Consistency between carbon neutrality and spatial issue of renewable energy: A case in Japan

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Overview

Japanese government declared its objective to reduce greenhouse gas emissions to net-zero by 2050. To meet this ambitious target, futher expansion of renewable energy is expected. However, some of these plants—for instance, those in forests —had a negative effect on the local environment and wildlife. Given these facts, Japanese gorvenment considers now spatial planning called "positive zoning" to determine the area where a few or no negative effect on nature for the installations of photovoltaic (PV) system and wind turbines. On the other hand, the expansion of renewable energy toward carbon neutrality and spatial planning that may regulate the installation is trade-off relationship. Hence, it is essential for decision makers to understand how total amount of renewable energy depending on spatial planning can affect realizing carbon neutrality.

Up to now, several studies conducted scenario analysis for carbon neutrality in several countries. However, previous studies on this topic have not necessary paid attention to the concistency between carbon neutrality and spatial planning.

Here, this study aimed to assess the impact to energy system by spatial planning under carbon neutrality. For this, this study developed installation scenarios for renewable energy according to a probability of local environment or conflicts with stakeholders. Moreover, this study assessed energy mix according to developed scenarios using "technology selection model" that determine combination of technologies to realize minimum energy system cost.

As results, in the case that PV system and wind turbines are fully installed only in the areas with a few or no competation area (Minor conflict areas), the percentage of renewable energy in total generated electricity in 2050 is 48%. Hence, it is necessary to utilize the other technologies such as nuclear power plant, CCS, ammonia power plant, and so on. On the other hand, in the extreme case that generated electricity is covered by only renewable energies, 156 GW capacity of PV system and 38 GW capacity of wind energy system must be installed in farmland and forest, respectively.

Thus, this study revealed that spatial issue of renewable energy is critical to realize carbon neutrality in Japan. The strategies to realize carbon neutrality significantly depends on local spatial planning. It is necessary to carefully consider this trade-off relationship when both strategies toward carbon neutrality and spatial planning is considered.

Methods

First, this study developed installation scenarios for renewable energy according to a probability of local environment or conflicts with stakeholders. Technicaly or legally available area for installation were classified into three levels depending on the degree of difficulty (Table.1). Second, potential capacity of PV system and wind turbines in each classified areas are estimated using Geoinformation system (GIS). Finally, based on the developed scenarios, this study assessed energy mix using "technology selection model" that determines combination of technologies to minimuize energy system cost.

Table 1. Conflict level classifications within available lands

	PV system and On-shore wind			Offshore wind		
	Slope	Forest	Farmland	Distance from shore	Shipping density	Fishery rights
Major conflict	< 30 º	Included (only wind)	Included (only PV)	0–5 km (visual angle: > 2º)	21*–30 ships/month	Inside fishery rights
Moderate conflict	< 30 º	Excluded	Excluded	5–10 km (visual angle: 1–2º)	4–20 ships/month	None (all fishery rights-related
Minor conflict	< 10 º	Excluded	Excluded	> 10 km (visual angle: < 1º)	0–3 ships/month (< 1 ship/week)	conflicts area considered major conflict area)

Results

In the case that PV system and wind turbines are fully installed only in the area with a few or no competation area (Minor conflict areas), the percentage of renewable energy in total generated electricity in 2050 is 48%. Even if all existing or planned nuclear power plants are fully worked, total generated electriricy from both energies does cannot fulfill total electricity demand in 2050. Hence, it is necessary to utilize the other zero emission technologies such as CCS, ammonia power plant, hydrogen power plant (Fig.1).

On the other hand, in the extreme case that PV system and wind turbines are allowed to install some restriction areas including forest or farmland (Major conflict areas), the genelated electricity from both energy may fullfill total energy demand in 2050 in the simulation. However, in order to actually realize this scenario, 156 GW capacity of PV system and 38 GW capacity of wind energy system must be installed in farmland and forest, respectively. Furthermore, average cost in power sector was also increased becaused of capital costs of solar and wind energy while fuel cost decreases (Fig.2).

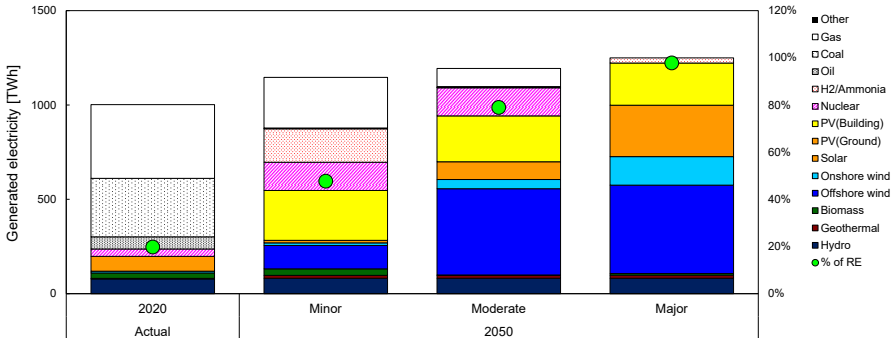

Fig.1 Generated electricity in 2050 [TWh]

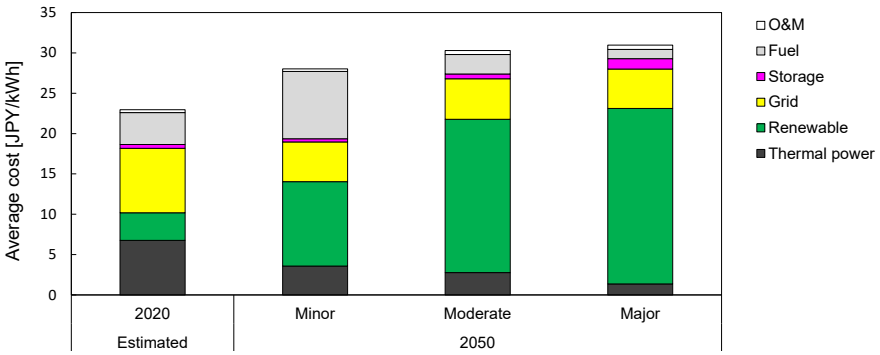

Fig.2 Average cost in power sector [JPY/kWh]

Conclusions

This study revealed that spatial issue of renewable energy is critical to realize carbon neutrality in Japan. If PV system and wind turbines are installed only in minor conflict areas, it is important to utilize various technologies such as nuclear power plant, CCS, ammonia power plant, hydrogen power plant. On the other hand, if these energy are installed even in some restricted areas, it is essential to carefully consider the environmental compatibility, competition with other industry including farming, or social acceptance.

This study provides fundamental insights into the development of future energy policies in Japan according to their environmental compatibility and competition between PV systems and onshore wind turbines. Thus, this study showed the strategies to realize carbon neutrality critically depends on spatial planning.