

## **Potential of electricity production by Photovoltaic in Osaka city and its thermal characteristics**

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### **Abstract**

The availability of solar energy potential in Osaka city was estimated in this study. The landuse data classified with five categories (high-rise housing, low-rise housing, industry, commercial and compounding) was used. The total solar insolation for the representative five areas was calculated for four days; summer solstice, the autumnal equinox, winter solstice, and the vernal equinox. The annual electricity production and the difference of the heat flux into buildings between with Photovoltaic and without Photovoltaic were calculated. From these results, it was found that the solar energy potential in Osaka city was 20000[GWh/year] and also the energy saving by the reduction of the heat flux into buildings was analyzed.

### **1. Introduction**

After the Tohoku Earthquake, we have faced the energy supply problem such as large-scale blackout at Kanto region. To improve energy security, we need to create the region-independent distributed energy supply system in addition to the large-scale power plants. It is very important to study various aspects of the introduction influence of the energy supply system and to provide useful information for consumer. People could make good decision by providing many choices. This study evaluates the solar energy potential in Osaka city.

There are several researches about the potential of PV (PhotoVoltaic) in the past. For instance, Japanese ministry of environment<sup>1)</sup> assessed the PV potential in Japan based on observed solar insolation. In this study we tried to model shapes of buildings in Osaka city and analyzed solar insolation.

### **2. Objective**

The purpose of this study is to suggest the PV usefulness providing the two aspects of the electricity generation and the heat flux into buildings for city planning.

### **3. Regional model**

In order to classify the land use of Osaka city, the 250m×250m mesh data made by planning and coordination bureau of Osaka city was used. This data includes landuse area, site area, gross floor area, plot ratio, and so on. Osaka city was classified with five categories; commercial, industry, high-rise housing, low-rise housing and compounding. The map classified with five categories in Osaka city in 2005 is shown in figure 1. Table 1 explains the criteria used for this categorization.

Hiroshima, Japan

Table1 Criteria for categorization

landuse ratio	Category	Plot ratio	Category	Average plot ratio landuse ratio	Average site area[m2]
<50% Residence	Resident	>300%	High rise	402%	54756
		<300%	Low rise	174%	34963
<30% Commercial structure	Commerce			55%	18013
<80% Industrial structure	Industry			95%	36412
Other	Compounding			C=16%,R=30%,I=54%	45318

※landuse ratio: (each landuse area)/(all landuse area), C:Commerce,R:Resident,I:Industry

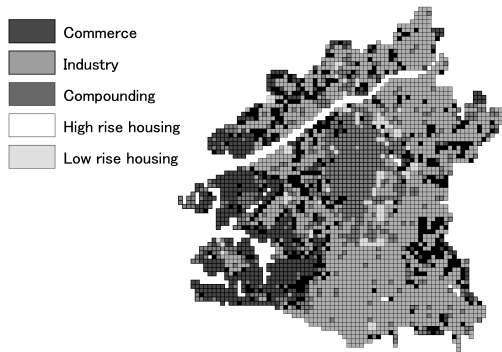


Fig.1 Five categorization in Osaka city

### 3.1 Selection method

The total solar insolation in Osaka city was calculated by the sum of meshes showed in Fig.1. Therefore it is very important to select the characteristic mesh of landuse in Osaka city. The representative of each mesh was selected by the conditions of the average landuse ratio and the average site area showed in Table 1.

The solar insolation was analyzed by selected representative mesh of each category. It was not suitable to estimate the total PV potential in Osaka city. In order to modify the difference of the solar insolation for each mesh, the landuse ratio was used.

### 3.2 Modeling method

The address of five representative meshes was identified. Floor number data and floor height data<sup>2)</sup> were used to determine the shapes of the buildings for the representative meshes. The building height was determined by assuming that one floor of resident and the other were 3m and 4m. The model of five categorizations is shown on Fig.2, 3, 4, 5, and 6, respectively.

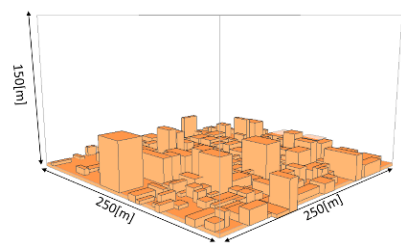
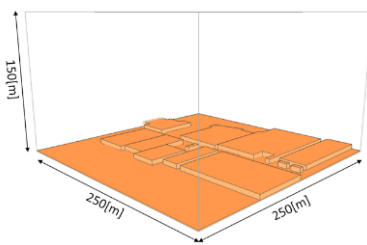
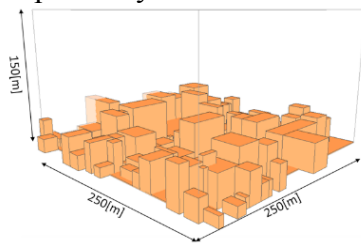


Fig.2 Commercial category, Fig.3 Compounding category, Fig.4 High-rise housing categor

