STUDY OF ENERGY CONSUMPTION IN LIBRARY BUILDING

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ABSTRACT

This research article presents the study of energy consumption, specific energy consumption (SEC) and energy utilization index (EUI) in electronics library at Pibulsongkram Rajabhat University. The library building was constructed by concrete, 4 floors, which do not have air conditioner in car parking at ground floor. The central unit air conditioner is for other floors in building. Chiller is the main equipment for air condition system that it is mainly consuming energy equipment. Then, others electric equipment and lighting system are lower, respectively. The result of this study found that peak demand for the building was 321.5 kW which is proportional by air conditioning system, others electric equipment and lighting system at 81.49%, 10.89% and 7.62%, respectively. Specific energy consumption (SEC) in building was 16.67 MJ/m^2, specific energy consumption in air conditioning area was 21.15 MJ/m^2 and specific energy consumption by library user was 6.97 MJ/person. The energy utilization index in building was 0.44. Our finding important implications for study of energy utilization and energy efficiency in library buildings.

KEYWORDS: Specific Energy Consumption, Energy Utilization Index, Library Building

1. Introduction

Energy is very importance in the daily life of human. The increasing of population effected to high energy usage then energy conservation program is necessary. Thailand began compulsory energy conservation program by promulgate the Energy Conservation and Promotion Act (EPC Act) since 1992 that regulated by Department of Alternative Energy Development and Efficiency (DEDE). A commercial building, including for government building, and factory which total installed transformer from 1,175 kVA or electric power meter from 1,000 kW or annual energy consumption from 20 Million MJ has to follow up this energy

conservation program. The three main objectives of this law are (i) attend high demand of energy consumption due to increasing of social and economics, (ii) retaining of energy security in efficient of both demand and supply side, (iii) introduce measures and technology, including to system, to decrease energy consumption. Figure 1 was shown operational structure of controlled building and factory.

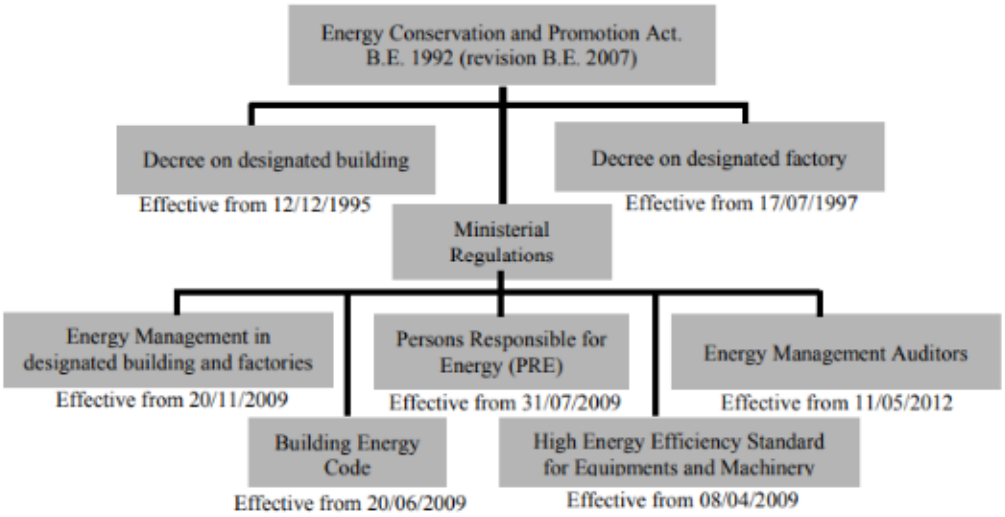

Figure 1 Structure of Energy Conservation and Promotion Act (EPC Act) [1, 2]

According to the statistical report on Thailand Energy Efficiency Situation in 2016, which conducted by the Department of Alternative Energy Development and Efficiency (DEDE), the amount of 79,929 kiloton of oil equivalent (ktoe) is the total final energy consumption by economic sectors which rising up 2.6% from the previous year. The sector of commercial totally consumed about 5,605 ktoe in electricity, according for 90.29% of total commercial energy or about 90.2% of its total energy consumption [3]. Most of energy usage in commercial sector is the electrical energy of building. Then, the energy management for buildings was reported to the Ministry of Energy. The report showed the energy consumption of buildings and guidelines for energy efficiency. Furthermore, the Cabinet endorsed a policy of energy conservation by decreasing the energy consumption in government buildings. Then, the government commanded to government agencies to reduce the energy consumption at least 10% of previous year by cabinet meeting on March 16, 2012 [4].

