Research for energy use of high environmental performance building in Japan

H Kobayashi¹ and H Takaguchi²

¹Department of Architecture, School of Creative Science and Engineering, Graduate School of Waseda University, 55N705 3-4-1 Okubo, Shinjuku-ku, Tokyo, Japan
email: koba-hiro1029@suou.waseda.jp

²Professor, Engineering Doctor, Department of Architecture, Faculty of Creative Science and Engineering, Waseda University, 55N705 3-4-1 Okubo, Shinjuku-ku, Tokyo, Japan email: takaguchi@waseda.jp

Abstract. Recently, the increase in energy consumption of commercial building is remarkable, and energy-saving is continuously required. Therefore, the government is promoting high environmental performance building. In this situation DECC (Database for Energy Consumption of Commercial building) committee collected the data of the energy consumption and published them as a database. However, analysis about High environmental Performance Building (HPB) has not been conducted in DECC database. So, I extract HPB from DECC database and analyze the consumption.

1. Introduction
Looking at the ratio of domestic energy consumption in Japan, the energy consumption in the civilian sector accounts for one-third of the total [1]. The Ministry of the Environment is developing high energy performance buildings such as ZEB and ZEH as energy-saving measures and promoting environmental performance evaluation systems for buildings such as LEED, CASBEE, and BELS [2]. DECC (Database for Energy Consumption of Commercial Buildings) has formed a database containing building information and energy consumption of non-residential buildings in Japan since fiscal 2007 under the initiative of the Sustainable Building Association [3]. Although there is information on energy-saving devices and energy-saving measures introduced in the building in this database, analysis focusing on energy-saving-oriented buildings has not been performed. In this research, we expand the database for buildings that acquire environmental certification and take measures to reduce carbon emissions through DECC survey and analyse energy consumption focusing on energy-saving-oriented buildings.

2. About DECC
As pointed out in IPCC Fourth Assessment Report, global warming is becoming more serious. And the main cause of global warming is due to human activity. In Japan, the household sector and business and other sectors that make up the consumer sector have been on a declining trend due to the penetration of energy-saving measures and economic downturns in recent years. However, in fiscal 2011, the impact of the Great East Japan Earthquake was significant, and in the household sector, it was up 48.1% from 1990 and 50.6% in the business and other sectors. Since the total volume is 10.7% from 1990, the increase in the home sector, business and other sectors is outstanding, and it is recognized that the reduction of CO₂ emissions in the field is the highest priority issue[3]. In order to reduce CO₂ emissions
and reduce energy consumption, it is important to accurately capture the actual situation of energy consumption and to develop a database that is effective for the extraction of effective measures. However, the database in Japan is poor compared to the amount of stock of the building, and the data number bias of the region is large. In addition, depending on the purpose of the investigation, there were problems such as differences in the items and definitions of the data being stored. In order to resolve this situation, the Environmental Database Review Committee for Commercial Buildings was established in 2006 with the support of the Ministry of Land, Infrastructure, Transport and Tourism and other organizations. In cooperation with universities and research institutes nationwide, we began collecting energy and water consumption of commercial buildings in Japan from 2007. In 2010, we released it as a database, Database of Energy Consumption for Commercial Buildings (DECC), which contains approximately 280,000 data. In 2011, the Great East Japan Earthquake changed significantly in the consumer business sector, including energy management, energy-saving mindset of managers and employees, and promotion of the introduction of high-efficiency equipment. Therefore, in 2012, an emergency survey was conducted to record the actual situation immediately after the earthquake. In 2013, we collected data for offices, government offices, commercial facilities, accommodation facilities, welfare facilities, and schools, and in 2014 for kindergartens, nurseries, research institutes, theatres and halls, exhibition facilities, sports facilities, and restaurants. It was a database that added two years after the earthquake. In this year's survey, we focused on the 2017 data on high environmental performance buildings obtained and analysed them. We have expanded our database by conducting surveys on buildings that have been completed in recent years and buildings that have been implementing energy-saving and low-carbon measures.

