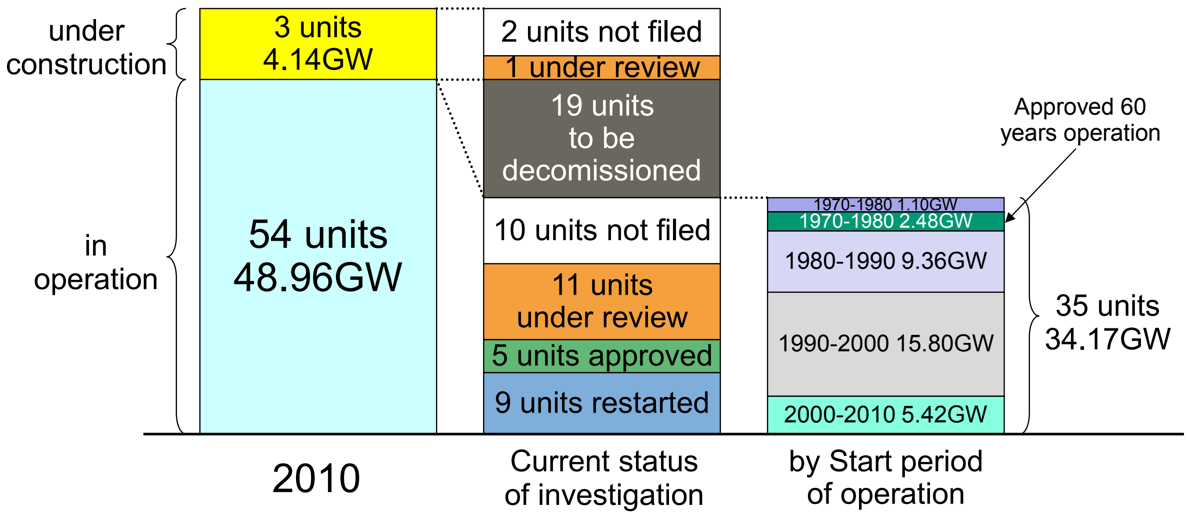
Figure 7: Grid-level system costs of selected generation technologies for shares of 10% and 30% of VRE generation




OECD/NEA (2018)

A new safety standard was set after the Fukushima accident, and electric utilities repaired some of existing power plants and applied their investigation to the Nuclear Regulation Authority (NRA), Japan to restart them. On the other hand, 4 broken units and 15 units whose cost for the repair is not economical will be decomissioned. Figure 8 summarized the current status of investigation for nuclear power (JANSI). It is expected that the capacity of 30GW will be required to satisfy 20-22% supply target in 2030 at a relatively high capacity factor (75-82%, actual average records before the Fukushima accident (1970-2010): 71.8% (JNES (2011))). Figure 7 shows that it is achievable if all of existing 35 units (total capacity 34.17GW) will be operated in 2030, however, 10 units (total capacity 9.33GW) have not been applied for the investigation yet. And more, it requires the use of old units. NRA sets 40 years operation in principle, and requests another investigation for additional 20 years operation. So, if the units operated after 1990, operated before 1990 and 60 years operation is approved at present (3 units, 2.48GW), and 3 units under construction (total capacity 4.14GW) are summed up, its total is 27.85GW and not sufficient. It means that increasing the units of 60 years operation or constructing new power plants is indispensable.

Figure 8: Current status of investigation for nuclear power in Japan (as of June 2018)




Coal has been recognized as a secure and relatively cheap base-load power in Japan and supplied 31.6% of power generation in 2015. However, it is difficult to increase the dependence on coal to achieve the target of average $CO_2$ emissions factor. The share of coal power generation in 2030 is planned to be lowered to 26% in the INDC (METI (2015)).

## 3 Evaluation of economic impacts by our econometric models

Under the circumstances as shown before, we evaluated the economic impacts if the operation of nuclear power plants will be limited in 2030 by using our econometric models. Figure 9 and Figure 10 shows the structure of the Macro Economic Model and the Energy Competition Model respectively (Hamagata (2017)). Both of those are annual base econometric models and the parameters were calculated by the past 20-30 year records. By using these models and the Input/output Model, the impact of changes in energy policy to the macro economy can be evaluated.

