Urban decarbonization, Smart city, Energy management

Large-scale building-integrated photovoltaics installation on building facades

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Abstract

The installation of photovoltaic (PV) modules is one of the most effective measures for decarbonizing urban building stock. The considerable potential of the process has been demonstrated using building-integrated PV (BIPV) modules. Earlier studies have provided significant knowledge about the PV potential of buildings, but a detailed investigation of the large-scale installation of BIPV modules on building façades has not been undertaken. In the present study, a model for estimating the hourly PV potential of building surfaces on a regional scale was developed and applied to commercial building stock in Tokyo, Japan.

The development method first generates sensor points at equal intervals in both the vertical and horizontal directions on the surface of the building. Next, the amount of solar radiation per unit area is calculated at each sensor point. Here, the height of obstacles such as adjacent buildings is detected using GIS data by direction, and solar radiation calculations are performed taking this into account. By performing Voronoi division around the sensor points and applying the results of the sensor point estimates, the amount of solar radiation and PV power generation on the entire surface of the buildings in the target area is quantified, taking into account the effects of the shading effect by adjacent buildings.

Background & Results

Analytical results showed that the generated PV power would be capable of satisfying 15%–48% of the annual electricity demand of the building stock in 2050, based on the extent to which the PV potential of building surfaces, especially façades, was exploited. This demonstrates the usefulness of BIPV for achieving a decarbonized society. Additionally, hourly estimation results showed that, if a higher economic efficiency is pursued, the use of large-scale installation of BIPV together with rooftop-mounted PV could increase the PV power generation without altering the hourly PV power fluctuation. However, electricity demand and generation analyses revealed the negative impacts of the larger-scale BIPV installation on the power system: The reduction in asset utilization and the increase in the need for flexibility.

Significance of the research and Future perspective

This development method makes it possible to quantify the potential for BIPV in urban areas, and provides quantitative information for examining this. The results of this research will be useful for policy makers who are formulating guidelines for the use of BIPV modules. The established model can be further expanded to clarify the installation surfaces suitable for BIPV, to predict supply and demand in large-scale deployment, to evaluate the impact on electricity supply and demand operations in power systems, and to analyze the demand for power system flexibility.

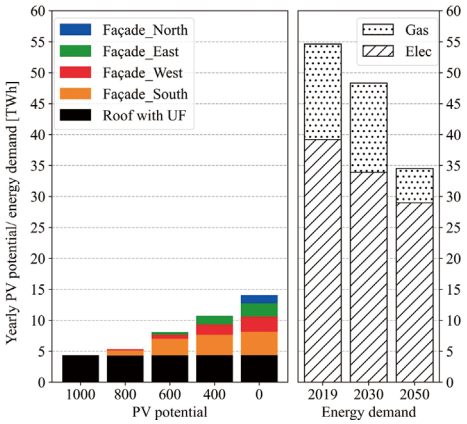

Fig. 1. Yearly PV generation potential in the case of setting each irradiance threshold [kWh/m^2/year] and yearly energy demand of each year. The word "Elec" means electricity.

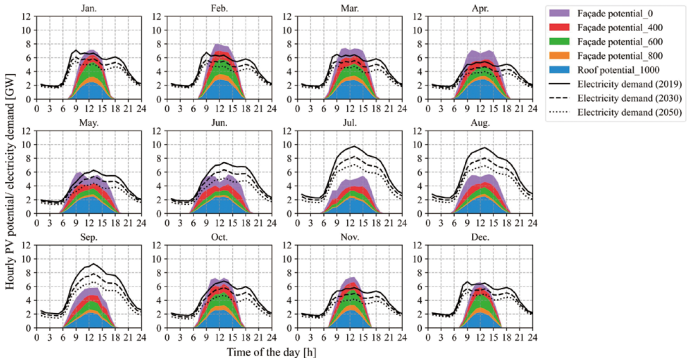

Fig. 2. Average hourly PV potential and electricity demand for sunny days in each month. Each colored area indicates the amount of added PV potential with an extension of the threshold value [kWh/m^2/year].

Patent	
Treatise	Shono, Keita; Yamaguchi, Yohei; Perwez, Usama et al. Large-scale building-integrated photovoltaics installation on building façades: Hourly resolution analysis using commercial building stock in Tokyo, Japan. Sol Energy. 2023, 253, 137–53. doi: 10.1016/J.SOLENER.2023.02.025 Yamaguchi, Yohei; Shoda, Yuto; Yoshizawa, Shinya et al. Feasibility assessment of net zero-energy transformation of building stock using integrated synthetic population, building stock, and power distribution network framework. Applied Energy. 2023, 333, 120568. doi: 10.1016/J.APENERGY.2022.120568 Perwez, Usama; Shono, Keita; Yamaguchi, Yohei et al. Multi-scale UBEM-BIPV coupled approach for the assessment of carbon neutrality of commercial building stock. Energy and Buildings. 2023, 291, 113086. doi: 10.1016/J.ENBUILD.2023.113086
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