The value of the specific energy consumption (SEC) and the energy utilization index (EUI) were directly affected by the consumption of energy of buildings. The increasing of specific energy consumption resulted in high energy consumption. The energy utilization index (EUI) was value of the comparison of difference of standard electricity utilization and actual energy consumption with actual energy consumption that indicated in positive and negative value if pass and not pass criteria, respectively [5]. The energy utilization index is a tool used in energy benchmarking of energy efficiency in same type of building or factory [6-8]. Orrawan R, et al. studied of the electric energy consumption of the science center building at Suan Sunandha Rajabhat University which found that specific energy consumption of the building was 27.91 MJ/m^2 and the proportion of electric load was divided into three systems, such as air conditioners, lighting and other systems, about 87%, 4% and 9%, respectively [9]. Pochkao A. studied and evaluated the energy consumption in the education building of Vongchavalitkul University and found that the energy usage was divided into three systems; i.e. 14% for lighting, 75% for air conditioning and 11% for other systems [10]. Many of researchers researched on energy consumption in building which found in same result of the main system that consumed energy was air conditioner then lighting [11-13]. The energy used in university buildings is influenced by building services provided in the facility. The energy used for providing services such as air condition system which varies depending on the efficiency of the systems and loads, lighting, electricity supply for equipment. A framework for representing ontology and relationships between the dependent variable (energy use) and independent variables is illustrated in figure 2.

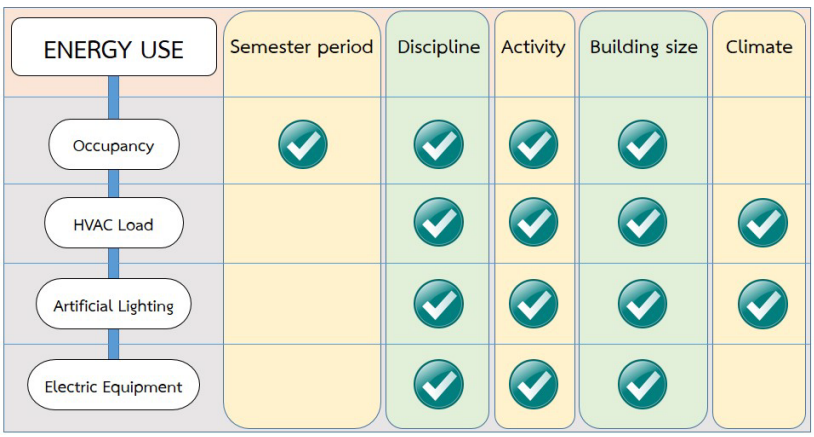

Figure 2 Ontology representing the energy performance of a university building [14]

2. Background

Pibulsongkran Rajabhat University was located in northern of Thailand, Phitsanulok province. Figure 3 shows electronics library building at Pibulsongkran Rajabhat University. The electronics library building was one of group of buildings which it was concrete building having 4 floors and total area of 16,784 m^2. The building had been air conditioned by chiller which it consumed high energy. The library was conducted green library policy but, however, there did not have instruments and equipment to evaluate energy consumption rate of the building. Therefore, this research aim to evaluate energy density of building.

Figure 3 Electronics library building

The objective of this research was to study the electrical energy consumption, specific energy consumption (SEC), and energy utilization index (EUI), of electronics library building at Pibulsongkram Rajabhat University, Phitsanulok, Thailand.

3. Methodology

This research was conducted by collecting the general data in the electronics library building; i.e. total area (unit of square meter, m^2), number of lighting, working hour of lighting, working hour of library, number of users and officers. Moreover, the power demand (kW) and electrical energy consumption (kWh) of all of building and chiller were collected by power recorder in February 2017, for 7 days, from Monday till Sunday which representing of mean energy consumption throughout the year. Due to operation behavior of building was be

repeatedly in routine every week when observed. The electrical data would be analyzed and evaluated the specific energy consumption and energy utilization index.

The general data of area for each floor and equipment, such as chiller, lighting and others, was gathered by surveying, studying form construction drawings. Additionally, observing and studying the behavior of electric appliances, officers, students and general users.

The data of power demand of the library building for lighting and others systems were collected by the power recorder which recording at main distribution board. Whereas, electric energy consumption of air condition system; i.e. chiller, cooling tower, air handling units, was collected from distribution board of air condition system. Figure 4 shows single line diagram of electrical system of the building.