Figure 9: Structure of the Macro Economic Model

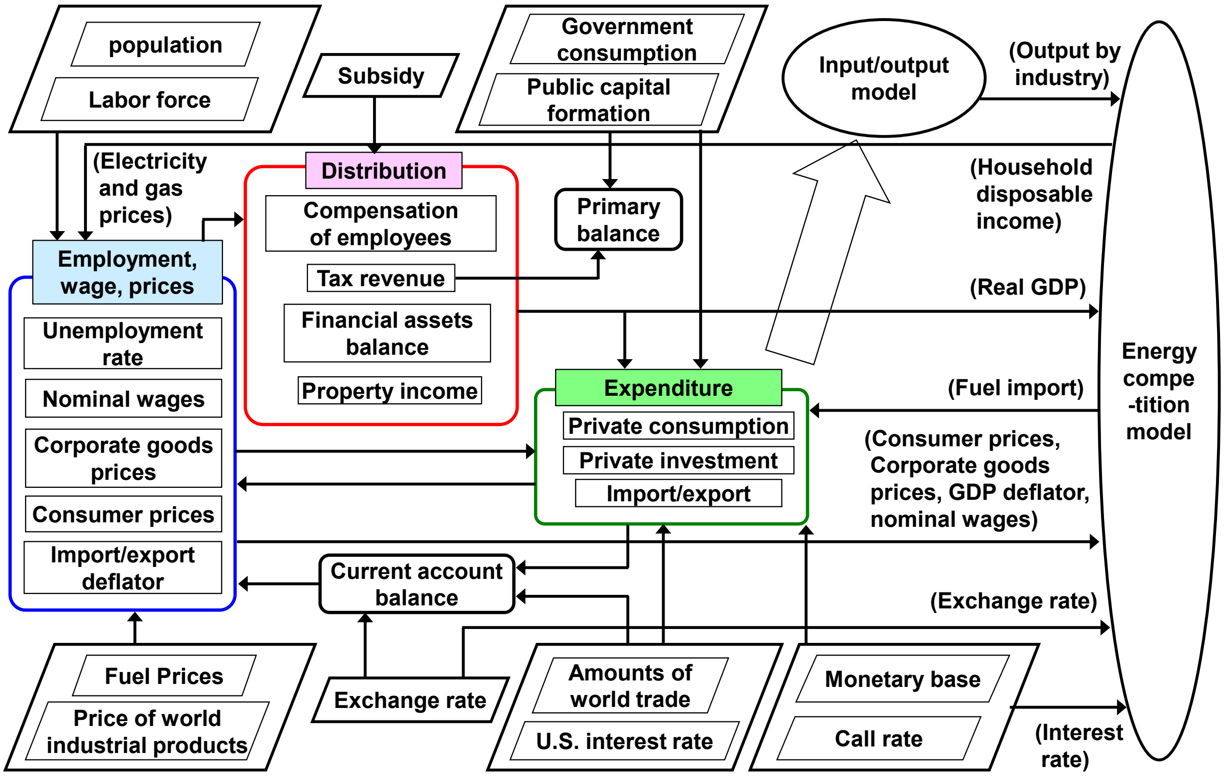
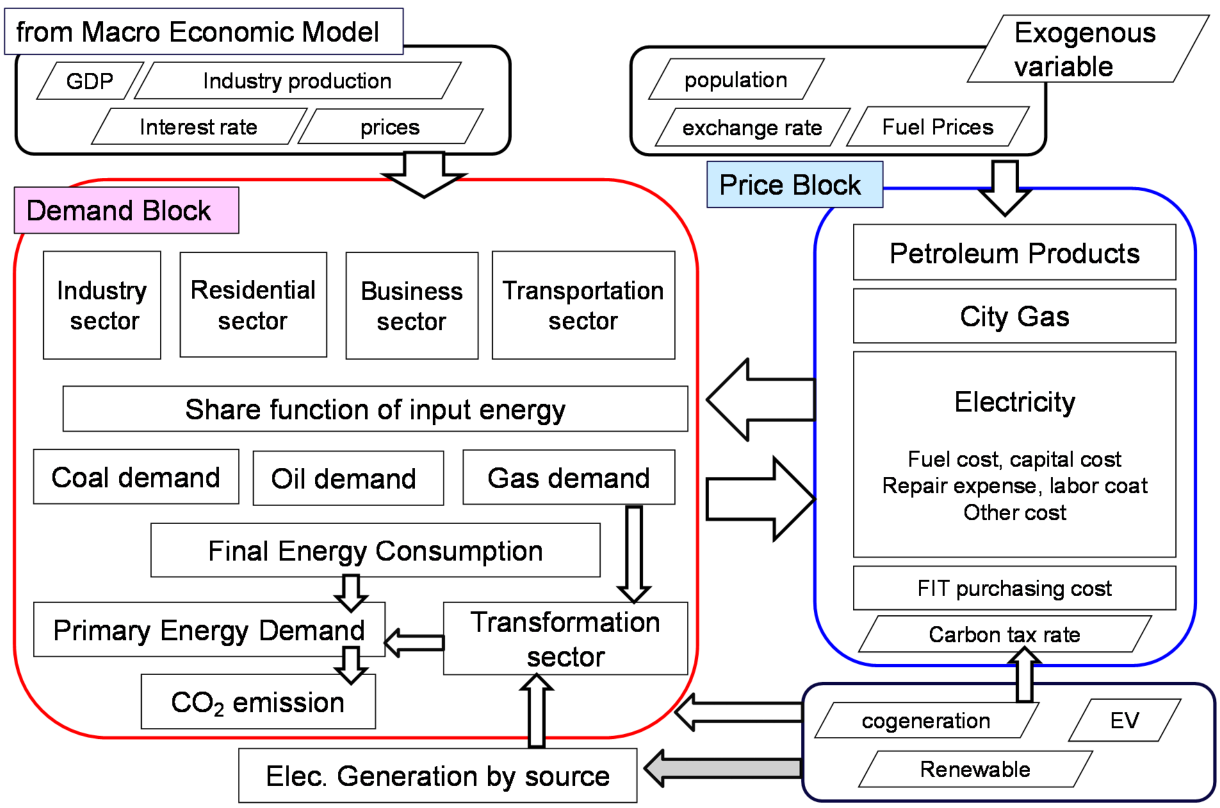