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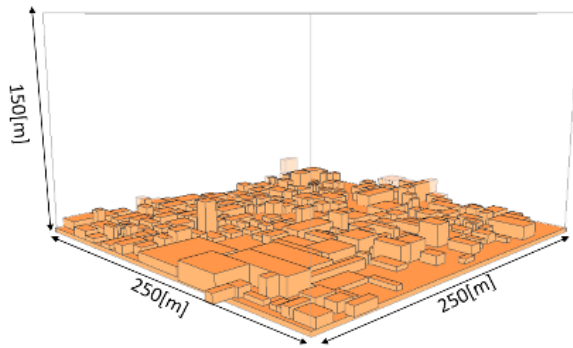


Fig.5 Low-rise housing category

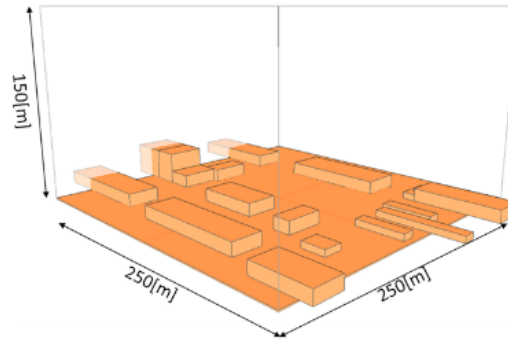


Fig.6 Industry category

### 3.3 Solar insolation analysis

A face receiving the direct solar insolation was identified by CG (Computer Graphics) method<sup>3)4)</sup> in which a parallel projection and a surface element were associated.

## 4. Result and discussion

### 4.1 Solar insolation

The solar insolation in each representative mesh for specific days was analyzed. Figure 7 shows the daily solar insolation for wall and roof of high-rise housing. The solar insolation of roof increased according to the increase of the solar insolation. But the solar insolation of wall depended on the solar insolation and solar altitude. Figure 8 shows the total solar insolation each specific day. The total solar insolation in summer solstice became the maximum and was over 3 times in midwinter. Figure 9 shows the total solar insolation of roofs and walls in five categories. The ration of walls in commercial and high-rise housing category was over 50%. Figure 10 shows the ratio of total solar insolation of each category in Osaka city. Supposing that the total solar insolation for low-rise housing was 100%, commercial, high-rise, compounding and industrial category were 83%, 70%, 54% and 38%, respectively. The solar insolation for resident category was over 50% in the total solar insolation. This differences of the solar insolation based on landuse depended on the shapes of buildings and the density of building. The urban planning may regulate this impact.

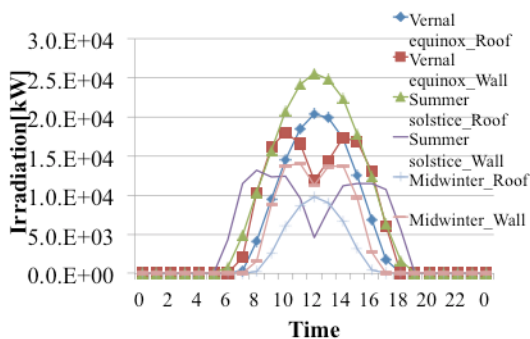


Fig.7 Solar insolation (High-rise housing)

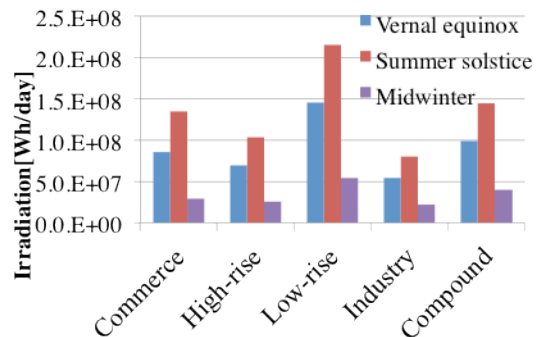


Fig.8 Solar insolation of specific day

Hiroshima, Japan

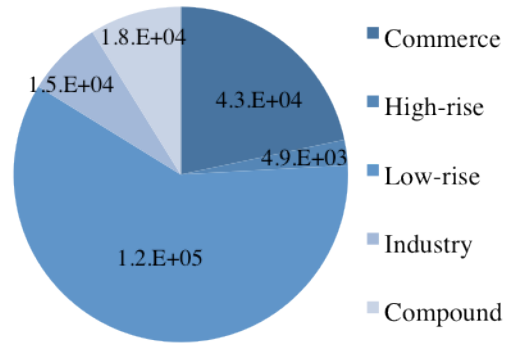
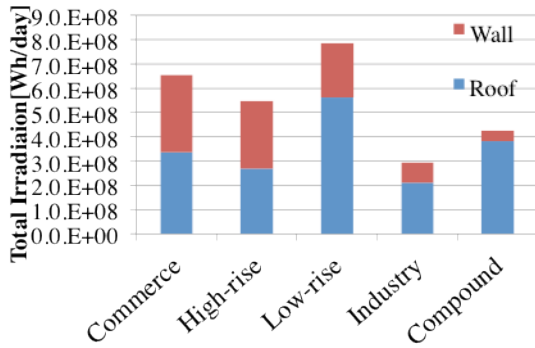


Fig.9 the ratio of wall and roof in Solar insolation

Fig.10 Annual solar insolation

#### 4.2 Photovoltaic

In order to calculate the electricity production from the solar insolation, PV panel was assumed to be installed on all walls and roofs of buildings. Due to the installation of PV, the reduction of the heat flux into building was estimated.

