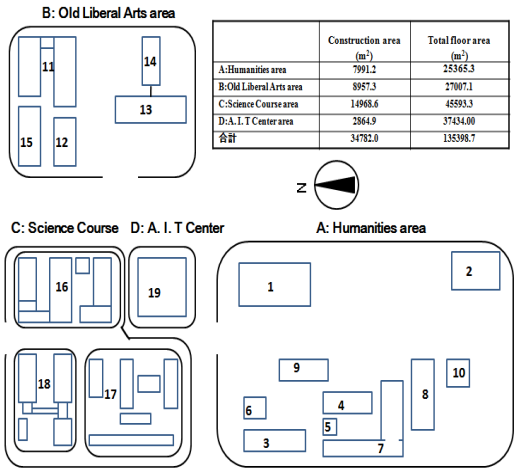
Sugimoto Campus for the period from April 2013 to March 2014, as part of promoting the "green campus" plan and application of similar monitoring mechanisms to all the buildings of the campus.

OVERVIEW OF THE INVESTIGATION

The investigated target is the Osaka City University Sugimoto Campus, including all the graduate and undergraduate departments with the exception of the college of medicine, which is located on a separate campus, and some infrequently used structures on the campus periphery. The main part of the Sugimoto Campus is roughly composed of 4 sections; the Humanities area (economy, business, law, literature, etc.), the old Liberal Arts area (University-wide general education building, advanced research organization building, common research building, basic education laboratory), the Science Course area (science, engineering, human life and science), and the Academic Information Technology Center building (library, restaurant, student computer rooms). The layout drawing and overview of the investigated target area is shown in Figure 1 and Table 1 respectively. The period of investigation is from April 2013 to March 2014.

Table 1. *Overview of investigated target*

	Building	Structure	Construction area (m^2)	Total floor area (m^2)
A:	Humanities area			
1	Student Support Center	RC 5	245.28	1242.14
2	Hohai Engineering Hydraulics	SL 1	1192.63	1192.63
3	Tanaka Memorial	RC 3	1628.80	3337.28
4	Law Faculty	SR 11	822.33	6408.01
5	Economic Research Institute	RC 4	924.52	3549.47
6	Urban Affairs Center	RC 3	259.20	894.24
7	Literature Faculty	RC 4	1271.78	4971.78
8	Business Faculty	RC 4	503.63	1978.93
9	Takahara Memorial	S 2	937.52	1448.27
10	Grand House	SL 2	205.49	341.91
B:	Old Liberal Arts area			
11	University-wide General Education (Phase 1)	RC 5/B1	2744.48	7980.23
12	University-wide General Education (Phase 2)	RC 5	1791.98	4505.09
13	Advanced Research Organization	RC 3	1257.98	3734.63
14	Common Research of Science	RC 5	1791.98	4505.09
15	Basic Education Laboratory	SR 5	1370.95	6282.02
C:	Science Course area			
16	Science	RC	4494.10	14526.43
17	Engineering	RC	6843.86	22656.45
18	Human Life and Science	RC	3630.65	8410.45
D:	Academic Information Technology Center			
19	Academic Information Technology Center	SRC	2864.94	37434.00



	Construction area (m^2)	Total floor area (m^2)
A:Humanities area	7991.2	25365.3
B:Old Liberal Arts area	8957.3	27007.1
C:Science Course area	14968.6	45593.3
D:A.I.T Center area	2864.9	37434.00
合計	34782.0	135398.7

Figure 1. *Layout of investigated campus areas*

METHOD OF INVESTIGATION

The current transformers (CT) are installed in the electric distribution boxes of each building in campus, which measure power consumption per minute. However, in consultation with the facility management department, to keep the amount of power data to a more manageable size, the power measurement is integrated over each 30 minutes. In this paper, using the basic data, we calculated the power consumption for the 1 year period, from April 2013 until March 2014.

RESULTS AND ANALYSIS

POWER CONSUMPTIONS OF THE HUMANITIES AREA

The Humanities area mainly contains the buildings of economic faculty, business faculty, law faculty and literature faculty. There are 10 buildings together, and the total footprint is 7991m^2, and the total floor area is 25365m^2. The monthly power consumption of each building in this area and total monthly power consumption of this area is shown in Figure 2.

The power consumption of law faculty is the largest compared it to the other building in this area. This may be due to a relatively larger number of people using this building, the large east and west-facing area of the building affecting the solar load, special usage schedules and functions in the building, among other possibilities.

From Figure 2, it shows that the peak month of power consumption appeared in July of summer and January of winter. It is affected by the use of heating and cooling.

