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TSUKUBA GREEN HOLONISM TOWN (II)—EXAMINING A PRELIMINARY ENERGY DEMAND–SUPPLY OUTLOOK

1 Ichiro Sugimoto, 2 Kenji Morita, 2 Hiroyuki Mitsuishi, 3 Masayoshi Ishida*
[1] Laboratory of Energy & Human Life Science Inc., 3-6-2, Asahigaoka, Ikeda-city, Osaka, Japan
[2] Japan Automobile Research Institute, Environment Research Division, 2530, Karima, Tsukuba, Ibaraki, Japan
[3] University of Tsukuba, Faculty of Engineering, Information and Systems, 1-1-1, Tennoudai, Tsukuba, Ibaraki, Japan

*Corresponding author e-mail: ichiro@energy-and-humanlife.com

ABSTRACT

This study proposes a draft system design for a solar photovoltaic (PV)-based energy community as an example of "Tsukuba Green Holonism Town" in Japan, as described in the previous report, "Building A Carbon-Neutral Community," and examines a preliminary energy demand-supply outlook in 2030. The energy outlook includes an allocation plan of zero-emission energy sources in the Ibaraki Prefecture and a set of residential electricity and heat demands estimated in winter, summer, and the other seasons. Japan decided to increase renewable energy sources (RES) from 18% in 2019 to 36%-38% energy mix in 2030, thus we are urged to deploy a considerable amount of RES in each region. The preliminary outlook identifies a particular problem in the PV-based energy community in Japan. Furthermore, an example of solving this problem is also suggested.

Keywords: energy community, renewable energy resource, solar photovoltaic, power-to-hydrogen, and fuel cell

INTRODUCTION

Japan fixed the sixth strategic energy plan on October 22, 2021, and decided to increase renewable energy sources (RES) from 18% in 2019 to 36%-38% energy mix in 2030 [1], therefore we are urged to install a considerable amount of RES in each region. Since 2013, the Tsukuba 3E Forum's workgroup has been discussing a low-carbon community in Tsukuba City [2] and developing a concept called "Tsukuba Green Holonism Town," which aims to implement a carbon-neutral community in harmony with its residents and workers by 2030 [3]. This study proposes a draft system design of an example of Tsukuba Green Holonism Town in Japan, which is a solar photovoltaic (PV)-based energy community, and examines the community's preliminary energy outlook for 2030. The preliminary outlook identifies a specific problem that PV dominant systems in Japan have, and a rational solution to this problem.

PV–BASED ENERGY COMMUNITY

This is an example of Tsukuba Green Holonism Town. A draft system design of this community, an allocation plan of zero-emission energy sources near and in the community, and a preliminary energy supply and demand outlook in 2030, including discussion are described below.

A Draft System Design

Fig. 1 shows a draft system design for a PV-based energy community. The energy community is expected to be equipped in an existing city area, in Tsukuba City, Ibaraki Prefecture, with about a hundred households. It consists of community facilities that are powered by PV plants and a nuclear power plant, common facilities which are installed in public buildings near the community, vehicle-to-microgrid integration (VmGI) facilities that are charging and discharging stations for electric vehicles (EV) and fuel cell vehicles (FCV), household demand-installed fuel cells (FC) and PVs, and household demand with only appliances.

An Allocation Plan of Energy Sources

Excluding hydroelectric generation, PV accounts for over 90% of RES capacity as of 2019 in Japan, and will account for over 50% in 2030. In 2030, the Ibaraki Prefecture will have two types of zero-emission energy sources: utility PV plants with a generation capacity of 399 kW for the energy community and a generated energy of 1192 kWh per day which is simulated based on solar insolation in the Tsukuba City for a year, and a nuclear power plant, Tokai No.2 Power Station with a capacity of 46 kW and generated electricity of 628 kWh per day based on its capacity factor 56.9%.

