Estimating energy consumption by purpose and analyse standby power in non-residential buildings in Japan

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Keywords

energy savings, commercial buildings, audit programme, energy management system, standby power, estimation

Abstract

The purpose of the study is to support energy saving endeavors in small and medium-sized non-residential buildings. The study measures the energy consumption of 18 non-residential buildings (2 banks, 2 City halls, 1 convention hall, 4 elderly nursing homes, 2 food plants, 2 school lunch facilities, and 5 restaurants) in detail, and develops an estimation method of their energy consumption by purpose. This study also analyse the measured data, and finds that standby power accounts for a large part of electricity.

To achieve energy savings in non-residential buildings estimating energy consumption by purpose is important since it will allow designers to calculate in how many years high efficient will pay back the investment more correctly. The correct estimates encourage the building owner to renew equipment.

Measuring the energy consumption of each purpose is very expensive, and non-residential building's owners cannot afford to pay for this type of assessment. The estimation method uses commonly available data, such as monthly energy consumption, to estimate energy consumption by purpose at a low cost. The study measures the energy consumption of each purpose, analyses these data, and develops the method.

The method separates building energy consumption into AC, domestic hot water, lighting, cooking, transformer loss, and other devices. The difference between the estimated consumption of each purpose and the measured consumption can be as high as 17 %. The estimated value of each purpose is close to the actual consumption, and the method can show the energy consumption of each purpose with a low cost.

The study analyses the standby power of two city hall buildings by using the measured electricity consumption data in detail. In this study, standby power consumption is defined as electricity consumption that is consumed despite a not-working day. The electricity consumption, which is not considered to be standby power consumption such as consumption by a computer server and an Emergency Power Supply (EPS), is carefully removed, but the electricity consumption of vending machines and the emergency exit signs is included. This study finds that standby power accounts for a large part of electricity consumption in a non-residential building. The standby power accounts for 14 % to 20 % of electricity consumption in a non-residential building. Further analysis is necessary to know the actual state of standby power in a non-residential building.

Introduction

The purpose of this study is to support energy saving in non-residential buildings by estimating the energy consumption for energy purpose. It is extremely important to understand energy consumption by purpose in order to develop an energy-saving diagnosis.

For a residential building, non-intrusive load monitoring methods for energy disaggregation (NILM) have been developing. NILM estimates the electricity consumption of individual appliances by analysing measured values of reactive power and real power. Batra et al. (2014) mentioned that a large number of applications and continuous variations of electricity consumption by VFD and HVAC systems 'increase the complexity of energy disaggregation in commercial settings'. It is thusly considered difficult to apply NILM to commercial buildings.

There are many energy simulation programs such as TRNSYS, Energy plus, and CIBSE TM22. Based on the input conditions, these programs simulate the energy use of buildings and estimate energy consumption by purpose. CIBSE TM22 is an energy diagnostic program created by the Chartered Institution of Building Services Engineers (CIBSE) for non-residential buildings. According to this program, 'much of effort expanded on TM22 aims to produce a reliable electricity end use breakdown' (Cohen, 2013).

This study does not adopt a simulation method to estimate energy consumption by purpose; instead, it investigates a method of estimating energy consumption by purpose by using monthly or daily energy consumption data. It then verifies its accuracy by comparing it with measured energy consumption data in detail. With this method, the number of purposes that can be estimated is smaller than through simulation, yet it is thought to reflect the actual energy consumption of a building.

This study also analyses standby power consumption in a non-residential building by using the measured data. The standby power consumption in a non-residential building has been researched little in Japan, and this study reports the results of the early stage research.

The estimation methodology

The study aims to estimate the annual energy consumption for AC, domestic hot water, lighting, cooking, transformer loss, and other devices (see Table 1)[1]. Table 2 shows the comparison between the energy purpose estimated in this study and the purpose defined in ISO 12655: 2013.

The monthly energy consumption trend for each purpose can be categorized (see Table 1). AC is a seasonal demand and is used little in spring and fall. Domestic hot water, lighting, cooking, transformer loss, and other devices are year-round demands. In the year-round demands, there are a purpose with large seasonal fluctuations and some purposes with little seasonal fluctuation. The year-round demand with large seasonal fluctuations is domestic hot water. The year-round demands with little seasonal fluctuation are lighting, cooking, transformer loss, and other devices.

This study develops the method of estimating the energy consumption for purpose by using data that is relatively easy to obtain, such as monthly utility bills. There are two well-known methods for estimating energy consumption by purpose without detailed energy measurement. One method is the rated energy method. It estimates the energy consumption by multiplying the rated energy input and the use of time by each equipment. The method is often used for lighting energy estimation. The other method is the baseline method. It assumes that the smallest monthly energy consumption in a year is the monthly year-round demand, and the difference between monthly energy consumption and the monthly year-round demand is the monthly seasonal demand. The method is often used for AC energy estimation.