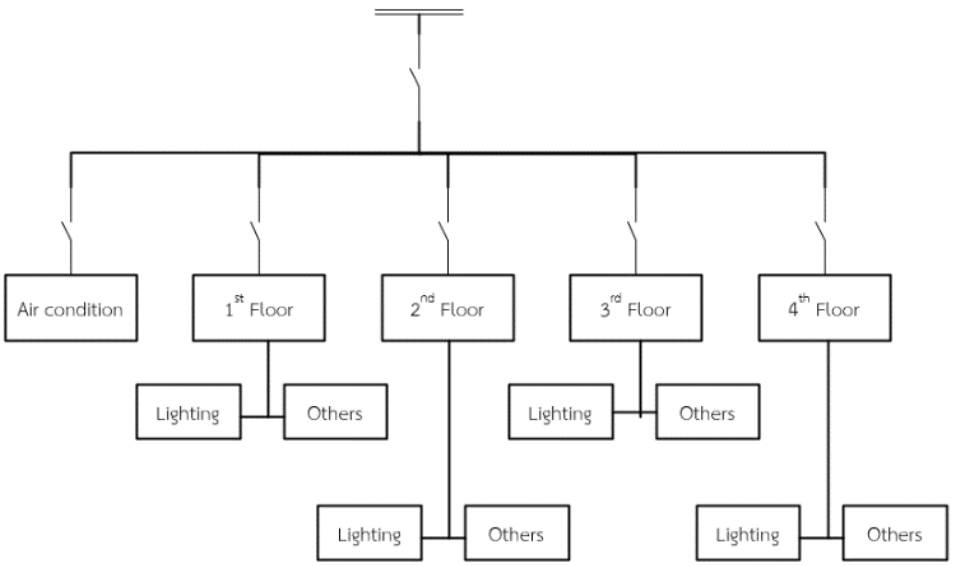

Figure 4 Electrical single line diagram

4. Lighting Power Density (LPD)

The power of lighting in the electronics library building was studied. The lighting power density (LPD) is related to the total power demand of lighting system (W) and total area, exclude parking area, in unit of square meter (m^2). The Lighting power density is the value of energy efficiency of lighting system which meaning of the usage of high efficiency of light bulb and device [15]. Moreover, mean lighting quality in each area had been collected by

illuminate meter and compare with the regulation or standard. The equation to calculate the lighting power density shown as follows [16]:

$$\text{LPD} = \frac{\text{Total power demand of lighting system}}{\text{Total area}} \quad (1)$$

5. Specific energy consumption (SEC)

The data of electric energy consumption and the total area of the library building were studied and analyzed. The specific energy consumption (SEC) could be calculated from average of power demand (kW) of the building and each system or could be calculated from the amount of the electric energy consumption in unit of kilowatt-hour (kWh) and divided by total area in unit of square meter (m^2). The equation to calculate the specific energy consumption shown as follows [9]:

$$\text{SEC} = \frac{[\text{electric energy consumption} \times 3.6]}{\text{total area}} \quad (2)$$

6. Energy Utilization Index (EUI)

The energy utilization index (EUI) is related to the standard electricity utilization (SEU) and electric energy consumption. The standard electricity utilization (SEU) of library is effected from amount of officers, students, day of working, total usage areas and temperature which the standard electricity utilization can be evaluated by mathematic model. However, group of institutes were categorized into 9 categories by Energy Policy and Planning Office which library was category 1, mathematical model of library was subcategory of 1-15. Hence, the standard electricity utilization can be evaluated by the following equation [17]:

$$\begin{aligned}\text{SEU} = \; & [(0.465 \times \text{amount of the officers}) + \\ & (0.132 \times \text{day of working}) \times \text{temperature} + \\ & \left(0.007 \times \text{students} \times \left(\text{total}\,\frac{\text{area}}{1000}\right)\right)]\end{aligned} \quad (3)$$

The energy utilization index was calculated using the following equation [15]:

$$\text{EUI} = \frac{[(0.9 \times \text{SEU}) - \text{electric energy consumption}]}{\text{electric energy consumption}} \quad (4)$$

7. Result and discussions

7.1 Total area of electronics library building at Pibulsongkram Rajabhat University

The electronics library has 4 floors which having total area about 16,784 m^2. The first floor is car parking, there is non-air condition area, having total area about 3,555 m^2. Other floors are bookshelves and reading area, there are air condition area, having total area about 13,229 m^2. For air condition area, the screw type water cooled chiller was installed is the main equipment to consume electric energy. The proportion of the total area of electronics library building was divided into 2 parts which there are the air condition area of 78.82% and non-air conditioner area of 21.18% as shown in Figure 5.