The simple equation (1) was used to calculate the electricity production.

$$P = I \times \eta \times A \quad (1)$$

where  $P$  is the electricity production,  $I$  is the solar insolation,  $A$  is the area and  $\eta (=0.1)$  is the PV efficiency.

In order to estimate the reduction of the heat flux, the equation (2) was used for some elements showed in Fig.11 based on the past studies<sup>5)6)7)</sup>.

$$c\rho \frac{\delta T}{\delta t} = K \left( \frac{\delta^2 T}{\delta x^2} \right) + S \quad (2)$$

where  $c$  is specific heat,  $\rho$  is density,  $K$  is heat conductivity and  $S$  is heat source/sink.

The elements near the PV panel consisted of room air, wall, outside air, glass, EVA, silicon cell, EVA, glass and outside air. The size of each element is showed in Table 2. Solar insolation, long-wave radiation, the electricity generation and sensible heat were consider as the heat source/sink on PV surface, silicon, and wall surface.

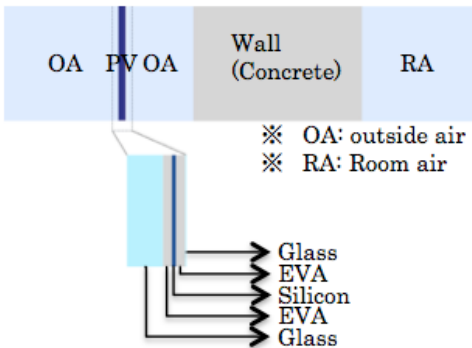


Fig.11 PV installed model

Hiroshima, Japan

Table 2 Parameter about PV installed model

	Outside air	PV					Outside air	Concrete	Room air
		Glass	EVA	Silicon	EVA	Glass			
Size[m]	0.1	0.0032	0.0008	0.00035	0.0008	0.0001	0.06	0.15	0.1
$K[W/(m \cdot K)]$	0.002	0.78	0.116	168	0.116	0.78	0.0021	1.6	0.02
$\rho [kg/m^3]$	1.163	3000	1200	2330	1200	3000	1.163	2400	1.16
$c[W/(kg \cdot K)]$	1007	500	1250	677	1250	500	1007	900	1007

#### 4.2.1 Electricity Generation

The electricity generating potential in Osaka city was calculated based on the calculated solar insolation of the five categories. It was assumed that all the surfaces of the building were installed with PV panels Fig.12 shows evaluated electricity production of five categories.

It was found out that the total production of electricity was about 20,000 (GWh/Year) . It showed that the amount of photovoltaic power potential existed about 2.6 time compared with the electricity sale in Osaka city(2009).

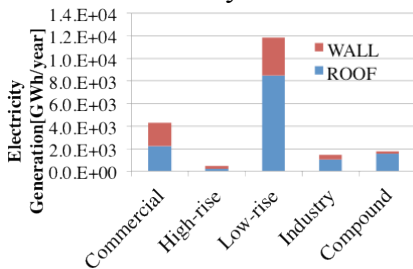


Fig.12 Electricity production

#### 4.2.2 Heat flux into building

The heat flux into buildings was calculated in 2 cases; with PV and without PV. Figure 13 shows the difference of heat flux into buildings in High-rise housing category in summer solstice day between 2 cases.

The difference on east wall had the peak in early morning and the difference on west had the peak in the afternoon. The difference on roof had the first peak in morning, the minimum on noon and the second peak in the evening. This behavior could be explained by the relation between the heat storage and the solar insolation. The additional research is required to analysis this behavior.

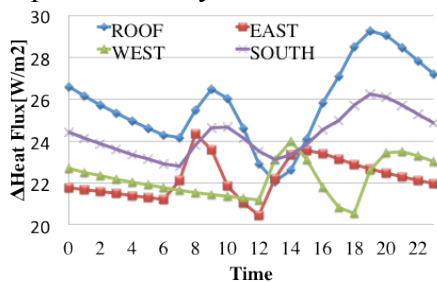


Fig.13 Daily heat flux difference (High-rise housing)

Hiroshima, Japan

## 5. Summary

The purpose of this study is to suggest the PV usefulness providing the two aspects of the electricity generation and the heat flux into buildings for city planning.

Osaka city was classified with five categories by using the 250m×250m mesh. It was found that electricity production potential from the solar energy in Osaka city was 20000 [GWh/year]. The performance of the heat flux into buildings by the installation of PV became clear. In order to confirm the representative of each category, the statistical analysis will be necessary.

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