An Analysis on the Impacts of Carbon Pricing on the Profit of Power Generation Sector*

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There are many discussions of policy measurements in order to mitigate Greenhouse gas emissions since COP21. Carbon pricing is one of the most important solutions to enhance investments in low carbon economy. Some report pointed out that carbon intensive energy resources including thermal power plants would face difficulty in recovering their investments under stricter environment regulations. This paper discusses impacts of carbon pricing on the profits of power generation facilities. The result of this analysis shows that the profits of thermal power plants would be heavily affected by the CO2 price level particularly in a lower wholesale power market price. Some papers illustrated that a future wholesale price would be lower than current level because of changes of power generation mix and promotion of energy conservation. Future discussions of energy and environment policies should take care of the impact of carbon pricing, considering the future power generation mix and the situation of wholesale power market.

Keywords: Thermal power plant, Nuclear, Carbon price, Profitability,

1. Introduction

On April 11, 2014, the first Basic Energy Plan after the Great East Japan Earthquake Disaster was established, determining the orientation of the energy policy that Japan should be aiming at going forward. In July 2015, The Long-term Energy Supply and Demand Outlook was determined as the basis of Japan's intended nationally determined contributions (INDCs), which was created by the Global Warming Prevention Headquarters. This was followed by the Paris Agreement adopted at the Conference of the Parties (COP21). The adoption of the Paris Agreement has led to a renewed focus on the future direction of greenhouse gas reduction, and interest in carbon pricing, which puts a price on carbon, as a means for its achievement has been growing.

In this study, we consider the impact of a carbon tax or other carbon pricing policy measures that impose an explicit carbon price on the profitability of energy systems, particularly power generation facilities.

*This article is a presenting at the 33rd Conference on Energy, Economy, and Environment that Japan Society of Energy and Resources (JSER) hosted.

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2. The Debate concerning carbon pricing

2.1 Recent Debate on Carbon Pricing

Carbon pricing is increasingly referred to in high level forums at international organizations, the G7 and the like. The Carbon Pricing Leadership Coalition was announced by World Bank President Jim Yong Kim at the United Nations Climate Summit 2014 (September 2014). At the World Gas Conference Paris 2015 (WGCPARIS2015, June 2015), major natural gas companies issued a proposal concerning carbon pricing policy. The G7 have announced agreements towards the establishment of a carbon market at the Elmau and Ise-Shima Summits in 2015 and 2016 respectively,

These discussions have animated the domestic debate as well, and the Ministry of Economy, Trade and Industry and the Ministry of Environment are discussing carbon pricing through the Long-term Global Warming Countermeasures Platform and the Climate Change Long-term Strategy Advisory Board, etc. respectively. Overseas, the European Union operates the massive EU emissions trading system (EU ETS), while the Obama administration in its Clean Power Plan (CPP) has referred to a federal system for emissions trading in addition to the existing emissions trading at the state level. Elsewhere, South Korea and China have begun operating similar systems. The Scandinavian countries and others have introduced carbon taxes.

Figure 1[1] is a summary by the World Bank and Ecofys (2015)[2)] of carbon prices when carbon taxes and emission trading are included. The Japanese carbon price is low compared to other countries since only the Global Warming Countermeasures Tax, at 289JPY/t-CO_2, is recognized as such for Japan.

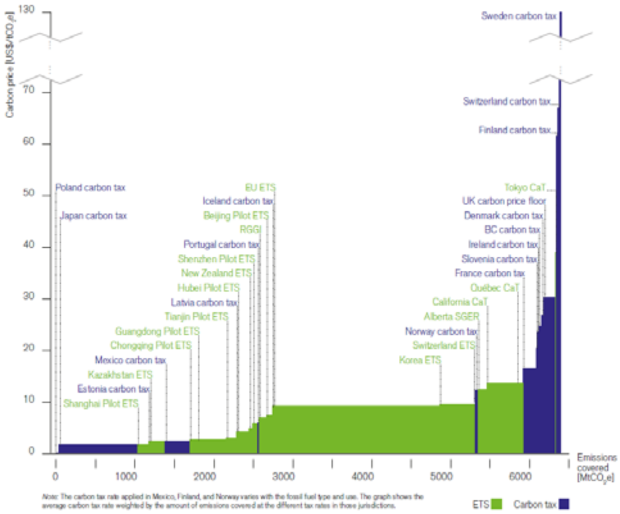

Figure 1 The Range of Carbon Prices and Current Carbon Pricing Policies[2)]