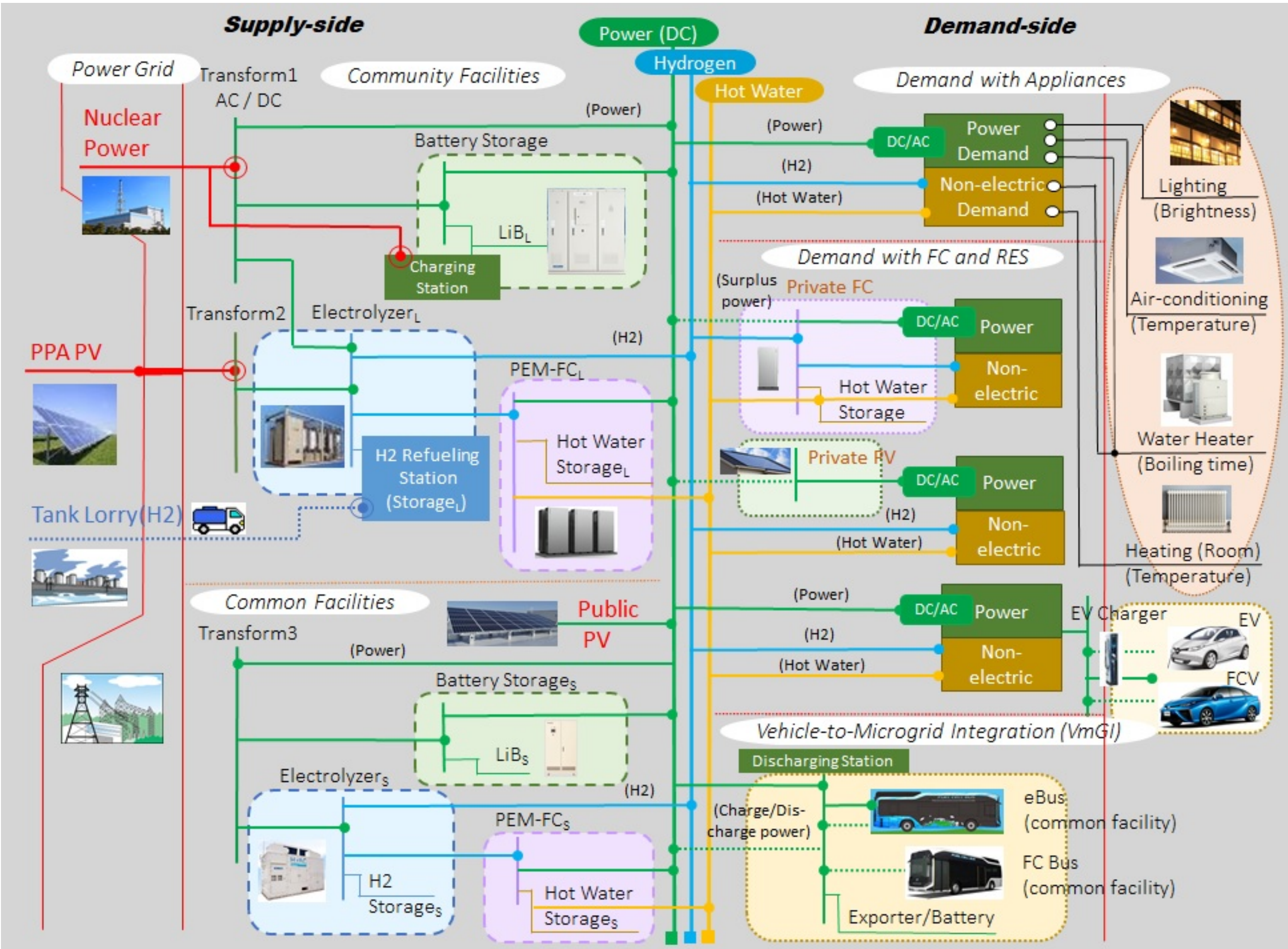

Fig. 1. System design for a PV–based energy community as an example of Tsukuba Green Holonism Town (draft)

A Preliminary Energy Outlook

According to reference [4], a set of residential electricity and heat demands in the Ibaraki Prefecture is designed in winter, summer, and other seasons. The residential demand is consistent with the electricity demand in 2010 in the Tokyo area, therefore it is necessary to consider the effects of energy efficiency and conservation (EE) in 2030. In comparison to the final energy consumption in 2013, Japan forecasts two types of EE in 2030: 10.2% and 22.9% of EE in the fifth and sixth strategic energy plans respectively [1]. In 2030, two types of EE in 2030 will lead the efficient demand, saving 10.2% and 22.9% of energy, respectively. The allocation plan and two types of energy demand, including energy-saving, indicate a preliminary energy outlook in 2030 in the PV-based energy community. Fig. 2 shows the preliminary energy outlook, which includes a preliminary energy supply from PV plants and nuclear power plants, and two types of energy demand with 10.2% and 22.9% of EE, and solar insolation in Tsukuba City in the terms of every three months. Notably, this energy outlook excludes conversion losses of AC-DC converters, power-to-hydrogen, and hydrogen-to-power, storage loss of batteries and hot water tanks, transmission loss of energy networks, and auxiliary power of the community facilities.