With the rated energy method, it is difficult to estimate the seasonal demand and the year-round demand with large seasonal fluctuation. The baseline method allows to estimate the seasonal demand, but it is difficult to estimate the year-round demand. This study develops a new estimation method using two methods.

Data

DATA USED FOR THE ESTIMATION METHOD

The data used for the estimation method are listed below. The data is thought to be obtained relatively easily in Japan.

1. Statement of monthly electricity, gas, and oil consumption (past one year or more).
2. Every 30-minute electricity consumption (past one year or more).
3. Hourly temperature data from the nearest meteorological observatory.
4. Detailed appliance data, the number of appliances, rated input and rated output of lighting, AC, domestic hot water.
5. Transformer capacity (kVA), load loss, and unload loss.

Table 1. Relationship between energy purpose and energy types for the estimation model.

Energy purposes	Seasonal demand/year-round demand	Seasonal fluctuation	Energy types			Remarks
			electricity	Gas (town gas, LPG)	Oil (kerosene, A heavy oil)	
AC	Seasonal	Large	×	×	×	
Domestic hot water	Year-round	Large	×			Estimating only Heat source
Lighting	Year-round	Little	×	×	×	
Cooking	Year-round	Little		×		Estimating only gas use
Other devices	Year-round	Little	×			Including home appliances, motor, electricity use in cooking and so on
Transformer loss	Year-round	Little		×		Mainly transformer loss

Table 2. The comparison between the energy purpose in this study and the purpose in ISO 12655: 2013.

ISO 12655:2013	This study
Space heating	AC
Space cooling	AC
Domestic hot water	Domestic hot water
Air movement	AC
Lighting	Lighting
Household/office appliances	Other devices
Indoor transportation	Other devices
Building auxiliary devices	Other devices
Cooking	Cooking
	Other devices (if heat source of cooking equipment is electricity)
Cooling storage	Other devices
Devices in data center	Other devices
Other specific functional devices	Other devices
	Transformer loss

BUILDING MEASUREMENTS DATA

To establish the estimation method and to confirm the validity of the estimate, the study has measured energy consumption in detail so that it can be classified for each purpose. Table 3 shows the total floor area, energy consumption per area, and measured points of each building. The reason why elderly nursing homes, food plants, school lunch facilities, and restaurants have been selected for the study is that these facilities are considered to have high heat demand. This study focused on the development of estimation methods of energy consumption for domestic hot water and cooking. Electricity consumption at most circuit breakers was measured, so that it was classified by purpose. Gas and oil consumption was measured for each device, if they were measurable. Heat value, water volume, temperature, etc. were considered, which are likely to influence energy consumption. The measurement interval was 1 minute. The measured data were collected every 5 minutes via the Internet so that it could be monitored in real time.

Result and analysis

ESTIMATING AC CONSUMPTION

Singling out AC consumption requires the baseline method. It is the method of setting the year-round demand with little fluctuation as the baseline and estimating the consumption of AC using the difference between the monthly energy consumption and the baseline. For the baseline method, the year-round demand with large fluctuation must be excluded from the monthly energy consumption.

If AC is not used in spring and fall

Figure 1 shows the monthly day average of electricity consumption in City hall B which uses little electricity for domestic hot water. The reason for using the monthly day average is that it removes the inconsistencies created by the difference in the numbers of days across months. The smallest monthly day average is the value in May 2015, and it is assumed as the baseline. The difference between the monthly day average of electricity consumption and the baseline is assumed as the AC monthly day average. The annual consumption of AC is estimated by multiplying the day average by the number of the days of each month and totaling them for 12 months.

If AC is used throughout the year

In the case that a building uses AC throughout the year, the consumption of AC is included in even the smallest monthly day average that is assumed as the baseline, and the consumption of AC can be underestimated.

In this case, the electricity consumption for AC can be estimated if the hourly electricity consumption data are available, which is becoming common thanks to the diffusion of smart meters in Japan. An example of Restaurant A is shown in Figure 2. The weekly day average electricity consumption is calculated from the smart meter data. The smallest weekly day average is assumed as the baseline, and the consumption of AC is estimated by totaling the difference between the weekly day average and the baseline throughout the year.