2.2 Future Outlook for Carbon Pricing

There is a possibility for the consideration of a more specific nature at the global level on carbon pricing as a useful means to reduce greenhouse gas emissions in response to the Paris Agreement in light of these discussions. The United Kingdom is debating the establishment of a floor for carbon pricing and raising it to 70 GBP/t- CO_2, and France likewise is considering the establishment of a floor. IEA (2015)[4)] assumes for the CO2 price 30USD (2014 price)/t-CO_2 in the Current Policy scenario and 30USD (2014 price)/t-CO2 in the New Policy scenario for Europe and South Korea and 100USD (2014 price)/t-CO2 in the 450 scenario for Europe, the United States and Japan.

As for carbon pricing including CO_2 prices, reports such as the one from Oxford University (2016)[4)] provide analyses of so-called "stranded assets," power generation assets for which the recovery of the investment becomes difficult due to future increases in the environment-related costs. In Japan, it is likely that discussions on greenhouse gas reduction measures including carbon pricing will deepen in forums such as the abovementioned advisory councils, but the impact should be examined carefully. Based on these considerations, this study analyzes the profitability of the power generation sector that may be affected by carbon pricing.

3. Analysis of Impact on the Power

3.1 The Wholesale Electricity Price in the Japan Market over the Years

The electricity sales price is important in evaluating the profitability of the power generation sector, and the wholesale electricity market price is an important indicator for the electricity sales price. In Japan, the day ahead spot market price at JEPX, the only electricity wholesale exchange in Japan, is referenced as the indicator for the market price of electricity. The JEPX market price is based on the marginal costs of the respective electricity sources. The Systems Design Working Group (2015)[6)] states that "the respective companies will conduct transactions on a 'marginal cost basis' under the current circumstances." The main cost items in the marginal cost of power generation are fuel costs, waste disposal costs and costs accruing during operation such as operation and maintenance costs. Figure 2 gives the seven-day moving average for the 24 hour-delivery price at JEPX. The market price varies with the rise and fall in fuel costs as the consequence of energy price shifts. It rose significantly in particular after the Great East Japan Earthquake as the nuclear power stations went out of operation. Currently, with energy prices in a slump, it is has sunk below 10JPY/kWh.

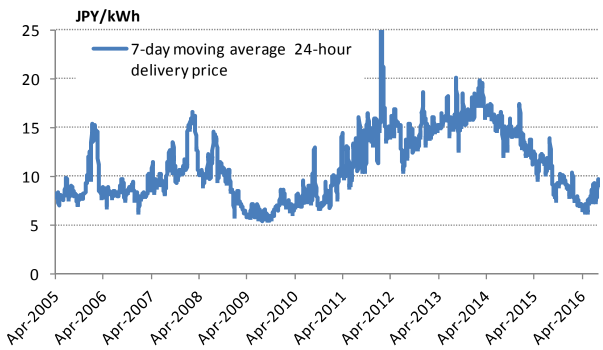

Figure 2 JEPX, Average 24-Hour Price[7)]

3.2 Simplified Calculation of the Impact of CO_2 Price on the Profitability of the Power Generation Sector

In this section, we provide an estimate of the profitability of the power generation sector by electricity source using the review sheet(s) created by the Power Generation Cost Verification

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[1] On this point, Arima (2016) 3) points out that in "considering carbon pricing in Japan, it is necessary to take energy taxes, feed-in tariffs and other indirect subsidies, regulatory measures under the Energy Conservation Act, voluntary action plans and other existing measures in addition to the Global Warming Countermeasures Tax."