POWER CONSUMPTIONS OF THE OLD LIBERAL ARTS AREA

There are 4 main buildings in the Old Liberal Arts area, with a total footprint of 8957m^2, and total floor area of 27007m^2. The monthly power consumption of each building in this area and total monthly power consumption of this area is shown in Figure 3.

The power consumption of the Advanced Research Organization Building is the largest in this area. The reason is that the building includes experimental facilities as well as the city Health and Sports Research Center. Because the use of Common Research of Science building and the Basic Education Laboratory building is limited to simple classroom experiments in basic science subjects, the power consumptions of the two buildings are not as large as one would expect of a full-purpose laboratory building.

POWER CONSUMPTION OF THE SCIENCE COURSE AREA

The Science Course area is 16 buildings including the faculty of science, faculty of engineering and faculty of human life science. Many experiments with large equipment are performed in the laboratories there. Power consumption of this area is the largest. The total footprint of the buildings in this area is 14969m^2, and the total floor area is 45593m^2. The monthly power consumption of each building in this area and the total monthly power consumption of this area is shown in Figure 4.

During the period from November 2013 until April 2014, the science faculty building stopped measuring power consumption due to reconstruction of the building. The faculty of human life science does not have large-scale experimental facilities. Hence, the power consumption is not as high as that of the science or engineering faculties.

Yet it is still approximately 2.6 times that of humanities buildings with the exception of the law building.

POWER CONSUMPTION OF THE ACADEMIC INFORMATION TECHNOLOGY CENTER AREA

The Academic Information Technology (A.I.T) Center area contains the university library and computer center as well as a restaurant. The footprint of the building, which has 4 underground floors and 10 floors above ground, is 2865m^2, and total floor area is 37434m^2. The total monthly power consumption of the Academic Information Technology Center area is shown in Figure 5.

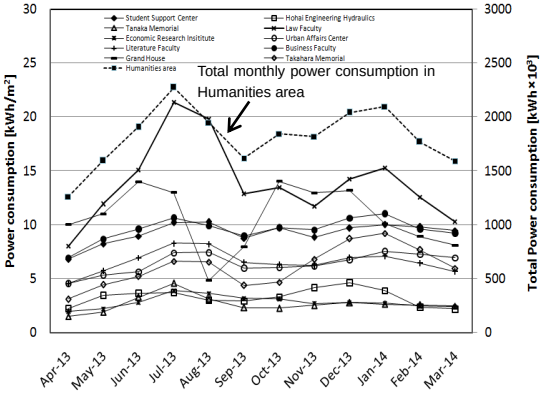


Figure 2. *Monthly power consumption of each building in the Humanities area*

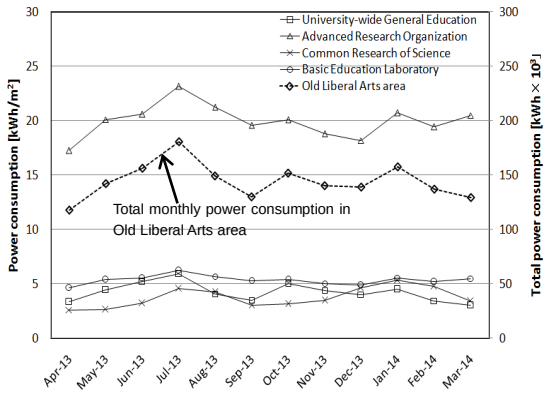


Figure 3. *Monthly power consumption of each building in the Old Liberal Arts area*

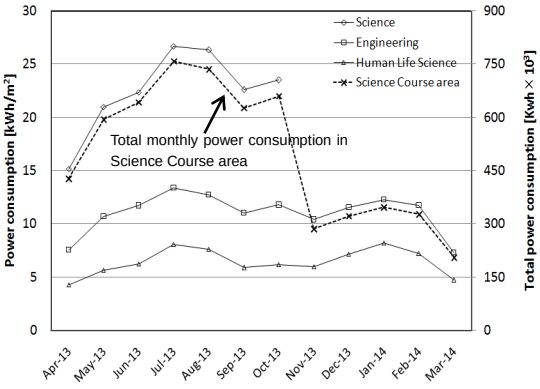


Figure 4. *Monthly power consumption of each building in the Science area*

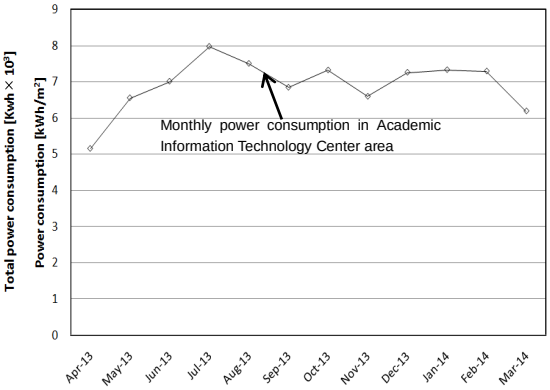


Figure 5. *Monthly power consumption of Academic Information Technology Center*

TOTAL POWER CONSUMPTION OF THE CAMPUS

The total monthly power consumption of all 4 investigated areas of the campus is shown in Figure 6. It is shown that the power consumption in July is the highest, and the power consumption in summer (June-October) is larger than it in the other months.

