Measurement of Energy Consumption on a University Campus by Using a Simple BEMS

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Energy consumption of a university campus was measured in 2013 and 2014. Annual electric consumption of the campus was 1.3×10⁷Kwh in 2013, and decreased about 1.1×10⁷Kwh (1%) in 2014. Annual gas consumption of the campus was 7.8×10⁶m³ (3.6×10⁶Kwh) in 2014. Electric consumption of air-conditioning and carbon dioxide emissions on campus were both estimated, air-conditioning decreased about 1.7×10⁷Kwh (9%), carbon dioxide emissions decreased about 1.1kg/m² (2.4%) in 2014. The relationship of outdoor temperature and electric consumption was examined. The correlation coefficient of outdoor temperature and electric consumption was 0.55, and correlation coefficient of outdoor temperature and electric consumption of air conditioning was 0.74.

Introduction
In our previous paper ¹, in order to realize the aim of “green campus”, the total electric consumption of buildings on the Osaka City University Sugimoto Campus were measured by using a simple “Building Energy Management System” (BEMS) for a period of one year from February 2013 to January 2014.

In this paper, we continued measurement of the total electric consumption on the university campus and report the measured results for a period of 2 years, which includes 2013 and 2014. In addition, we also estimated the electric consumption due to air-conditioning and the carbon dioxide emissions on the campus for the 2 years. The relationship of outdoor temperature and electric consumption was also examined.

1. Outline of measured subject
Osaka City University Sugimoto Campus was divided into four areas. “A” is the Humanities area, “B” is the Old Liberal Arts area, “C” is the Science Course area and “D” is the Academic Information Technology (A. I. T) center area. The detail of the campus areas is shown in Table-1.

2. Measured results
2.1 Annual reduction rate of electric consumption
By a method proposed by Ohashi ², base of electric consumption (E_base(n)) and variation of electric consumption (E_act(n)) are derived from the following formulas:

\[ E_{\text{base}}(n) = \text{base}_{\text{avg}} \times 24(h) \times D(n) \]  
\[ E_{\text{act}}(n) = E_{\text{all}}(n) - E_{\text{base}}(n) \]

Where, “E_base(n)” is base of electric consumption in month n [Kwh/month], and “n” is from January to December; “base_{avg}” is minimum value of average hourly electric consumption during holidays of Saturday, Sunday in month n [Kwh]; “D(n)” is total number of days in month n [days]; “E_act(n)” is variation of electric consumption in month n [Kwh/month]; “E_all(n)” is the total electric consumption of month n [Kwh/month].

Comparing the electric consumption of 2013 to 2014, it showed E_all(12 months) decreased about 1.1×10⁷Kwh (1%) from 1.4×10⁷Kwh in 2013, E_base(12 months) decreased about 5.0×10⁶Kwh (0.05%), and E_act(12 months) decreased about 1.0×10⁷Kwh (3.8%). The result is shown in Figure-1.

![Figure-1 Reduction rate of electric consumption of 2013 and 2014](image)

### Table-1 Overviews of measured subject

<table>
<thead>
<tr>
<th></th>
<th>A: Humanities area</th>
<th>B: Old Liberal Arts area</th>
<th>C: Science Course area</th>
<th>D: A.I.T Center area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total footprint (m²)</td>
<td>7791</td>
<td>8957</td>
<td>17834</td>
<td>2865</td>
</tr>
<tr>
<td>Total floor area (m²)</td>
<td>25365</td>
<td>27007</td>
<td>83027</td>
<td>37434</td>
</tr>
</tbody>
</table>

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</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>2335</td>
<td>1736</td>
<td>6590</td>
<td>3106</td>
</tr>
<tr>
<td>2014</td>
<td>2300</td>
<td>1704</td>
<td>6580</td>
<td>3074</td>
</tr>
<tr>
<td>Reduction rate (%)</td>
<td>1.5</td>
<td>1.8</td>
<td>0.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>
2.2 Reduction rate of energy consumption in 4 areas

The monthly energy consumption (electric and gas) of the 4 areas in 2013 and 2014 is shown in Figure-2. Reduction of electric consumption in the 4 areas is shown in Table-2.

Comparing 2014 to 2013, the reduction rate of annual electric consumption is about 1.5% for area A, about 1.8% for area B, about 0.2% for area C and about 1% for area D. The electric consumption of Science faculty buildings located in area C was not measured for a period from November 2013 to May 2014 due to repair work of its buildings. Thus, the reduction for area C is not 0.2% in fact. Additionally, reduction of electric consumption for a period from July to September accounted for 67% of the total annual reduction. Annual gas consumption of campus was about 7.8×10^5 m^3 (3.6×10^6 Kwh) in 2014, and there was no measuring gas data in 2013.

3. Estimation of energy consumption of air-conditioning

Electric consumption of air-conditioning in 2013 and 2014 was estimated by a method from a previous paper 1. We also measured the gas consumption of air-conditioning in 2014. The result is shown in Figure-3. Comparing 2014 to 2013, the average electric consumption of air-conditioning decreased about 8.6% in the summer cooling period, and decreased about 9.8% in the winter heating period.

Comparing the gas consumption of air-conditioning to electric consumption of air-conditioning in 2014, it showed that gas is about 1.7 times higher in the cooling period, and about 2.5 times higher in the heating period. In order to cut the peak power demand, gas energy has become a main energy source for air-conditioning in Osaka City University Sugimoto Campus.