ESTIMATING THE YEAR-ROUND DEMAND WITH SMALL SEASONAL FLUCTUATIONS

Lighting

The energy consumption for lighting is calculated by multiplying the rated inputs and the annual use time by each lighting appliance. Unlike AC, lighting consumes the rated input almost constantly, so if the use time of each lighting appliance is known, the lighting energy consumption can be estimated by totalling the product of the rated input and the annual use time of each lighting appliance. If there is a human detection sensor and an illuminance sensor, the utilisation factors should be assumed. The annual energy consumption for lighting is a

Table 3. The measured points of energy consumption data.

building	floor area (m²)	energy use per area (MJ/m²)	measured points											
			EL	TG	LPG	AO	OT	OH	RT	RH	WT	WV	WS	HW
Bank A	285	311	68	0	0	0	2	2	1	1	0	0	0	0
Bank B	316	416	75	0	0	0	1	1	1	1	0	0	0	0
City hall A	15,100	247	258	0	3	0	1	1	0	0	0	6	0	0
City hall B	2,611	187	172	0	0	0	2	0	1	0	0	0	0	0
Convention hall	6,000	515	146	0	3	0	1	0	5	5	2	2	0	1
Elderly nursing home A	3,265	426	63	0	2	0	7	5	0	0	6	4	0	0
Elderly nursing home B	5,298	392	390	0	1	0	3	1	6	6	11	4	0	0
Elderly nursing home C	4,013	513	271	0	0	0	1	1	7	7	4	0	0	1
Elderly nursing home D	4,877	840	307	0	3	0	1	1	6	6	8	3	0	1
Food plant A	1,370	8,981	98	0	2	1	0	0	1	1	0	9	1	3
Food plant B	1,830	3,305	72	0	4	0	3	3	1	1	2	2	0	3
School lunch facility A	960	1,457	76	0	0	0	1	1	1	1	0	0	0	0
School lunch facility B	2,432	3,600	223	0	2	0	1	1	2	2	0	0	0	0
Restaurant A	1,163	5,957	125	5	0	0	1	1	5	5	0	3	0	3
Restaurant B	626	5,672	70	2	0	0	1	1	2	2	2	0	0	2
Restaurant C	313	16,641	51	7	0	0	1	1	2	2	2	0	0	2
Restaurant D	495	7,461	72	0	3	0	1	0	2	3	2	0	0	2
Restaurant E	1,486	5,410	117	2	0	0	1	1	3	3	0	2	0	2
Total			2,654	16	23	1	29	21	46	46	39	35	1	16

EL: Electricity, TG: Town Gas, LPG: Liquefied Petroleum Gas, AO: A heavy oil.
OT: Outside Temperature, OH: Outside Humidity, RT: Room Temperature, RH: Room Humidity.
WT: Water Temperature, WS: Water used for Steam boiler, HW: Heat supplied from boiler.

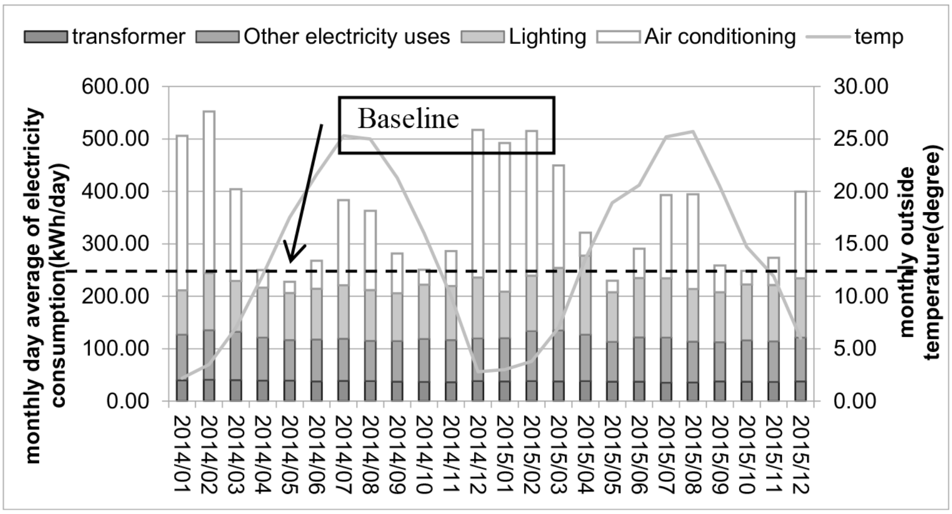

Figure 1. The monthly day average of the electricity consumption and the baseline (City hall B).