3. Survey Overview

3.1 Definition of High environmental Performance Buildings (HPB)
Table 1 shows the definition of High environmental Performance Buildings (HPB). In this research, we defined buildings that have acquired environmental performance certifications such as LEED, CASBEE, and BELS, and buildings that utilize subsidies such as ZEB as HPB.

| Type                                           | Details                        |
|------------------------------------------------|--------------------------------|
| CASBEE Architecture                            | Ranked S & A                   |
| CASBEE Realty                                   | Ranked S & A                   |
| CASBEE (Local)                                  | Ranked S & A (open data)       |
| LEED Certified                                  | Ranked Platinum & Gold (non-confidential) |
| Environment Planning (Mun. of Tokyo)            | Those built after 2011         |
| SHASE Technology Award                          | Awarded                        |
| Sustainable Building Award                      | Awarded                        |
| BELS (Non-residential)                          | Certified                      |
| ZEB Projects                                    | Projects utilizing subsidies   |
| Program for Leading Sustainable Building        | Projects utilizing subsidies   |
### 3.2 Survey method

Table 2 shows the survey overview. For the buildings shown in Table 1, requests were sent by e-mail to managers whose contacts were known in previous surveys, and by mail to new survey destinations. Table 3 shows the survey items. We collected two years' worth of data on energy consumption and water consumption in 2016 and 2017. In addition to energy consumption and water consumption, we collected the presence or absence of energy conservation measures.

| Survey target          | Non-residential buildings in Japan |
|------------------------|-----------------------------------|
| Survey period          | 2018/08/31〜2018/12/31            |
| Survey method          | New Questionnaire survey by mail |
|                        | Continue Questionnaire survey by email |

#### Table 2. Survey overview.

#### Table 3. Survey items.

| Energy consumption Water consumption | Monthly consumption of electricity, city gas, LPG, petroleum fuel, district heat supply, and water supply |
|--------------------------------------|---------------------------------------------------------------------------------------------------|
| Energy conservation measures         | Presence or absence of power saving measures and promotion status Planning system for energy conservation measures |
|                                      | Energy conservation measures implemented and future policies Existence of energy-saving equipment Measures that seemed effective |
| Heat source equipment                | Type of main heat source equipment |
| Other                                | Contract power Building renovation, equipment renovation |

### 4. Survey Result

#### 4.1 Number of answers

In 2018 research, there were 1,854 requests for continuous surveys and 1,779 requests for new surveys, totalling 3,633 buildings. In the continuing survey, the number of responses was 328 and a recovery rate of 17.7%. In the new survey, the number of responses was 261, a recovery rate of 14.7%. A total number of responses is 589, and a recovery rate is 16.2%.

#### Table 4. Number of surveys / Number of answers / Recovery rate.

| Survey type | Number of surveys | Number of answers | Recovery rate |
|-------------|-------------------|-------------------|---------------|
| Continue    | 1,854             | 328               | 17.7%         |
| New         | 1,779             | 261               | 14.7%         |
| Total       | 3,633             | 589               | 16.2%         |

#### 4.2 Number of questionnaires collected and number of valid data

We screened 308 data for 2016 and obtained 253 effective responses. We also screened 505 data for 2017 and obtained 432 effective responses. We made these effective responses as master data for analysis. In this research, we analysed using data from 2017. As for screening, after collecting data into a database using Microsoft Access input tool (Group A), error checking such as the presence or absence of duplicate data, judgment of building use, etc. (Group B), total floor area and energy consumption data Buildings with a building are extracted (Group C). The energy consumption basic unit was calculated
from the extracted buildings, and data not excluded by the two outlier tests (Group E) was defined as
the number of valid data in the master data for analysis. The outlier test is performed by year, region,
and application, and the significance level of the Smirnov-Grubbs test is 5%.

4.3 Attributes of data
Figure 1 shows the ratio by region. Kanto accounted for about 30% of the total. Figure 2 shows the ratio
by building use. For building use, private offices accounted for 32.4%, followed by public offices 18.1%.
This is because the new research destination was limited to private offices and public offices.

