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Time-series evaluation of net energy potentials of solar power generation and electric vehicles in Japan

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ABSTRACT

In order to introduce renewable energy and electric vehicles in a coordinated manner, the complementary relationship between them needs to be quantitatively identified and policies developed. Therefore, this study conducted a time-series evaluation based on electric vehicle demand, solar power potential, and electric vehicle potential in Japan. As a result, it was found that many municipalities can achieve more than 99% self-sufficiency in the maximum introduction case, however in urban areas, renewable energy and electric vehicles alone cannot achieve net-zero self-sufficiency. Furthermore, it was found to be affected by charging restrictions. It is importance of peak shifting by charging other types through non-automobile recharging.

Keywords: PV, EV, charge and discharge, potential evaluation

NONMENCLATURE

Symbols	
D	electricity demand
F_e	electricity consumption of the car
P_{net}	Net electric energy
PPV	Solar power generation
P_{net}	Charging energy

1. INTRODUCTION

The IEA's 2050 net-zero scenario is a pathway to decarbonization [1]. Japan has also set a goal of 46% reduction by 2030 and net zero by 2050. To achieve this goal, energy decarbonization is indispensable, and renewable energy is seen as a promising option. On the other hand, solar power can only be generated during the daytime, when renewable energies become the main source of power. Storage facilities will be needed to meet nighttime demand. In addition to storage batteries, the use of electric vehicles such as V2G is being studied [2]. In order to introduce renewable energy and electric vehicles in Japan in a coordinated manner in the future, it is necessary to develop an introduction policy that takes advantage of Japan's regional characteristics. In this study, a time-series evaluation based on publicly available data is conducted for use in policy making. For 45 prefectures, excluding islands, we evaluated electricity demand, photovoltaic potential, electric vehicle potential, and self-sufficiency.

2. SIMULATION CONDITIONS AND CALCULATONS

2.1 Outline

In this study, net electric energy is obtained from electricity demand, renewable energy potential, and the charge/discharge potential of electric vehicles. A positive net value indicates a large electricity demand, while a negative net value indicates a large charge/discharge potential of renewable energy and electric vehicles. This is calculated hourly, and the percentage of time with negative net electricity to 8760 hours is calculated as the self-sufficiency rate.

2.2 Demand and Installation setting

The net electric energy P_{net} is composed of the electricity demand D, the electricity consumption of the car F_e, solar power generation P_{pv} and charge used at that time P_c as shown in Equation 1.

$$P_{net} = D + F_e - P_{pv} - P_c \quad (1)$$

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Electricity demand was estimated as hourly electricity demand for each prefecture based on annual electricity demand by prefecture from METI Electricity Statistics [3] and hourly electricity demand for each area. PV generation was only used the renewable energy in this study, and hourly solar radiation settled average year, optimum tilt angle, azimuth angle 0° and prefectural capitals. The area was estimated from the potential of each prefecture to introduce solar power generation from the Ministry of the Environment and was used as hourly solar power generation potential [4]. The number of electric vehicles was estimated using the number of cars owned by each prefecture [5] as shown Fig. 1, and the electric vehicle penetration rate was set; the battery capacity per car is 62 kWh, the initial charge is 50% of capacity, the stopping rate is 90% [6], the electricity consumption is 7 km/kWh, and the charge and discharge current limits and the percentage of capacity available for charge and discharge are variable values.

In this study, two cases are set as conditions. In the maximum introduction case, where the charging and discharging current limit is 50 kW, the percentage of capacity available for charging and discharging is 80%, and the electric vehicle penetration rate is 100%. In the charge restriction case, charging and discharging current limit is 6 kW and the ratio of capacity available for charging and discharging is limited to 50% from the maximum installation case.