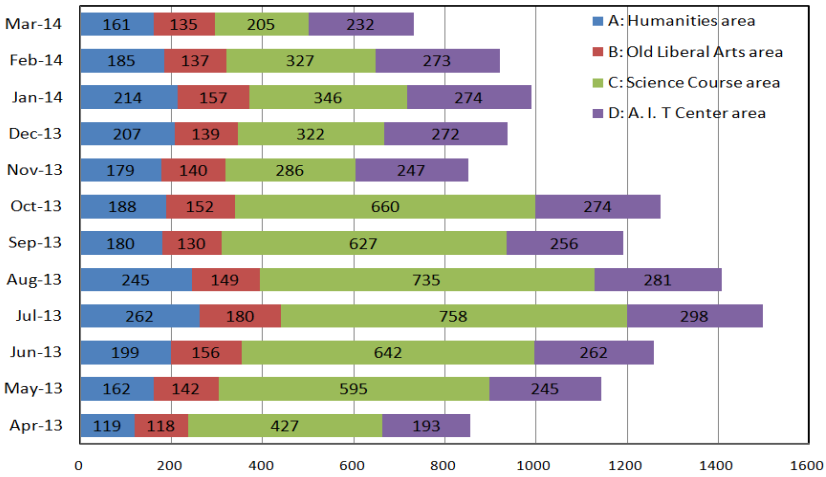


Figure 6. *Total monthly power consumption of the campus*

POWER CONSUMPTION OF ELECTRIC LIGHTS AND PLUG LOAD

THE POWER CONSUMPTION BY DAY OF THE WEEK

To explore the change in power consumption by day of week, we investigate the two University-wide General Education buildings in detail, which is in the Old Liberal Arts area, and calculate the daily power consumption from April 2013 to March 2014. The daily power consumption and building use schedule are shown in Figure 7 and Table 2 respectively (as example on July).

In July, it is seen that the power consumption of Mondays tends to be the largest, at about 15kWh for each building, followed by Wednesday, Tuesday, Thursday, and Friday. The lowest values (excepting holidays) are on Saturday and Sunday during the semester. Comparing the largest power consumption of Mondays to the other weekdays, the value is from 1.2 to 2.5 times larger. However, there is also about 6kWh power consumption on Saturdays and Sundays.

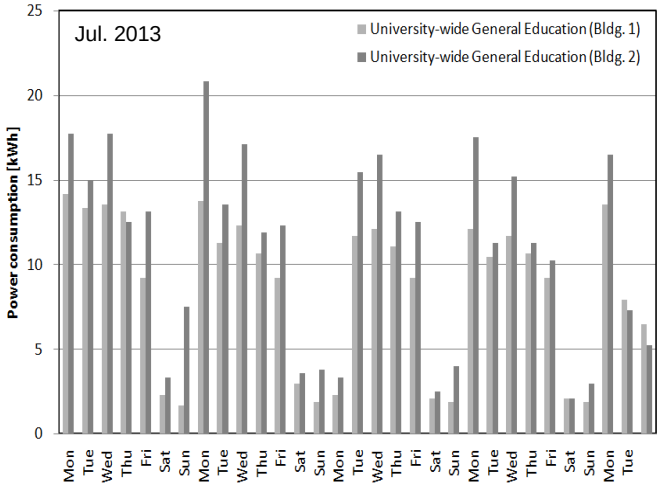


Figure 7. *Daily power consumption in General Education Buildings*

Table 2. *Building use schedule*

Weekdays	Classroom / Class Schedule	University-wide General Education (Bldg. 1)	University-wide General Education (Bldg. 2)
Monday	9:00~10:30	○	○
	10:40~12:10	○	○
	13:00~14:30	×	○
	14:40~16:10	○	×
	16:20~17:50	○	×
Tuesday	9:00~10:30	○	○
	10:40~12:10	○	○
	13:00~14:30	○	×
	14:40~16:10	×	×
	16:20~17:50	×	×
Wednesday	9:00~10:30	○	○
	10:40~12:10	○	○
	13:00~14:30	○	○
	14:40~16:10	×	○
	16:20~17:50	×	×
Thursday	9:00~10:30	○	×
	10:40~12:10	○	○
	13:00~14:30	○	×
	14:40~16:10	×	×
	16:20~17:50	○	×
Friday	9:00~10:30	×	○
	10:40~12:10	×	○
	13:00~14:30	×	×
	14:40~16:10	○	×
	16:20~17:50	×	○