Figure 10: Structure of the Energy Competition Model



Case setting is shown in Table 2. The growth rate of real GDP in the Base Case was set to be 1.7% p.a., which is same as the governmental assumption in the INDC target, by adjusting the external conditions such as the growth rate of world economy and exchange rate. The share of nuclear power in 2030 will be 22% in the Base Case (same as the INDC target). In the other cases, it will be only 15% and the deficit will be supplemented by LNG power (the LNG Case) or solar power (the Renewable Case). The share of 15% almost corresponds to the amounts that all of existing power plants operated after 1990 and two units under construction will be operated at 70% capacity factor). In each case, the cost of power generation will rise and it will bring the increase in domestic commodity prices and, it will bring losing international competitiveness for industries and decreasing in consumption for households as the secondary effect. We evaluated its economic impacts by the changes in real GDP, real output and capital investment of industry, and the cost of electricity supply until 2030.

Table 2: Case setting

| Case Name | Growth Rate of Real GDP | Share of Power Generation | | |
|---|---|---|---|---|
| | | Nuclear | LNG | Renewable |
| Base | 1.7% p.a. | 22% | 27% | 22% |
| LNG | - | 15% | 34% | 22% |
| Renewable | - | 15% | 27% | 29% |

Figure 11 shows the changes in the cost of electricity supply. Supplementing the deficit by LNG will bring 0.5 trillion yen cost up more than the Base Case in 2030. In the Renewable case, it will be tripled to 1.5 trillion yen. It will bring the rise in electricity price, and consecutively, decrease in real income of household and capital investment by industry. Cumulative reduced amounts of capital investment until 2030 compared with the Base Case will be 2.3 trillion yen in the LNG Case and 2.5 trillion yen in the Renewable Case (Figure 12). Manufacturing industry will be suffered larger than non-manufacturing industry, because the impact of losing international competitiveness is serious. As a result, real GDP in 2030 will be decrease by 2.5 trillion yen in the LNG Case and 2.7 trillion yen in the Renewable Case (Figure 13). Energy-originated $CO_2$ in 2030 will increase by 1.9% in the LNG Case compared with the Base Case. On the other hand, it will decrease by 0.5% in the Renewable Case on account of the shrink of the economy.

Figure 11: Estimated cost of electricity supply

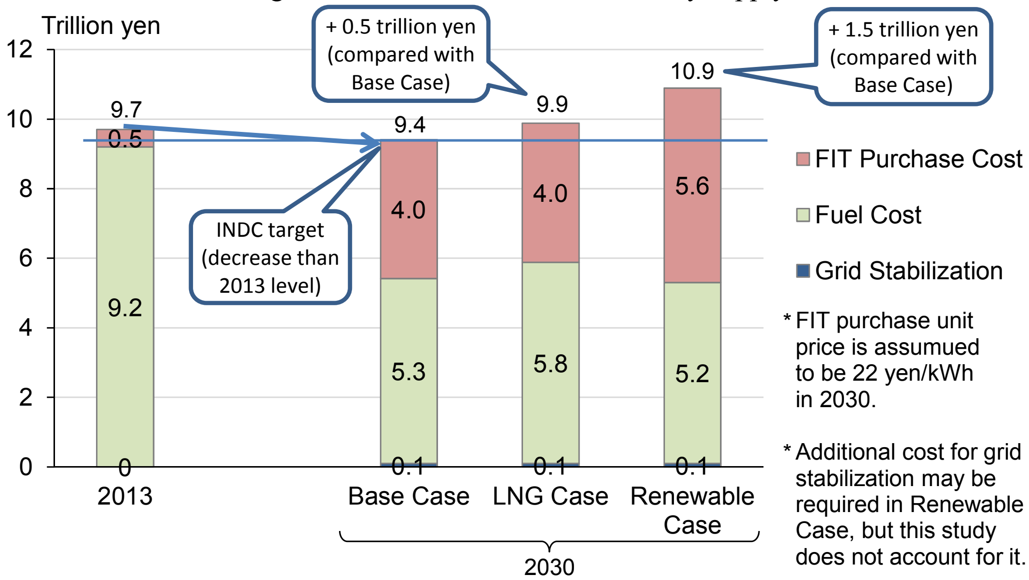


Figure 12: Changes in capital investment (compared with the Base Case)