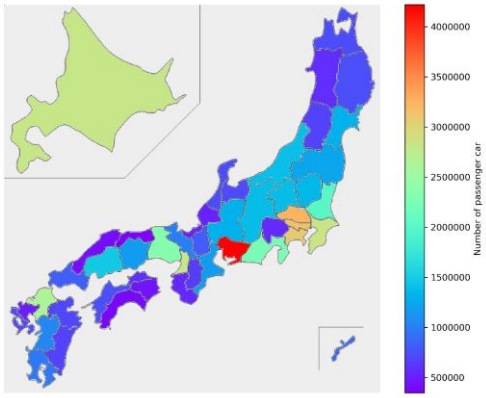

Fig. 1 Number of cars owned by each prefecture

3. RESULTS AND DISSCUTIONS

3.1 Relationship between the PV potential and Demand

Fig. 2 shows the 3.1 the relationship between the PV potential and demand. The red dotted line was average demand, blue dotted line was average renewable energy potential and green line was equilibrium line between demand and potential. In urban areas such as Tokyo, Osaka, and Kanagawa, demand far exceeds renewable energy potential. And then, Aichi and Chiba, where demand is large, also have large renewable energy potential. Although Ibaraki and Tochigi are located close to Tokyo, they are below the green line in the figure, which means that their potential exceeds demand and they could supply Tokyo.

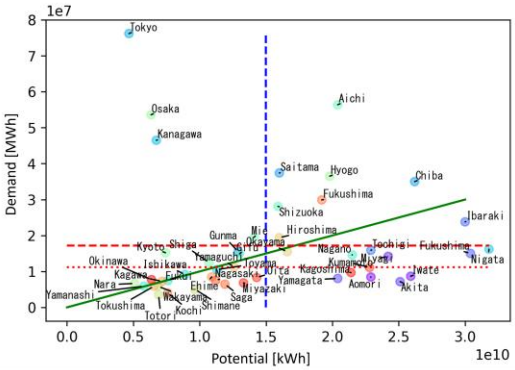

Fig. 2 Relationship between the PV potential and demand

3.2 Time-series evaluation in each area

In the maximum introduction case, the net electricity consumption is negative for all time periods in 25 of the 45 prefectures, as in Ibaraki Prefecture in Figure 3. It is meaning that the self-sufficiency rate within the prefecture is 100%. In addition, all prefectures, including those with high demand such as Ibaraki Prefecture and Tokyo shown in Figure 4, reached the upper limit of their recharging capacity, indicating that there is sufficient renewable energy potential for the number of automobiles owned. On the other hand, due to high demand in Tokyo, there are 4371 hours (50.1% of the self-sufficiency rate) in which the net amount of electricity is positive.

In the charge restriction case, the number of prefectures where the net amount of electricity is negative for all hours is reduced to 3 prefectures. In Ibaraki Prefecture, 52 hours are positive (99.4% of the prefecture's self-sufficiency rate).