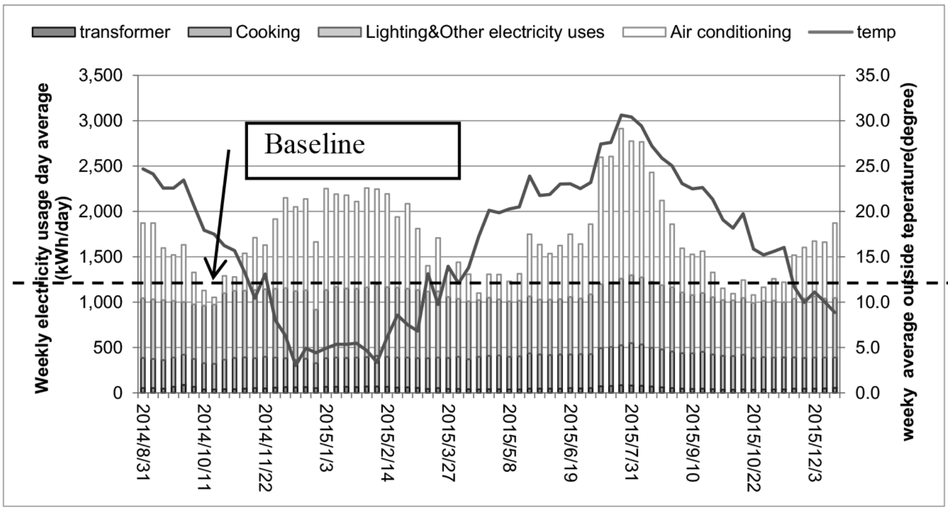

Figure 2. The weekly day average of the electricity consumption and the baseline (Restaurant A).

sum of the product of the rated input, the annual use time and the utilisation factors of each lighting appliance.

Transformer loss

The following formula estimates the transformer loss. First, the annual equivalent load factor is estimated from the monthly electricity consumption. 1.1 is multiplied to the monthly electricity consumption because it accounts for the decrease in the power factor of the secondary side of the transformer. The rated unload loss and the rated load loss can be known from the specification. The annual transformer loss is estimated from the annual equivalent load factor, the rated unload loss, and the rated load loss.

$$\mathrm{AF} = \sum_{m} \left(\frac{E_m \times 1.1}{\sum_n T_n \times D_m \times 24} \right)^2$$

$$\mathrm{ALF} = \sqrt{\frac{AF}{12}}$$

$$\mathrm{Loss} = (UL\text{-}LL \times ALF^2) \times 8760$$

ALF Annual Equivalent Load Factor
E_m Monthly electricity consumption (month m) (kWh)
T_n Capacity of transformer n (kVA)
D_m The number of days in month m
24 24 hours per day
12 12 months in a year
Loss Transformer Loss (kWh)
UL rated unload loss (kW)
LL rated load loss (when load factor is 100%) (kW)
8760 8760 hours in a year

ESTIMATING THE YEAR-ROUND DEMAND WITH LARGE SEASONAL FLUCTUATIONS

Domestic hot water demand

To estimate the energy consumption for domestic hot water, the following conditions must be satisfied.

1. A steam boiler is not used for domestic hot water.
2. The amount of hot water used is constant throughout the year.
3. The energy consumption to heat supply water is larger than the energy consumption to reheat hot water[2].
4. The energy consumption for domestic hot water is larger than for cooking if gas is used for both at the building.

The energy consumption for domestic hot water is estimated from the supply temperature and the efficiency of the heating equipment. The supply temperature is estimated by using the formula below. The region is determined by the annual average of the outside temperature.

ST = coefficient × OT + intercept
+ 3 from September to February

ST = coefficient × OT + intercept
+ 3 from March to August

ST Supply Temperature (degree)
OT Outside Temperature (degree)

The following formula calculates the energy consumption for domestic hot water. In (1) and (2), the total amount of hot water used is a sum of hot water supplied from the boiler and water added. In (3), the hot water temperature is a weighted average of the temperature of the hot water from the boiler and the supply temperature. In (4), the boiler energy consumption is the product of the volume of hot water supplied from the boiler and the difference between the temperature of the hot water and the supply temperature divided by the efficiency. Equation (5) is derived by using (1) to (4). In (5), the boiler energy consumption is the product of the volume of hot water used and the difference between the temperature of the hot water used and the supply divided by the efficiency. Assuming that the volume of hot water used per day is constant throughout the year, equation (6) shows that the energy consumption of the boiler is proportional to the difference between the hot water temperature and the supply temperature divided by the efficiency (α).

Table 4. The water temperature estimation formula in Japan.

region	coefficient	intercept	region	coefficient	intercept
1st	0.664	3.466	5th	0.866	1.665
2nd	0.664	3.466	6th	0.852	2.473
3rd	0.605	4.515	7th	0.922	2.097
4th	0.605	4.515	8th	0.692	7.167

Reference: The National Institute for Land and Infrastructure Management et al., 2013, p308 Table 2.4.2.

$$V_{use} = V_{boiler} + V_{water} \quad (1)$$

$$1 = \frac{V_{boiler}}{V_{use}} + \frac{V_{water}}{V_{use}} \quad a = \frac{V_{boiler}}{V_{use}}, b = \frac{V_{water}}{V_{use}} \quad (2)$$

$$T_{use} = a \times T_{boiler} + b \times T_{water} \quad a + b = 1 \quad (3)$$

$$E_{boiler} = \frac{V_{boiler} \times (T_{boiler} - T_{water})}{COP} \quad (4)$$

$$E_{boiler} = \frac{V_{use} \times (T_{use} - T_{water})}{COP} \quad (5)$$

$$E_{boiler} \propto \alpha \quad \alpha = \frac{(T_{use} - T_{water})}{COP} \quad (6)$$

