Development of a Method for Estimating Building Photovoltaic Potential Using a 3D Urban Model (PLATEAU)

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1. INTRODUCTION

(1) Background

In October 2020, the Japan government declared that it aims to achieve zero greenhouse gas (GHG) emissions and carbon neutrality by 2050[1]. Carbon dioxide accounts for 85% of Japan GHG emissions. Therefore, reducing carbon dioxide emissions is directly related to reducing GHG emissions. In addition, the Tokyo Metropolitan Government is promoting the increased use of renewable energy sources to reduce emissions of GHG that contribute to global warming, to achieve carbon half by 2030, and to achieve zero emissions by 2050. Against this background, an ordinance was enacted for the first time in Japan in 2022 to make the installation of photovoltaic panels mandatory in newly built buildings, including single-family houses, from April 2025. With the enactment of this ordinance in Tokyo, it is thought that the same movement will accelerate nationwide in the near future.

On the other hand, even if photovoltaic panels are installed on buildings with uniform specifications, they may not generate enough power in urban areas where the roof area is smaller than in suburban and rural areas, the distance between neighboring buildings is smaller, and high-rise buildings are distributed in the vicinity, which may create shade[2]. As a result, it is expected that some buildings will not contribute as much to GHG reduction as expected. In other words, to effectively reduce greenhouse gas emissions in the entire urban space, it is ideal to be able to estimate the amount of electricity generated by each building for the entire city and propose optimal power generation facilities for each building.

(2) Objective

In order to estimate the amount of electricity generated by the installation of photovoltaic panels in more detail, this study develops a method to estimate the amount of electricity generated by each building by using a brand-new 3D urban model (PLATEAU) released by MLIT in 2020 and providing data on solar radiation and hours of sunlight. In addition, we will develop a scheme for conducting the above studies and implement to the PLATEAU for clarification of the usefulness, issues, and limitations of the scheme.

2. OUTLINE OF THIS STUDTY

In this study, in order to determine the roof area, solar radiation, and hours of sunlight of individual detached houses, we first spatially integrated the PLATEAU data with a digital residential map (Zenrin Co. Ltd.) and extracted buildings that are used as detached houses. Next, the roof area of each building was calculated, and the climate grid data from the National Land Information was spatially integrated with the roof area of each building to provide information on solar radiation and hours of sunlight for each building. Finally, the amount of electricity generated was calculated using these values, and the usefulness of photovoltaic power generation for each building was clarified. The target area of this paper is Setagaya Ward, which has the largest population and the largest number of households in Tokyo and a high density of buildings of various sizes.

3. ESTIMATION OF POWER GENERATION

This study estimate the amount of electricity generated by photovoltaic power generation for each building. First, the amount of solar radiation and sunshine hours necessary to estimate the amount of electricity generated are spatially integrated for each building. Next, we estimate the amount of electricity generated by each building considering the area of the solar panels installed on each building. Generally, solar radiation is used to estimate the amount of electricity generated by photovoltaic power generation, and there are few cases in which the hours of sunlight are considered. In Setagaya-Ward, the target area of this study, according to the climatic grid data, the amount of solar radiation is uniform throughout the entire area. However, the hours of sunlight vary from place to place. Therefore, based on the Photovoltaic Power Generation Installation Guidebook[3] , we calculated the annual power generation (Ep) and estimated annual power generation (Ep_g) for each building. Ep and Ep_g are calculated by Equations 1 and 2, respectively.

$$Ep = H \times P \times K \times 365 \quad (1)$$

$$Ep_g = Ep \times S \quad (2)$$

Where, H, P, and K denote the average daily irradiance, system capacity (kW), and loss factor (0.73) specified by NEDO, respectively. S is the value obtained by dividing the sunshine hours of the building to be estimated by the average sunshine hours over the past 30 years (1991~2020) in Tokyo based on data from the Japan Meteorological Agency. The installed area is half of the roof area[4], and the system capacity is calculated by multiplying the area by 200 W/m².