Working Group[8]. Operation and maintenance costs, fuel costs and social costs are added up as the cost for operating a power generation facility, while the electricity sales price in the market is posited as revenue. The difference between the cost and revenue becomes the single year profit that is used to recover the capital costs. The comparison of the profitability of the respective electricity sources was conducted by doing simple calculations of the number of years required for the estimated single-year profit to reach the total construction cost for the respective electricity sources.

$$V_i = (com_i + cf_i + \mathrm{csc}_i) \times Cap_i \times \mathrm{HR} \times LF_i \quad (1)$$

$$\mathrm{P}_i = \mathrm{Price} \times Cap_i \times \mathrm{HR} \times LF_i \quad (2)$$

$$C_i = cp_i \times Cap_i \quad (3)$$

$$Y_i = C_i \div (\mathrm{P}_i - V_i) \quad (4)$$

V_i: Single year power generation facility operating costs; com_i: operation and maintenance costs; cf_i: fuel costs; csc_i: social costs; Cap_i: capacity; HR: hours during calendar year (8,760 hours); LF_i: load factor; P_i: Electricity sales unit price; C_i: total construction costs; cp_i: unit cost for construction; Y_i: years required to recover total construction costs; i: type of electricity source (nuclear, coal, gas)

Table 1 gives the specifications for the estimate. See item 8) in the bibliography for the values.

Table 1 Specifications for the Estimate

	Capacity (10,000kW)	Unit cost of construction (10,000JPY/kW)	Load factor (%)	O&M costs (JPY/kWh)	Fuel costs (JPY/kWh)	Social costs (JPY/kWh)
Nuclear	120	37	70	3.5	1.5	0.3
Coal	80	25	70	1.7	5.1	4.0
Gas	140	12	70	0.6	10.0	1.8

Note: The values for 2030 under the New Policy Scenario are used for fuel costs and social costs.

The following figures show how the values in formula (4) change when the electricity sales unit price and the CO_2 price—the latter is included in social costs—change.