V_{use} The volume of hot water used at the temperature of T_{use}
V_{boiler} The volume of hot water supplied from boiler at the temperature of T_{boiler}
V_{water} The volume of supply water at the temperature of T_{water}
E_{boiler} The energy consumption of a boiler
COP Boiler efficiency

Estimating domestic hot water if domestic hot water and cooking use the same energy source

This section shows a method of estimating the consumption for domestic hot water, if cooking and domestic hot water uses the same energy source. If the energy source is gas, the regression equation is created by the monthly day average gas consumption and α. The intercept of the regression is the monthly day average consumption for cooking, and the difference between the monthly day average gas consumption and the monthly day average consumption for cooking is the monthly day average for domestic hot water.

Estimating domestic hot water if domestic hot water and AC use the same energy source

This section shows a method of estimating the consumption for domestic hot water, if AC and domestic hot water uses the same energy source. If the energy source is gas, the regression equation, in which the intercept is set to 0, is made from the monthly day average gas consumption in the period when the building does not use AC and α (see Figure 3). By substituting α in the period when the building uses AC, for the regression, the energy consumption for domestic hot water can be estimated. The value subtracting the domestic hot water from the monthly day average gas consumption is the monthly day average consumption for AC.

Estimating domestic hot water if it is powered by electricity

The consumption for domestic hot water powered by electricity cannot be estimated without measuring the consumption for domestic hot water. When the electricity consumption for domestic hot water can be measured for about a month, the estimation becomes possible.

In Japan, the domestic hot water is mostly supplied by midnight electricity because of its discounted price, and the midnight consumption is measured by a utility company. On the other hand, the midnight electricity does not include electricity used in daytime to heat water when the heat storage becomes short. Therefore, if only the midnight electricity is considered for domestic hot water, the value can be underestimated.

The electric equipment for domestic hot water is generally an electric water heater or a heat pump water heater in Japan. The efficiency of the electric water heater is constant. However, the efficiency of the heat pump water heater changes depending on the outside temperature. Therefore, it is necessary to figure out its efficiency for outside temperature from catalogues and specifications.

The regression equation with the intercept set to 0 uses the measured monthly day average consumption for domestic hot water and α. By substituting α for the regression, the energy consumption for domestic hot water can be estimated.

ESTIMATION BY PATTERN RECOGNITION

Estimation of energy consumption by purpose is made by combining the methods described above according to the sources and purposes of energy used in a building. Table 5 shows possible combinations patterns of energy sources and purposes used in buildings.

Pattern 1 and Pattern 2

Since the energy source for domestic hot water is only oil, electricity does not include year-round demand with large seasonal fluctuation. AC is estimated by the method of Estimating AC consumption, lighting and transformer loss is by the method of Lighting and Transformer loss in Estimating the year-round demand with small seasonal fluctuation. The energy consumption for other devices is the remainder after excluding AC and other values known from total energy consumption.

Pattern 3

AC, lighting, transformer loss, and other devices powered by electricity are estimated by the method of Pattern 1 and Pattern 2. Domestic hot water and cooking are estimated by the method of Estimating domestic hot water if domestic hot water and cooking use the same energy source.

Pattern 4

Domestic hot water and cooking supplied by gas can be estimated if the gas consumption for AC is measured. Domestic hot water and cooking are estimated by applying the remainder of subtracting AC from gas to Pattern 3. AC, lighting, transformer loss, and other devices are estimated by the method of Pattern 1 and Pattern 2.

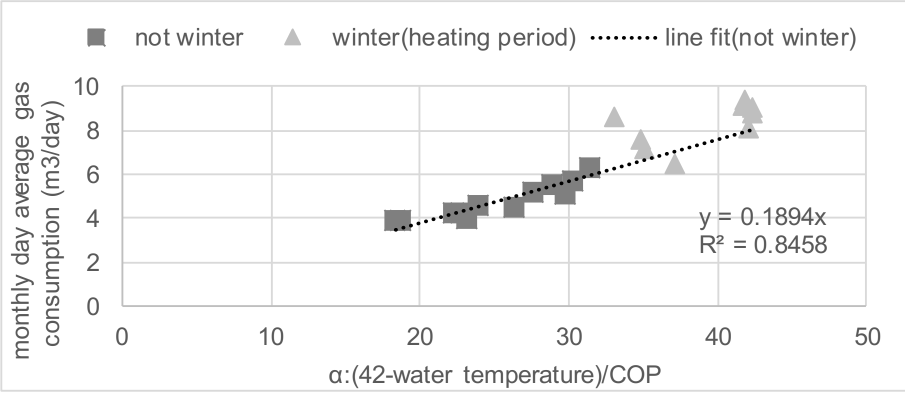

Figure 3. The monthly day average gas consumption and the line fitting.