(Class: ○ No class: ×)

THE POWER CONSUMPTION BY HOUR

In order to investigate the power consumption by hour, the power consumptions by the time of day are tabulated. As an example, the largest power consumption on a Monday is shown in Figure 8. It shows that the peak time of power consumption occurs from 9:30 to 13:00, about 80kWh, with a slight dip at 15:00, and begins to decline slowly from 15:30. The reason is considered as that there are relatively more classes in the morning, and the classrooms are usually used by the students while they have their lunch.

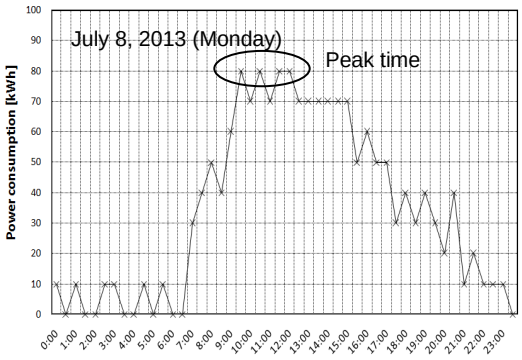


Figure 8. *The power consumption by time on July 8, 2013*

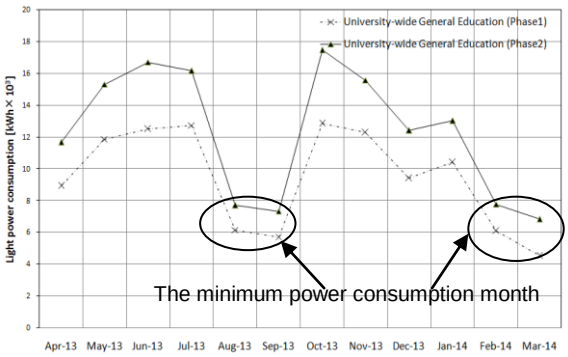


Figure 9. *Monthly power consumption of lighting and plug load in the two General Education Buildings*

THE MONTHLY POWER CONSUMPTION OF LIGHTING AND PLUG LOADS

In order to explore the monthly changes in the power consumption of lighting and plug load of classrooms in the Old Liberal Arts area, we have investigated the two University-wide General Education Buildings (Bldg. 1 and Bldg. 2) in the Old Liberal Arts area. The results and holiday schedule are shown in Figure 9 and Table 3 respectively.

The lowest lighting and plug load occurs in August, September, February and March, because these months are holidays. However, the power consumption is still about 5.7×10^{3}kWh.

Table 3. *Holiday schedule of year*

First semester	4/1 ~ 8/4
Summer vacation	8/5 ~ 9/30
Second semester	10/1 ~ 2/13
New year break	12/23 ~ 1/6
Spring vacation	2/14 ~ 3/31

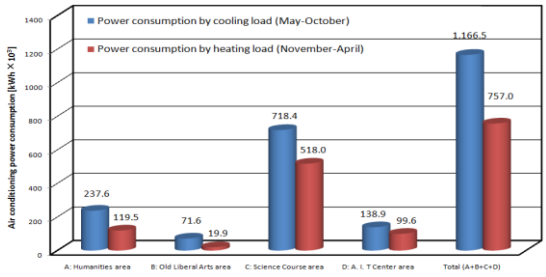


Figure 10. *The annual power consumption of air conditioning of Sugimoto Campus*

ESTIMATION OF THE POWER CONSUMPTION OF AIR CONDITIONING

In order to estimate the power consumption of air conditioning, the mid-term (April, May, October and November) is assumed to be non-air conditioning period, we use the average power consumption of the months to estimate the power consumption of air conditioning in summer and winter. The annual power consumption of air conditioning of Sugimoto Campus is shown in Figure 10.

Comparing the annual power consumption of air conditioning of four areas in Sugimoto Campus, it is showed that the Science Course area is the largest in all the areas, followed by the Humanities area, Academic Information Technology center area and the Old Liberal Arts area. Looking at the whole, the annual power consumption by cooling load is 11.7×10^5kWh (8.7kWh/m^2), and by heating load is 7.57×10^5kWh (5.6kWh/m^2). The power consumption by cooling load is about 4.1×10^5kWh (3.1kWh/m^2) larger than the heating load.