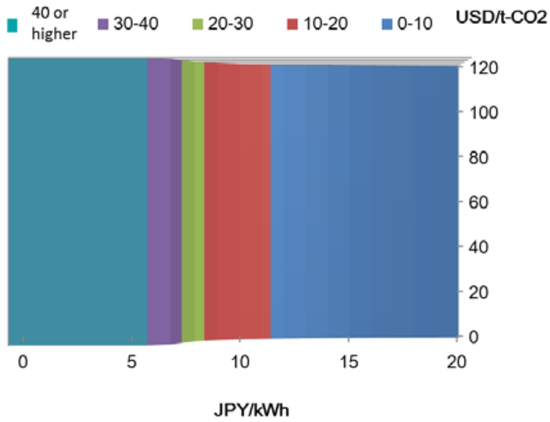

Figure 3 Analysis Results for Nuclear Power Generation

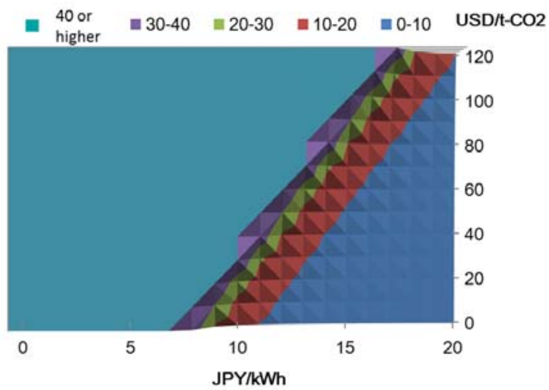

Figure 4 Analysis Results for Coal-Fired Power Generation

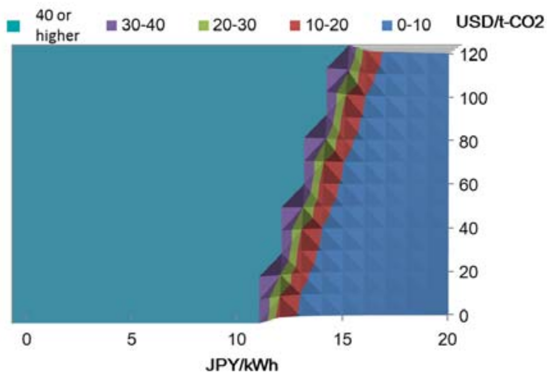

Figure 5 Analysis Results for Gas-Fired Power Generation

The results show that the impact of changes in the CO_2 price vary significantly according to the carbon density of the fuel. Figure 3 shows that a nuclear power station, which does not emit CO_2, does not have its profitability affected by changes in the CO_2 price, making it an electricity source that is strongly resistant to variation risk from the CO_2 price. Gas- and coal-fired power generation is affected by variations in the CO_2 price. Particularly when the electricity sales price is low, the cost-to-revenue ratio rises with the result that the impact of variations in the CO_2 price also grows. In the case of coal-fired power generation, with the electricity sales price at 12JPY/kWh, if the CO_2 price is 10USD/t-O_2, the single-year unit profit is 4.4JPY/kWh, so it will require nine years of the single-year profit to recover capital costs, while if the CO_2 price is 30USD/t- CO_2, the single-year unit profit is 1.0JPY/kWh, so it will require 14 years of the single-year profit to recover capital costs. Similarly, In the case of gas-fired power generation, with the electricity sales price at 12JPY/kWh, if the CO_2 price is 10USD/t- CO_2, the single-year unit profit is 1.0JPY/kWh, so it will require 19 years of the single-year profit at a load factor of 70% to recover capital costs, while if the CO_2 price is 30USD/t- CO_2, it will require 59 years to recover capital costs.

4. Analysis

As demonstrated in the previous chapter, the impact of variations in the CO_2 price on the profitability of the power generation sector is particularly large when the electricity sales price is low. Therefore, the outlook for the electricity sales price will be important when considering the profitability of the power generation sector in the future as the consequence of variations in the CO_2 price.

4.1 Future Outlook for the Wholesale Electricity Price in the Market and the Composition of Electricity Sources

Regarding future fuel prices, the IEA (2005)[4] and the Current Policy and New Policy scenarios from the Power Generation Cost Verification Working Group (2015)[8] all assume that energy prices will gradually rise. At the same time, regarding the wholesale electricity market price, there are analyses that indicate that it will remain stable or even slightly decline from current levels. Komiyama (2016)[9] estimates the 2030 electricity price in eastern Japan at around 10JPY/kWh under the assumptions for energy unit costs and share of reusable energy sources in the Long-term Energy Supply and Demand Outlook. RITE (2015)[10] in its analysis of power generation costs under scenarios with different electricity source compositions produces estimates of approximately 12-15JPY/kWh, equal to or slightly lower than the current level[2]. The outlook from the Agency for Natural Resources and Energy (2015)[11] has fuel costs for thermal and nuclear power declining from 9.2 trillion JPY in 2013 to 5.3 trillion JPY in 2030, the idea being that the availability factor for thermal power will decline in particular. In this regard, in the Long-term Energy Supply and Demand Outlook[11], oil-fired power generation, with high marginal costs, will have a 3% share in 2030, a steep decline from the 10.6% share for oil in the amount of electricity generated and received for the general electricity business[12]. Moreover, Nagai (2016)[13] points out that in the future, the wholesale electricity price will be determined in much of the time bands year-round by the short-term marginal cost of gas-fired combined-cycle power generation.

4.2 Analysis in Light of Japan's Future Outlook for the Composition of Electricity Sources

The following is an analysis of the profitability of electricity sources when gas-fired power generation becomes the electricity source that determines the market price. Figure 6 shows the variation of the CO_2 price and the concomitant variation of the profitability of the respective electricity sources in a situation where the marginal cost of gas-fired power generation is 11JPY/kWh when the CO_2 price is at 0USD/kWh.