Table 5. Energy use patterns in a commercial building.

Pattern	Energy source	AC	Domestic hot water	Lighting	Cooking	Transformer loss	Other devices
Pattern 1	Electricity	E	-	E	O	E	S
	Gas	-	-	-	E	-	-
	Oil	-	E	-	-	-	-
Pattern 2	Electricity	E	-	E	O	E	S
	Oil	-	E	-	-	-	-
Pattern3	Electricity	E	-	E	O	E	S
	Gas	-	E	-	S	-	-
Pattern4	Electricity	E	-	E	O	E	S
	Gas	D	E	-	S	-	-
Pattern5	Electricity	E	-	E	O	E	S
	Gas	-	-	-	E	-	-
	Oil	S	E	-	-	-	-
Pattern6	Electricity	D	D	E	O	E	S
Pattern7	Electricity	D	D	E	O	E	S
	Gas	-	-	-	E	-	-

"E" is estimable, "D" is difficult to estimate, "S" is calculated by subtracting the sum of energy consumption estimated for energy uses from the energy consumption of each energy type. "O" is the consumption cannot be estimated, and the consumption is included in the other electricity uses. "-"is that the energy source is not used for the energy use.

Pattern 5

Domestic hot water and AC from oil are estimated by the method of Estimating domestic hot water if domestic hot water and AC use the same energy source. AC, lighting, transformer loss, and other devices are estimated by the method of Pattern 1 and Pattern 2. Gas is only used for cooking.

Pattern 6 and Pattern 7

Since domestic hot water is powered by electricity, if the electricity consumption for domestic hot water is measured for at least a month, AC and domestic hot water can be estimated by the method of Estimating domestic hot water if it is powered by electricity. After the estimation of AC and domestic hot water, lighting, transformer loss, and other devices are estimated by the method of Pattern 1 and Pattern 2.

COMPARISON BETWEEN MEASURED AND ESTIMATED ENERGY CONSUMPTION

Using the measured energy consumption data of Bank, Restaurant C and elderly nursing home B, the study compares the estimated consumptions of energy purpose with the measured values.

Table 6 shows the measured value and the estimated value of each energy purpose in Bank A. This building consumes only electricity for AC, lighting, and other devices. It does not use domestic hot water and transformer. The totals are not the same because the estimated value is calculated by the monthly bill, and the meter-reading period is slightly different from the measured period.

Table 7 shows the measured value and the estimated value of Restaurant C. It uses electricity for AC, lighting, transformer,

Table 6. Comparison between measured and estimated consumption (Bank A).

Energy consumption (GJ/year)	AC	Lighting	Other devices	Total
Measured value	22.3	10.8	54.3	87.5
Estimated value	24.4	11	52.7	88.1
Difference	8 %	1 %	-3 %	1 %

Table 7. Comparison between measured and estimated consumption (Restaurant C).

Energy consumption (GJ/year)	AC	Lighting	Cooking	Other devices	Transformer loss	Total
Measured value	84.9	1,141.3	3,453.3	521.1	2.4	5,203.0
Estimated value	95.2	1,263.3	3,252.2	598.6	0.9	5,210.2
Difference	10 %	11 %	-6 %	13 %	-151 %	0 %

Table 8. Comparison between measured and estimated consumption (Elderly nursing home B).

Energy consumption (GJ/year)	AC	domestic hot water	Lighting	Cooking	Other devices	Transformer loss	Total
Measured value	469	371	229	251	519	268	2,108
Estimated value	440	393	191	251	727	92	2,094
Difference	-6 %	6 %	-17 %	0 %	40 %	-66 %	-1 %

and other devices. It uses gas for AC, cooking, and domestic hot water. Because Restaurant C is a Chinese restaurant and consumes 10 times more gas for cooking than domestic hot water, its monthly day average consumption of gas does not show the seasonal fluctuation. In this comparison, domestic hot water is included in cooking.

For lighting, AC, and other devices, the estimated values are about 10 % larger than the measured values. For cooking, the estimated value was very close to the measured value. The proportion of transformer loss in the total energy consumption is small, so it has little influence on the result.

Table 8 shows the measured value and the estimated value of Elderly nursing home B. It uses electricity for AC, domestic hot water, lighting, transformer, and other devices. It uses gas only for cooking.