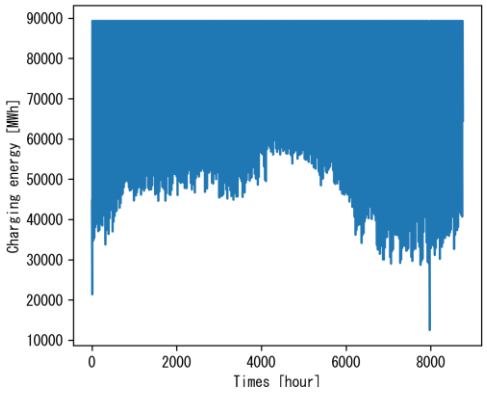

Fig. 3(a) Charge energy in Ibaraki

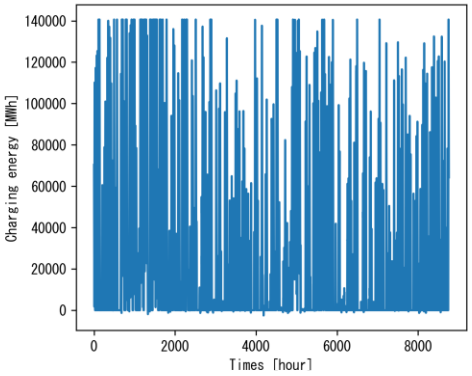

Fig. 4(a) Charge energy in Tokyo

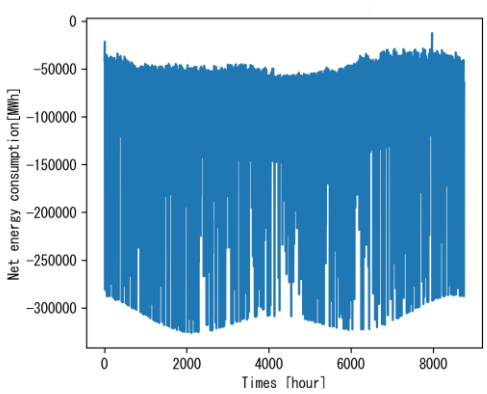

Fig. 3(b) Net energy consumption in Ibaraki

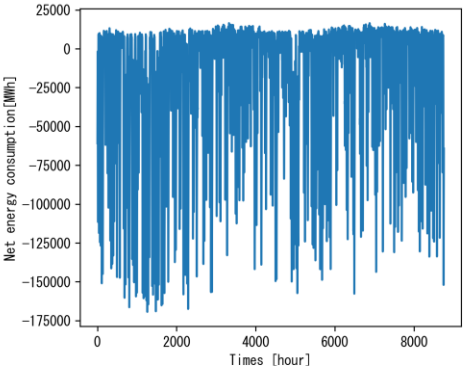

Fig. 4(b) Net energy consumption in Tokyo

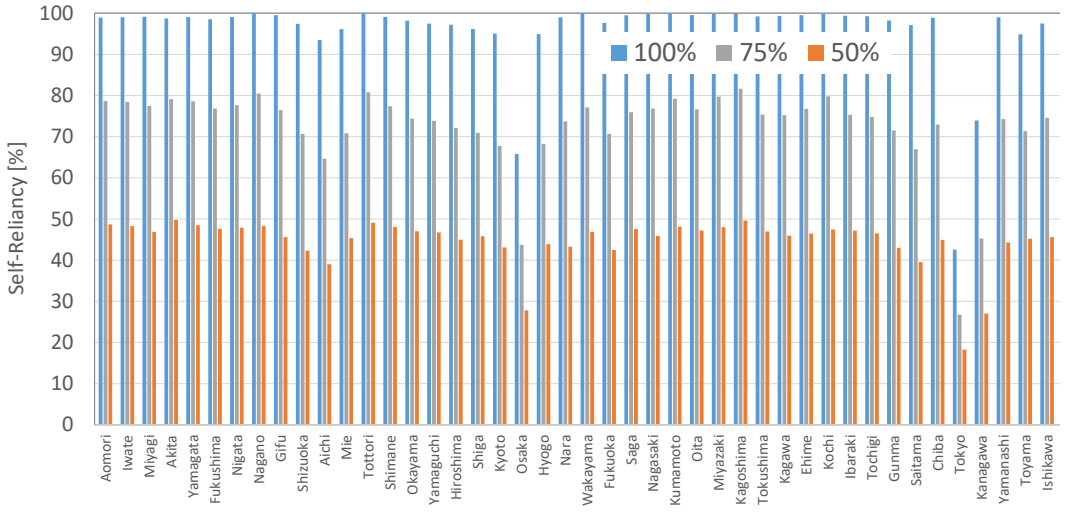

Fig. 5 self-sufficiency rate

4. CONCLUSION

Many municipalities can achieve an in-prefecture self-sufficiency rate of 99% or higher, even in the maximum introduction case. However, it is difficult to achieve a single 100% self-sufficiency rate in urban areas, and the in-prefecture self-sufficiency rate is greatly affected by the charging capacity constraints.

Therefore, while it is needed to utilize automobiles, it is still important to shift peaks by recharging renewable energy through storage batteries. It was also indicated that it is essential to build the energy-mix using other renewable energies and energy sources such as hydrogen.

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DECLARATION OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. All authors read and approved the final manuscript.

REFERENCE

[1] IEA, NetZero by 2050 - A Roadmap for the Global Energy Sector-, 2021

[2] Timothy D. Hutty, Alejandro Pena-Bello, Siyuan Dong, David Parra, Rachael Rothman, Solomon Brown. Peer-to-peer electricity trading as an enabler of increased PV and EV ownership. Energy Conversion and Management 2021; 245:114634

[3] METI Agency for Natural Resources and Energy, Electricity Survey Statistics, 2020

[4] Minister of the Environment, Renewable Energy Potential System, 2022

[5] Automobile Inspection & Registration Information Association, Statistics of Number of Automobiles Owned, 2020

[6] Mohri Y, Wakai R, Yamamoto S. An Analysis about the Characterstic of Car Ownership, Traveling, and Parking Using OD Data of Rord Traffic Census. Proceedings of the 53rd Annual Conference on Civil Engineering and Planning 2016; 43-07: 1855-1859