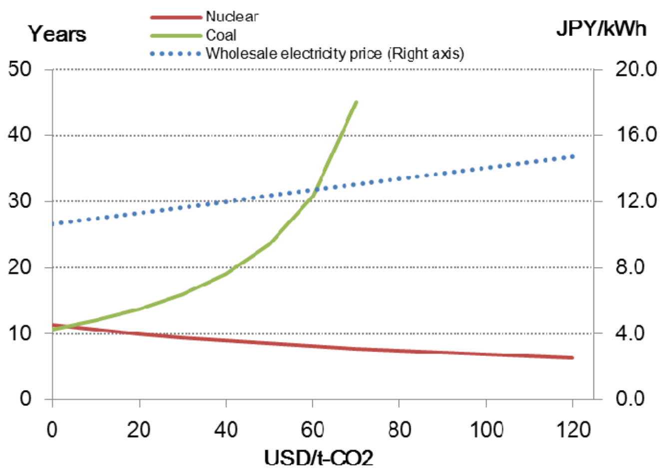

Figure 6 Profitability Variation by Electricity Source Resulting from CO_2 Price Shifts

(The sum of fuel costs and operation and maintenance costs for gas-fire power generation is assumed to be 11JPY/kWh)

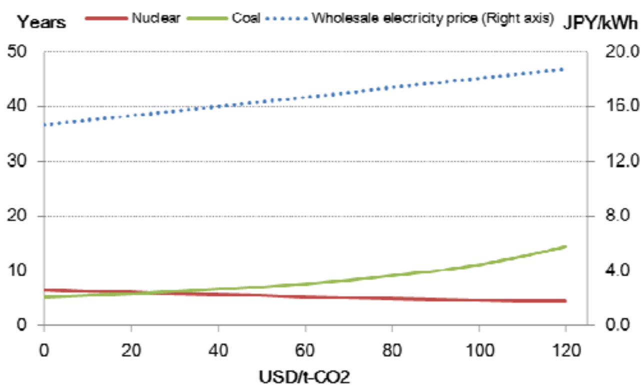

Figure 7 Profitability Variations by Electricity Source Resulting from CO_2 Price Variations

(The sum of fuel costs and operation and maintenance costs for gas-fire power generation is assumed to be 15JPY/kWh)

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2 The power generation cost calculated by RITE is not the marginal cost since appears to include the capital costs of the power generation station.

Figure 6 shows that when the CO_2 price rises, so does the marginal cost of gas-fired power generation, causing the wholesale electricity price to rise as well. As Nagai (2016)[13)] points out[3], the capital costs for facilities that are more efficient than a marginal facility can be recovered but not for those that are not. With coal-fired power generation, the costs increase by more than the rise in the wholesale electricity price. At 60USD/t- CO_2, the single-year profit declines to one-thirtieth of the total construction costs. Nuclear power does not emit CO_2, so it sees its profitability rise by the same amount as the rise in the wholesale electricity price. It should be noted that when there is the possibility that the power generation mix changes in the future with a declining wholesale electricity price as the result, there is the possibility that investment plans for coal-fired power generation both planned and existing will be affected significantly even at low CO_2 price levels in the 10-20USD range.

5. Conclusion

This study analyzed the impact of the CO_2 price in particular, an explicit carbon price, on the profitability of electricity generation facilities. It revealed that if the wholesale electricity price in the market goes down due to such factors as declining energy prices, changes in the power generation mix, and the large-scale entry of feed-in tariff (FIT) electricity sources into the wholesale market, variations in the CO_2 price will have a significant impact on the single-year profitability of thermal power generation, and that if the CO_2 price rises in the future, there is a risk that the profitability of investments in power generation will take a major hit. Policy tools for greenhouse gas reduction countermeasures including carbon pricing should be examined with care, not only for the impact on future equipment composition, keeping in mind electricity source composition and the state of electricity supply and demand, but also for the impact on existing assets in light of the supply and demand situation and market conditions.

[3] He points to the possibility that even some electricity sources among highly efficient gas-fired power generation facilities may be unable to recover capital costs when the wholesale electricity price is determined by the short-term marginal cost for gas-fired combined cycle power generation facilities.

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