The annual energy consumption was divided into 3 season periods, which contains middle period (April-June, October-November), summer period (July-September) and winter period (December-March). The average monthly energy (electric and gas) consumptions of the 3 season periods in 4 areas are shown in Figure-4.
4. Estimation of carbon dioxide emissions

The carbon dioxide emissions of the 4 areas in 2013 and 2014 were calculated and shown in Figure-5. Comparing 2014 to 2013, it showed that the annual reduction of carbon dioxide emissions is about 1.6 kg/m² (1%) on the whole campus.

5.1 Annual change in electric consumption of lighting

To explore the change in electric consumption of lighting for 2 years, we measured and analyzed the electric consumption of lighting in the University-wide General Education buildings in detail, which are located in area B. Comparing 2014 to 2013, it showed that the electric consumption of lighting decreased about 0.5% as shown in Figure-6.

6. Relationship of temperature and electric consumption

6.1 Hourly electric consumption

The hourly base of electric consumption (E_base(t)) is defined as the average hourly electric consumption on weekdays during middle period (April-June, October-November), when the air-conditioning is not used. E_base(t) is derived by using the following formula.

\[
E_{\text{base}(t)} = \frac{\sum E(t)_{\text{weekday}}(n)}{N} \quad (3)
\]

Where, “\(\sum E(t)_{\text{weekday}}(n)\)” is the sum of hourly electric consumption at the same time during the middle period [Kw]; “\(t\)” is time which is from 1 to 24 [hour]; “\(n\)” is month which includes April, May, June, October and November [-]; “\(N\)” is the number of hourly electric consumption data \((E(t)_{\text{weekday}})\) at the same time [-].

The hourly electric consumption of weekdays \((E(t)_{\text{weekday}})\), outdoor temperature \((T_o)\) and E_base(t) of 2013 and 2014 are shown in Figure-8.

From Figure-8, we see that the \(E(t)_{\text{weekday}}\) for the time period from 10:00 to 19:00 is the highest, and account for about 57% of the total \(E(t)_{\text{weekday}}\) of one day. Comparing 2014 to 2013, the \(E(t)_{\text{weekday}}\) decreased about 5%. The reduction of \(E(t)_{\text{weekday}}\) from 10:00 to 19:00 accounted for about 72% of the total reduction of one day.

In addition, we also compared the outdoor temperature \((T_o)\) of 2013 and 2014, it showed that the proportion of temperature difference for a time period from 10:00 to 19:00 accounted for about 60% of the total temperature difference of one day.

5.2 Monthly change in weekday lighting electric consumption

The change in monthly electric consumption of lighting by weekdays was analyzed, and the result is shown in Figure-7. With the exception of holiday months, the electric consumption of lighting by weekdays tends to be the largest on Monday, followed on Wednesday, Tuesday, Thursday and Friday. Comparing 2014 to 2013, the reduction rate of lighting on weekdays is about 2%.
6.2 Examination of the correlation
In order to explore the relationship of T₀ and hourly electric consumption, we analyzed the correlation of T₀ and hourly electric consumption. Due to the highest electric consumption in July, as an example, we chose the T₀ above 30°C, and discussed the influence of T₀ on the hourly electric consumption. The correlation of T₀ and hourly electric consumption is shown in Figure-9. It showed that the correlation coefficient is about 0.56 in 2013, and about 0.57 in 2014.

Figure-9 Correlation of T₀ and hourly electric consumption in 2013 and 2014 (T₀ is above 30°C)

The electric consumption in July is the highest, and a relatively large amount of electric consumption was consumed by air-conditioning, thus it is important to examine the relationship of T₀ and electric consumption of air-conditioning. The correlation of T₀ and hourly electric consumption of air-conditioning is shown in Figure-10. It showed that the correlation coefficient is about 0.72 in 2013, and about 0.76 in 2014. The average T₀ in 2013 is about 5.3°C higher than 2014.

7. Conclusions
In this research, the following overviews were obtained.
(1) The total electric consumption of Sugimoto Campus was about 1.3×10⁷Kwh in 2013, and decreased about 1.1×10⁷Kwh (1%) in 2014. Annual gas consumption of campus was 7.8x10⁶m³ (3.6x10⁶Kwh) in 2014. Comparing 2014 to 2013, the annual electric consumption decreased about 1.5% for area A, about 1.8% for area B, about 0.2% for area C and about 1% for area D.
(2) Comparing 2014 to 2013, the average electric consumption of air-conditioning decreased about 8.6% in the cooling period and decreased about 9.8% in the heating period. Gas consumption of air-conditioning was investigated in 2014, it showed that gas consumption is about 1.7 times higher in the cooling period, and about 2.5 times higher in the heating period. Thus, in order to cut the peak electric demand, gas energy has become main energy source for air-conditioning in Sugimoto Campus.
(3) Comparing 2014 to 2013, it showed that annual carbon dioxide emissions on the campus decreased about 1.6kg/m² (1%).
(4) Comparing 2014 to 2013, the electric consumption of lighting decreased about 0.5%. The reduction rate of lighting by weekdays was about 2%.
(5) The correlation coefficient of outdoor temperature and total electric consumption was 0.56 in 2013, 0.57 in 2014. The correlation coefficient of outdoor temperature and air-conditioning electric consumption was 0.72 in 2013, and 0.74 in 2014.

References