4.4 The average value of the energy consumption by building use
Figure 3 shows the average value of the energy consumption by building use. The largest energy
consumption was in hospitals, followed by supermarkets. The smallest was the hall after the elementary
school junior high school.
5. Analyse

In this year's survey, in addition to existing survey sources, a questionnaire was sent to buildings that have been completed in fiscal 2012 or later for private offices and public offices, as well as buildings that have obtained environmental certifications and energy certificates such as CASBEE, BELS, and LEED. Therefore, we classified the analyzed buildings into the following four categories and analyzed them. Table 5 shows the classification of analyzed buildings.

Table 5. Classification of analyzed buildings.

| Category                                                                 | Buildings in the year |
|--------------------------------------------------------------------------|-----------------------|
| 1) Buildings completed before 2011                                       | All 〜2011            |
| 2) Buildings completed after 2012                                       | All 2012〜            |
| 3) Buildings completed before 2011 and have acquired environmental       | HPB 〜2011            |
| certification                                                             |                       |
| 4) Buildings completed after 2012 and have acquired environmental         | HPB 2012〜            |
|   certification                                                           |                       |

5.1. Private Offices

Figure 4 shows the distribution of energy consumption of buildings of private office. When comparing the overall energy consumption, it can be seen that the 208 MJ decreased before 2011 and since 2012. This is a significant difference at 5% in the Student’s t-test (df=137, t=2.47, p=0.0146). Since 2012, it can be said that the number of buildings with a small number of primary energy consumption has increased. On the other hand, with regard to high environmental performance buildings, it can be seen that the primary energy consumption number has decreased by 248 MJ since 2012 from before 2011. This is a significant difference at 5% in the Student’s t-test (df=112, t=2.70, p=0.0080). Since 2012, the environmental performance of buildings has improved significantly. Further, since the value of the energy consumption is large compared to the average value of the office applications in high environmental performance buildings before 2011, it can be seen that HPB is not necessarily small energy consumption.

Table 6. Results of the Student's t-test (two-sided test).

| What to compare       | df  | t   | p     | significance level |
|-----------------------|-----|-----|-------|--------------------|
| All 〜2011, All 2012〜 | 137 | 2.47| 0.0146| 5% (p<0.005)       |
| HPB 〜2011, HPB 2012〜| 112 | 2.70| 0.0080| 5% (p<0.005)       |
5.2. Public Offices

Figure 5 shows the distribution of energy consumption of buildings of public office use. When comparing the overall primary energy consumption, it can be seen that the decrease of 225 MJ before 2011 and since 2012. This is a significant difference at 5% in the Student’s t-test (df=74, t=1.99, p=0.0193). On the other hand, with regard to high environmental performance buildings, the energy consumption was 17MJ larger than 2012 ago and beyond 2012. The average value of the energy consumption of the high environmental performance building is 129MJ smaller than the average value of the whole. This is a significant difference at 10% in the Student’s t-test (df=122, t=1.98, p=0.0701).

Table 7. Results of the Student's t-test (two-sided test).

| What to compare | df  | t   | p    | significance level |
|-----------------|-----|-----|------|--------------------|
| All 〜2011, All 2012〜 | 74  | 1.99| 0.0193| 5% (p<0.05)         |
| All, HPB        | 122 | 1.98| 0.0701| 10% (p<0.10)        |

Figure 4. Energy Consumption of Private Offices.

Figure 5. Energy Consumption of Public Offices building.
5.3. Aging of energy consumption

Figure 6 shows the aging of energy consumption using the data of DECC published. Looking at the aging of the private offices, we can see that energy consumption has been on a declining trend since 2006. In 2017, this is a decrease of 34.1% compared to 2006. The 2017 samples include new buildings and HPB since 2012, so the rate of decline is likely to be increasing. When we look at the aging of government public offices, energy consumption is decreasing. Compared to the office, energy consumption is generally small, but the rate of decrease is small. 2017 is a decrease of 11.6% compared to 2006. Since the number of samples in recent years is small, it is necessary to continue to investigate in the future.

