[*COST EVALUATION CONSIDERING TIME-SHIFTED ELECTRICITY DEMAND OF INDUSTRIAL SECTOR IN ENERGY-CHAIN MODEL*]

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Overview

When a large amount of renewable power generation is introduced, it is essential to deal with VREs' (variable renewable energy) variability and intermittency in order to maintain the stability of the power system. Japanese government aims to install 64 GW (7.0% of total electricity generation) of solar generation capacity and 10 GW (1.7% of that) wind in 2030. If we cope with the stability only by a large amount of energy storage equipment, the energy system cost may increase significantly. Demand-side response resources are expected to be cheaper than energy storage equipment, but they are not fully utilized at present due to insufficient consumer incentives and technical difficulties.

An energy-chain model which is developed by Yamamoto [1] simulates the entire energy-chain from primary energy supply to supply-demand balance and final service demand in Japan. In this study, we incorporate time-shifting of industrial electricity demand into the model, and analyze how it affects the entire Japanese energy-chain, and evaluate its system cost.

Methods

In the energy-chain model, energy services in the industrial sector are defined as three types of heat supply service (industrial heating, high-temperature boiler and low-temperature boiler) and four types of services of non-heat service (other electricity, other gas, other liquid and other solid) as Fig. 1. We consider that a part of other electricity in industrial sector (hereinafter referred to as "industrial electric demand") can be time-shfted.

We assume that a part of electricity demand can be time-shifted by manufacturing companies in energy intensive industry which can build up a certain amount of stock of the products. In addition, the power consumption for one week does not change depending on the time-shifting of electricity demand, since it does not affect the weekly production volume of the companies. Based on the state in which industrial power demand remains unshifted, three cases are simulated where the rate of time-shifted electricity demand volume is 1%, 3% and 10% to the total industrial electric demand.

Results

Fig. 2 shows the change in electricity generation capacity. The capacities of LNG combined cycle (LNGCC) and lithium-ion (Li-ion) batteries in time-shifted cases are smaller compared to the base case. The capacities of other power sources (nuclear, hydro, coal, IGCC, LNG, petroleum, fixed pumping, variable pumping, NaS battery, wind, solar) are stable. As the percentage of time-shifed volume increased, the generation capacity decreased monotonically, but the generation capacity reduction per unit adjusted time-shifting rate decrease.

Table 1 shows the conversion of total costs and CO_2 emissions into per kWh of time-shifted industrial electricity demands. Total cost consists of fixed costs which includes equipment costs from power generation to final service demand, and variable costs such as fuel costs and operation and management costs. In each case, the fixed cost portion is larger than the variable cost portion in the total cost reduction. The reduction of the total cost and the CO_2 emission per time-shifted demand are almost constant among the three cases.

Fig. 3 shows the calculated total cost of energy-chain in the base case and 1%, 3%, and 10% time-shifted cases. The total cost was reduced by 8.9 billion JPY in 1% time-shifted case compared with the base case. The total cost reduction increase gradually from 1% time-shifted case to 10% time-shifted case.

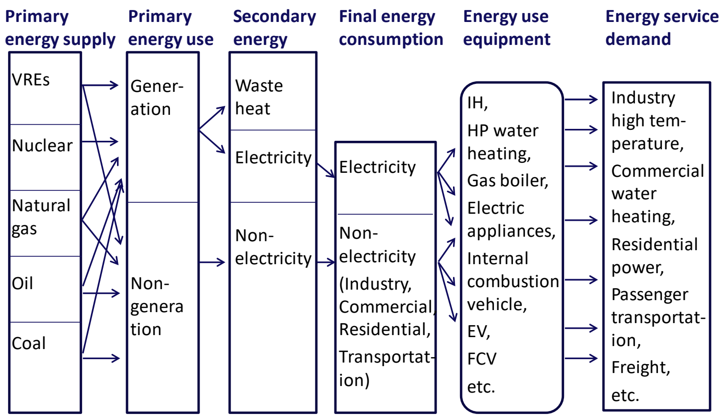

Fig. 1. Energy-chain model structure

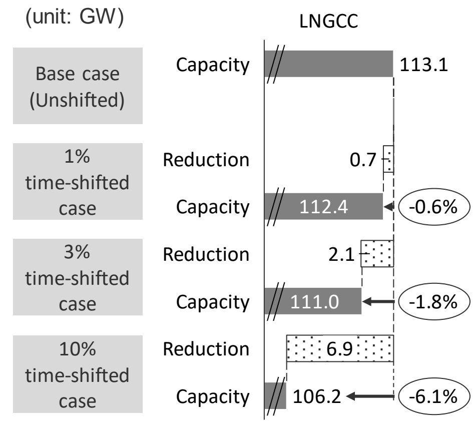

Fig. 2. Generation capacity of LNGCC and Li-ion battery

	Rate of time-shifted industrial electricity demand		
Cost	1% case	3% case	10% case
Total cost reduction (JPY/kWh)	5.68	5.63	5.51
Variable cost (JPY/kWh)	1.39	1.39	1.28
Fixed cost (JPY/kWh)	4.29	4.25	4.22
Reduction of CO2 emission from power generation sector (kg-CO2/kWh)	0.020	0.019	0.018

Table 1. Cost and CO2 emission change per time-shifted electricity demand

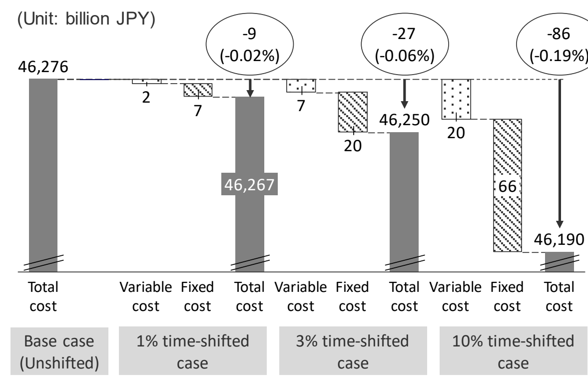

Fig. 3. Total cost of the energy-chain

Conclusions

The savings of total cost of energy-chain was 5.68 JPY / kWh per time-shifted electricity demand in 1% case. It would make sense to allocate some of the total cost savings to financial incentives for the consumers who accept time-shifting of electricity demand. In addition, it is worth considering that designing incentives in consideration of the CO_2 emission reduction effect. Note that the this calculation results are those in a whole Japan, and may vary by regional locations. The benefit of time-shifted industrial electricity demand may be greater if the amount of VREs is large enough in the region.

It is also characteristic that fixed costs accounted for about three-quarters of the total cost savings. The reason for the fixed cost reduction is leveling of the peak load that shifts the demand curve.

This study showed a reduction in total cost. The ancillary service market which is scheduled to be established after 2021 will be useful to leverage time-shifting of the industrial electricity demand by taking into account of the total cost reduction of entire energy-chain as the source.

References

[1] Hiromi Yamamoto, "An Effect of Electrification and Active Operation Time-Patterns of Electric Appliances Calculated by an Energy-Chain Model in Japan", Journal of Japan Society of Energy and Resources, Vol. 40, No.6, 2019