Discussion

Based on the allocation plan, PV accounts for over two-thirds of the energy supply, therefore solar insolation affects the amount of electric power supply in the energy community. Fig. 2 shows that energy supply varies by plus or minus 20% seasonally compared to the annual average, energy demand with 22.9% of EE varies from -15% in spring and autumn to +40% in winter compared to the annual average, and a demand-supply rate is calculated as 1.45 in winter, 0.59 in spring, 0.69 in summer, and 0.86 in the autumn.

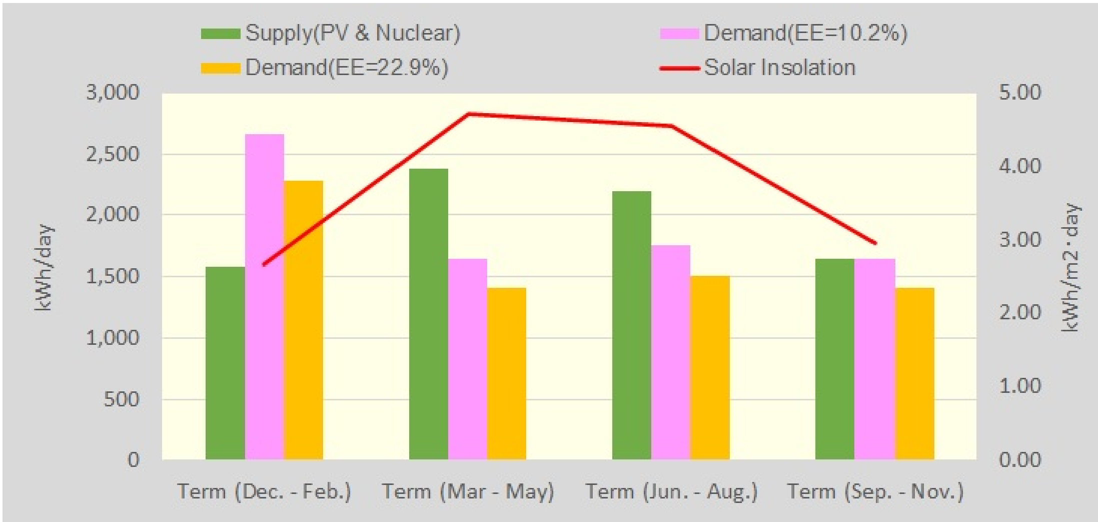

Fig. 2. Energy outlook of the PV–based energy community from December to November (preliminary)

The seasonal energy gap between supply and demand in winter is remarkably different from the other seasons in the PV-based energy community in Japan. These results show that the draft system combined with a demand response (DR) can balance energy in the spring, summer, and autumn if capacities of the facilities are fixed properly, but an additional system and backup mechanism is essential for the winter. An example of solving the winter energy gap is suggested, such as FCVs dispatching power at charging stations to the electric network as the VmGI facilities and an adaptive hydrogen distribution for hydrogen refueling stations (HRS), and FC cogeneration plants supplied by HRSs as the community facilities in the winter.

CONCLUSIONS

This paper proposed a draft system design of a PV-based energy community as an example of Tsukuba Green Holonism Town, and examined a community's preliminary energy demand-supply outlook for 2030. The outlook suggests that a hybrid hydrogen-battery storage and energy network mechanism combined with DR is expected to apply to the energy community effectively in the spring, summer, and autumn. As a gateway to solve the seasonal energy gap in Japan, an additional system such as FCVs for power dispatching to the community and FCs supplied by HRSs, and a backup mechanism, such as flexible hydrogen distribution for HRSs, are necessary for the winter.

NOMENCLATURE

DR	*Demand Response*	*EE*	Energy Efficiency and conservation	*EV*	Electric Vehicle
FC	Fuel Cell	*FCV*	Fuel Cell Vehicle	*HRS*	Hydrogen Refueling Station
PV	Solar Photovoltaic	*RES*	Renewable Energy Source	*VmGI*	Vehicle-to-Microgrid Integration

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