| (MJ/㎡/year) | 2006 | 2007 | 2008 | 2010 | 2011 | 2012 | 2015 | 2016 | 2017 |
|-------------|------|------|------|------|------|------|------|------|------|
| Private Offices | 1,787 | 1,768 | 1,661 | 1,621 | 1,479 | 1,381 | 1,313 | 1,327 | 1,178 |
| (N) | 809 | 1,098 | 1,332 | 627 | 241 | 272 | 132 | 91 | 140 |
| Public Offices | 1,099 | 1,087 | 1,094 | 1,118 | 1,000 | 988 | 996 | 924 | 971 |
| (N) | 928 | 832 | 899 | 514 | 275 | 275 | 155 | 37 | 78 |

Table 8. Results of the Student's t-test (two-sided test).

![Figure 6. The development of the years in energy Consumption.](image)

6. Conclusion

In this research, we analysed the energy consumption by focusing on the building which acquired environmental performance etc. based on the latest data of 2018. The conclusion is described below. Comparing the private offices and public offices in 2011 and 2012, it was found that energy consumption for buildings as a whole decreased. Therefore, it can be said that the environmental performance of the building has improved since 2012. In addition, although the value of the energy consumption of HPB was significantly smaller than the average value of the overall in the public office, there was no significant difference in the private office. Therefore, it is pointed out that the acquisition of energy-saving performance evaluation does not necessarily contribute to the performance improvement of the building in the whole. Looking at the aging from 2006 to 2017, both private offices and public offices energy consumption has been declining. In 2017, private offices decreased 34.1% from 2006 levels and public offices were 11.6% compared to 2006. In future research, the number of samples will be...
continuously increased, and more detailed examination focusing not only on the age of construction but also on the size of the building and the building area is necessary.

Acknowledgments
This research was established at the Japan Sustainable Architecture Association (JSBC) with the support of the Ministry of Land, Infrastructure, Transport and Tourism. This project was carried out as part of the activities of the Environmental Database Review Committee for Commercial Buildings (Chairman: Shuzo Murakami, Chairman of the Building Environment and Energy Conservation Organization). I would like to express our gratitude here.

References
[1] Agency for Natural Resources and Energy, Annual Report on Energy in FY 2017, https://www.enecho.meti.go.jp/about/whitepaper/2018pdf/whitepaper2018pdf_2_1.pdf, Accessed 2020/01/08
[2] Ministry of the Environment, Ministry of the Environment Re-Energy Acceleration and Maximization Promotion Program 2018 Edition, p18-22 https://www.env.go.jp/earth/matome.pdf, Accessed 2020/01/08
[3] Japan Center for Climate Change Actions, Trends in Carbon Dioxide Emissions by Sector in Japan (1990-2017), https://www.jccca.org/chart/chart04_05.html, Accessed 2020/01/08
[4] TAKAGUCHI Hiroto, IZUTSU Shimpei, WASHIYA Satoshi, DEVELOPMENT AND ANALYSIS OF DECC (DATA-BASE FOR ENERGY CONSUMPTION OF COMMERCIAL BUILDING) (Part1) Development on basic database of DECC, Transactions of AIJ. Journal of environmental engineering 77(678), 699-705, 2012-08
[5] TAKAGUCHI Hiroto et al, ENERGY CONSUMPTION AFTER GREAT EARTHQUAKE OF EAST JAPAN:Development and analysis of DECC (Data-base for Energy Consumption of Commercial building) Part 2, Transactions of AIJ. Journal of environmental engineering 79(703), 795-801, 2014
[6] TAKAGUCHI Hiroto et al, Study on Database of Energy Consumption for Commercial Buildings (DECC) Part 111, Outline of the Investigation on the Energy Consumption in 2013, Summaries of technical papers of annual meeting, 1055-1056, 2014
[7] Japan Sustainable Building Consortium Data-base for Energy Consumption of Commerical buildings, http://jsbc.or.jp/seminar/files/H29_decc_panf.pdf, Accessed 2020/01/08