For AC and domestic hot water, the difference between the measured and the estimated is about 6 %. The consumption for lighting is underestimated, and the difference is 17 %. The fact that the building managers' report on the use time of lighting applications was slightly shorter affected the difference. The difference of transformer loss is 66 %. The building uses 6 transformers, and they are aging. Since the estimation does not take into consideration the performance deterioration due to aging, it may have influenced it. Since the measurement error is included in the transformer loss, it also may have affected it. In Elderly nursing home B, Transformer loss and other devices should be evaluated in total. The measured value is 784, and the estimated value is 818, which is very close.

From these comparisons, it can be concluded that the method can estimate energy consumption by purpose up to a particular degree of certainty.

Estimation of Standby Power Consumption

This chapter analyses the standby power consumption of non-residential buildings based on the detailed building measurements. In this paper, standby power is defined as electricity consumption despite the fact that the facility is inoperative. The study of standby power for non-residential buildings has hardly progressed in Japan, and this study is intended to conduct a rudimentary research on standby power consumption in Japanese non-residential buildings.

In the following, the standby power consumption is estimated for two city halls. The reason for selecting the city halls is that their working hours are stable. It is difficult to define standby power concretely, but in this paper it is decided as follows.

1. AC: the electricity consumption when AC is not used.
2. Lighting and Outlet: the electricity consumption when there are no employees within the building; however, the electricity consumption of computer server and EPS is excluded.
3. Transformer: load and unload losses.

The method of calculating standby power consumption is as follows.

1. AC: This study sets the threshold value by analysing the electricity consumption data of AC equipment. When the measured electricity consumption is less than the threshold value, the equipment is regarded as non-use, and the consumption is considered as the standby power consumption.
2. Lighting and outlets: This study sets the threshold value by analyzing the electricity consumption data of lightings and outlets applications. When the electricity consumption is less than the threshold value, the appliances are regarded as not used, and the consumption referred to as the standby power consumption. The consumption of computer servers and EPSs is excluded.
3. Transformer: Calculate transformer loss by the formula mentioned before.

The standby power of outlets includes the electricity consumption of vending machines when the building is closed. The standby power of lighting also includes the consumption of the emergency exit signs. There might be an objection to using these as standby power, but their proportion of the total standby power is thought to be small, and this study analyses them as standby power.

The annual standby power consumption of City hall A is shown in Figure 4. The standby power accounts for 14 % of its annual electricity consumption. The standby power of the AC heat source mainly is the consumption of the crankcase heater of the heat pump chillers.

The annual standby power consumption of City hall B is shown in Figure 5. The standby power consumption of City hall B accounts for 20 % of its annual electricity consumption. The standby power of the AC heat source is mainly the consumption of the crankcase heater of the heat-pump multi-air-conditioners. The reason why the ratio of the standby power consumption to the total electricity consumption in City hall B is large is that City hall B is a building whose energy saving has progressed. In City hall B, high efficient equipment for AC and lighting was installed, and that results in saving energy by more than 15 % compared with the past. Therefore, the ratio of the standby power consumption to the total electricity consumption is quite high.

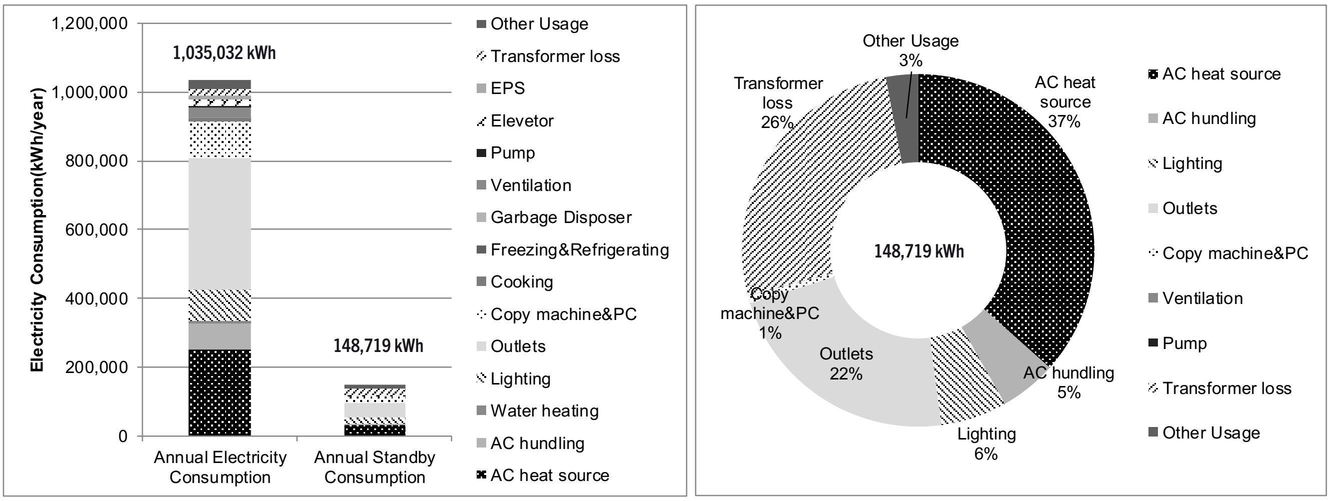

Figure 4. The annual standby power consumption of purpose (City hall A). (Note: PC is Personal Computer EPS is Emergency Power Supply.)