Keywords Photovoltaic, Solar radiation, Daylight hours, 3D urban model (PLATEAU)

4. EVALUATION OF POWER GENERATION

Fig. 1 shows the estimated amount of electricity generated by a detached house, and **Fig. 2** shows the estimated power generation per unit area around Sangen-Jaya Station, Setagaya-Ward. By understanding this information, we can identify areas where electricity can be generated more efficiently. According to **Fig. 2**, power generation efficiency is higher on the south side of the station. In addition, **Table. 1** shows the estimated number of households by generation for all households in Setagaya Ward. According to NEDO, the average amount of electricity generated by a house in Japan is estimated to be 6,000 to 8,000 kWh. Therefore, the results shown in **Fig. 3** are generally considered reasonable.

5. PROSPECTS OF THIS STUDY

In response to the recent trend toward decarbonization, it is possible that municipalities that have not yet considered installing photovoltaic panels on detached houses will do so on a nationwide basis in the future. In such cases, simulation of photovoltaic power generation using the results of this study will enable selection of areas and houses where photovoltaic panels should be preferentially installed, which is expected to lead to effective reduction of greenhouse gases and environmentally friendly urban development.

6. CONCLUSION

This study developed a method to estimate the amount of electricity generated by the installation of photovoltaic panels in a single detached house, thereby estimating the amount of electricity generated by each building. One of the challenges of this study is to analyze whether the electricity generated can cover the power consumption of a house in order to achieve zero emissions. To determine the power consumption, it is necessary to develop a method to estimate the power consumption per unit area of a detached house. In addition, the calculations were performed assuming that photovoltaic panels are installed over half of the roof area. However, it is necessary to consider a more detailed installation area to achieve zero emissions. Although this study conducted the estimation for only Setagaya Ward, Tokyo, we would like to clarify the usefulness of this study by applying it to a wider area, based on the above issues.

References

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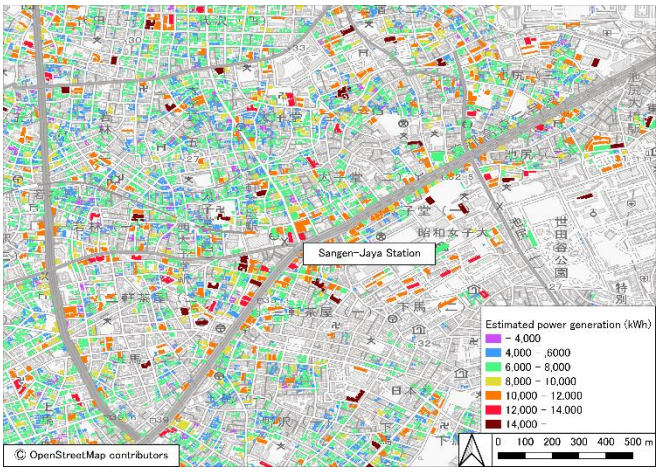

Fig. 1 Estimated annual power generation in detached houses around Sangen-Jaya Station

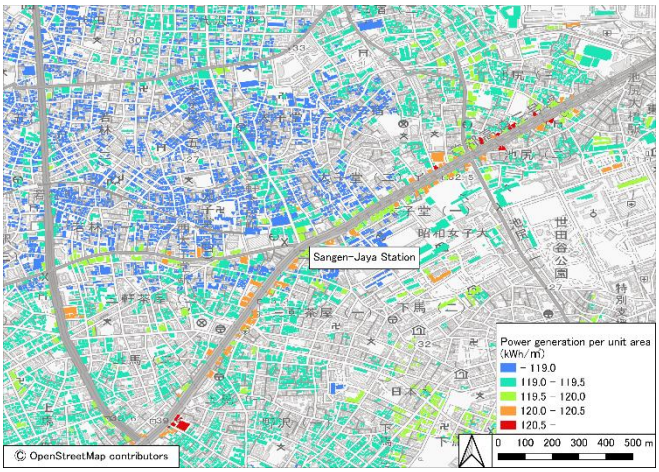

Fig. 2 Estimated power generation per unit area in detached houses around Sangen-Jaya Station

Table 1. Number of Buildings by Estimated Generation (For detached houses in all of Setagaya Ward)

Estimated power generation (kWh)	Number of households	Rate (%)
- 4,000	8,038	4.84
4,000 – 6,000	27,280	16.43
6,000 – 8,000	50,721	30.56
8,000 – 10,000	39,357	23.71
10,000- 12,000	20,367	12.27
12,000 – 14,000	10,578	6.37
14,000 -	9,663	5.82
Total	166,604	100.00