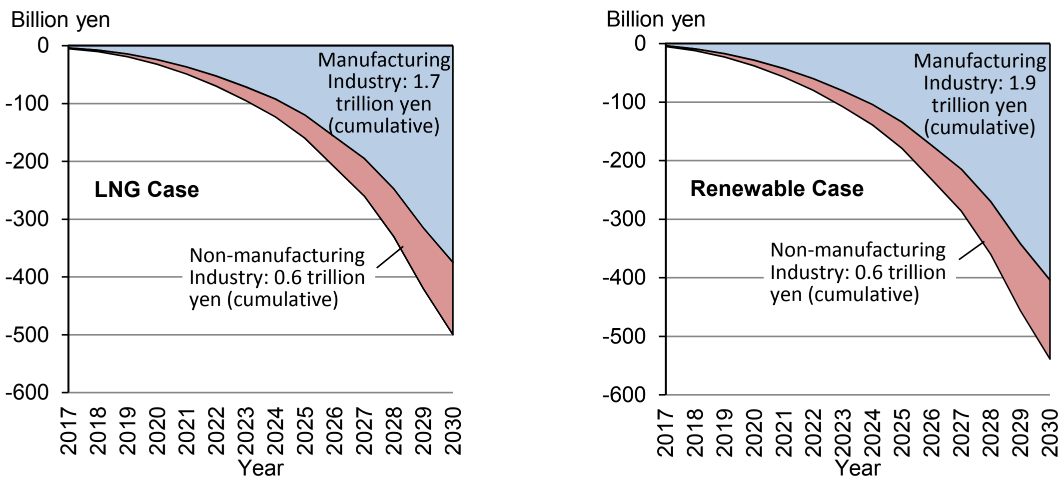
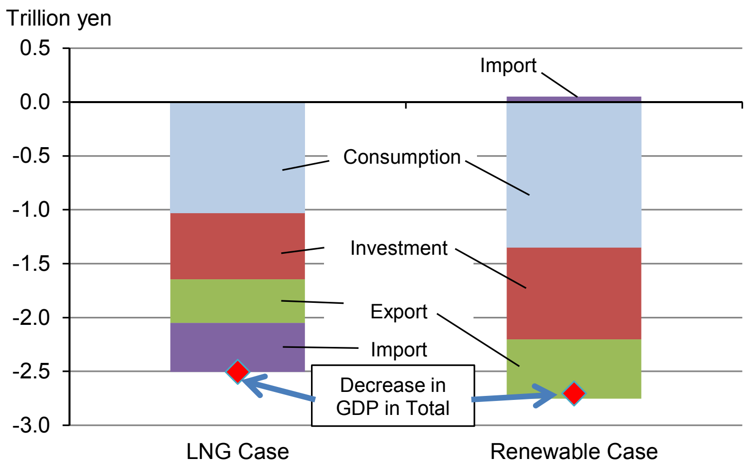



Figure 13: Changes in real GDP in 2030 (compared with the Base Case)




# 4 Conclusions

In this paper, we discussed current status of energy supply in Japan and the importance of nuclear power to achieve the INDC target in 2030. And we evaluated the economic impacts by using our econometric models. Major findings are summarized as follows:

- It is necessary for Japan to achieve not only the INDC target for $CO_2$ emission reduction, but also improving self-sufficiency rate of energy and lowering electricity costs for preserving international competitiveness of industry at the same time.
- It is considered that no single energy source can satisfy those needs, because renewables are still expensive compared with other countries.
- Recovering the use of nuclear power is expected in the INDC target, however, its pathway is still steep. Increasing the units which are approved for 60 years operation or constructing new power plants is necessary for it.
- It is expected that nuclear power is important for achieving the three issues at the same time, and non-negligible economic loss may happen if the use of nuclear power will be limited than the target in the INDC.

We used the macro-type economy models in this simulation. There is some discussions that the impacts of macro-type economy models might be evaluated larger than the case by using the computable general equilibrium (CGE) model (Goto (1995), Jorgenson (2016)). We would like to check it by constructing our own CGE model in future.

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