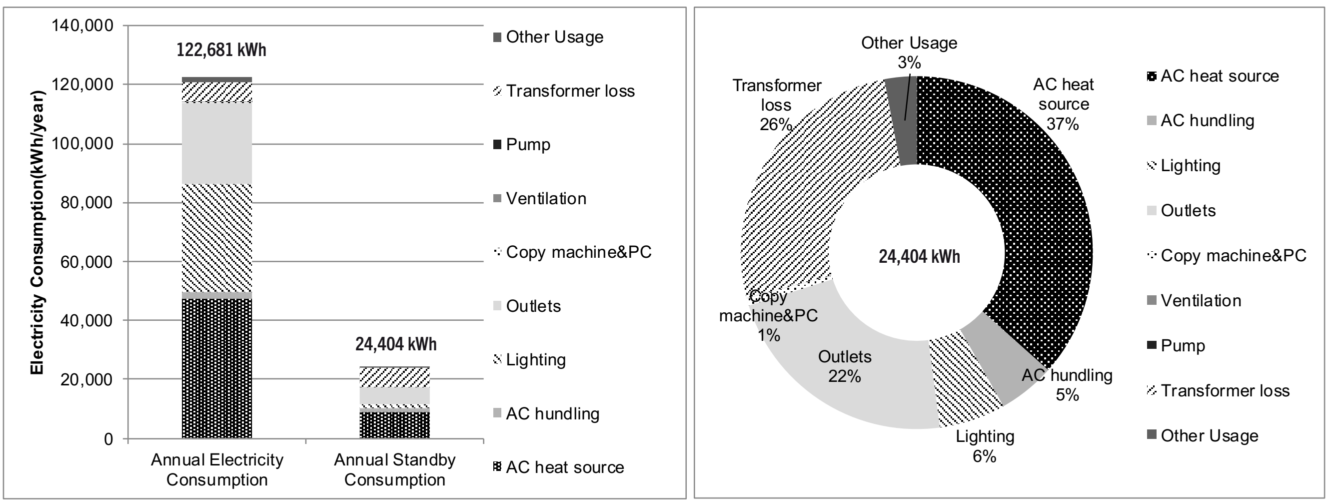

Figure 5. The annual standby power consumption (City hall B). Note: PC is Personal Computer.

This study conducted a rudimentary analysis of standby power consumption. The ratio of the standby power consumption of City hall A to the annual electricity consumption is 14 %, and for City hall B it is 20 %.

Conclusion

The study develops the method to estimate the energy consumption of each purpose by using commonly available data such as monthly energy bills. The comparison between the estimated energy consumption of each purpose and the measured value shows a maximum difference of 17 %. It is concluded that the method can estimate the energy consumption of each energy purpose at a certain degree of certainty. The estimated value helps an non-residential building's owner to decide the priority of adopting energy conservation measures. It also makes it possible to more accurately estimate energy saving, CO_2 reduction, and pay-back years.

The study finds that standby power consumption in a non-residential building accounts for 14 to 20 % of the total electricity consumption. In this study, standby power consumption is defined as electricity consumption that is consumed despite a not-working day but excludes consumption by a computer server or an EPS that needs to be operated. The electricity consumption of vending machines and emergency exit signs is included in the standby power in this study. As energy saving in a building progresses, the percentage of standby power consumption relative to the total consumption increases. It is extremely important to take measures against standby power for further energy conservation. Therefore, further research on standby power consumption in a non-residential building will be necessary.

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Endnote

1. The study has researched the method to estimate the energy consumption for cooling storage. The method is very complicated and measuring electricity consumption of cooling storage for at least one month is necessary for the estimation. A non-residential building like an office only consumes small electricity for cooling storage. So, it does not describe the estimation method for cooling storage.
2. In Japan, supplying only heat to a bathtub is popular to warm up a cold bath. The method in the study estimates the energy consumption for domestic hot water from the supply temperature, so if much energy to warm up a cold bath is used, this method cannot estimate the energy consumption for domestic hot water.

Acknowledgements

The original idea for this study came from Prof. Kazuhiko Ogimoto Institute of Industrial Science, University of Tokyo.

This study was supported by the Ministry of Environment of Japan. All errors and omissions are solely the authors' responsibility.