ESTIMATION OF CARBON DIOXIDE EMISSIONS

Using the emission factor of carbon dioxide, the annual power consumption is converted to carbon dioxide emissions. The carbon dioxide emission factor of Kansai Electric Power is about 0.475kg/kWh (Ministry of the Environment Government of Japan, 2014). We use the emission factor of carbon dioxide to calculate the annual carbon dioxide emissions of all the investigated building of Sugimoto Campus, shown in Figure 11.

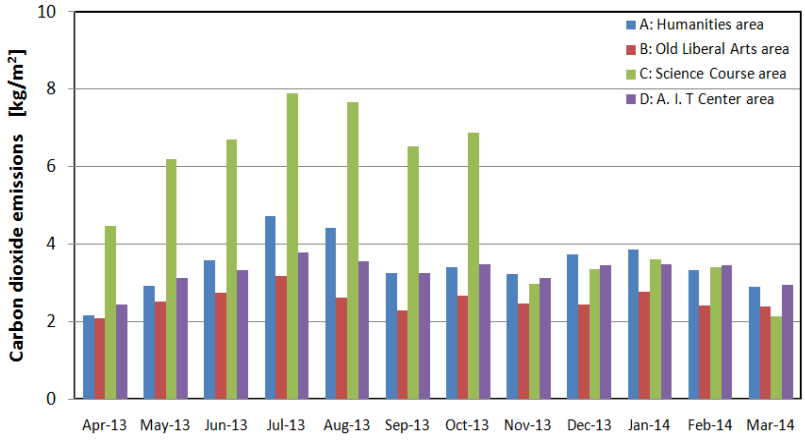


Figure 11. *The monthly carbon dioxide emissions of Sugimoto Campus*

From the estimated result, it shows that the carbon dioxide emission of Sugimoto Campus is about 6210ton per year, about 45.9kg/m^2 per year.

Comparing the carbon dioxide emission of all the investigation buildings, it shows that the carbon dioxide emission of Science Course area is the largest, about 2817ton per year (61.8kg/m^2 per year). It is greatly affected by such as machinery and laboratory equipment of Science Course building.

CONCLUSIONS

We investigated the power consumption of Osaka City University Sugimoto Campus during the period from April 2013 to March 2014, and obtained the overviews of the following.

(1) The total power consumption of the campus is 1.5×10^6kWh (11.08kWh/m^2) in July, 1.26×10^6kWh (9.31kWh/m^2) in January. The monthly power consumption for these two months in summer and winter respectively is the largest.

(2) Comparing the power consumption of four areas in the Campus, the power consumption of Science Course area is the largest, about 6.1×10^6kWh (134kWh/m^2). The reason is considered as that there are such as machinery and laboratory equipment in the science Course buildings.

(3) There is still annual power consumption of values varying from 7.3×10^6kWh to 9.2×10^6kWh used in Sugimoto Campus during summer and winter holidays.

(4) Detailed examination of daily data for the two University-wide General Education buildings showed the largest daily power consumption occurs on Mondays in July, averaging about 15kWh. The value is from 1.2 to 2.5 times larger than the other weekdays. The peak time of power consumption occurs from 9:30 to 13:00, about 80kWh. The lowest electric light power consumption occurs in August, September, February and March. It is because these months are holidays. However, the electric light power consumption is still about 5.7×10^3kWh during the holidays.

(5) The annual power consumption of air conditioning on the campus is estimated to be 19.2×10^5kWh (14.2kWh/m^2), and the power consumption by cooling load is 4.1×10^5kWh (3.1kWh/m^2) larger than it by heating load.

(6) The annual carbon dioxide emission is estimated as 6210ton (45.9kg/m^2) in Sugimoto Campus.

ACKNOWLEDGEMENT

The authors sincerely acknowledge Osaka City University Strategic Research "Green Campus Plan for Low-carbon Dioxide and Understanding of the Energy Consumption of University (representative: Kazuo Emura)" for their report.

REFERENCES

Ohashi, T. et al. (2014) Estimation of energy end-use breakdown in Science Research Facilities. J. Environ. Eng. AIJ, Vol. 79, No. 699, pp. 443-450.

Yuan, J. and Emura, K. (2013) Development of simple visualization system for energy consumption of building. Summaries of technical papers of annual meeting (Environ. Eng. 2), AIJ, pp. 1473-1474.

Ministry of the Environment Government of Japan (2014) Coefficient used in the calculation of greenhouse gas emissions (H25). →http://www.env.go.jp/en/