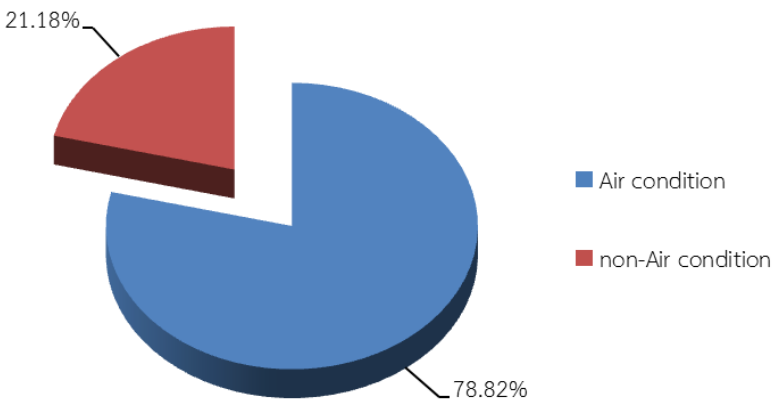

Figure 5 Area of air condition and non-air condition of electronics library building

7.2 Data Analysis

The proportion of the electric power demand (kW) in the electronics library building was divided into three systems, such as air condition system, lighting system and other system, about 81.49%, 10.89% and 7.62%, respectively as shown in Figure 6. Though, the electric power demand of air condition system was highest but, due to, the library building was be air conditioned by chiller which it was operated routine in every day. Therefore, the proportion of electric power demand of air condition system had been stable since installed. The electric power demand of air condition system should not be analyzed on this research.

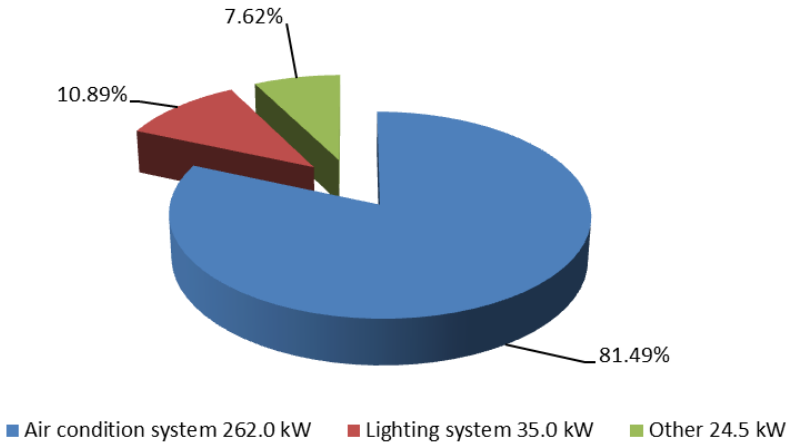

Figure 6 Electric power demand in the electronics library building

The power demand of lighting system in the library building was shown in Figure 7. The power demand of lighting system at 3rd floor was maximum about 42.58% due to this floor is provided for reading and more of collected books than other floors. The power demand of lighting system at 2nd floor about 39.07% was comparable with 3rd floor because the main gate and computer zone were located at this floor where it was crowded of people, whereas, the power demand of lighting system for 1st and 4th floors were similarity about 9.28% and 9.07%, respectively, due to the 1st floor was car parking which it is required less of luminance, the 4th floor is for managements, conference rooms and theatres.

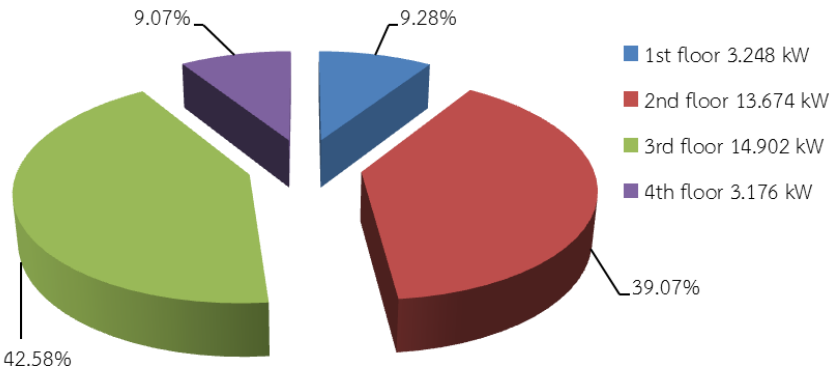

Figure 7 Proportion of power demand of lighting system by floor

The power demand of lighting system was less because of the electronics library building was conducted energy saving measure which they were control the quantity of

lighting to turn on. Due to more quantity of lighting figures when design, whereas, it can be controlled when operation, such as car parking area, etc. The actual lighting power compare with installed lighting power was shown in Table 1. However, actual lighting power would be controlled by controlling number of light which it cause of low lighting quality. The lighting quality should be controlled by Building Control Act [18]. This research was conducted by record the lighting quality of each area and found that it can be reduced in some areas and it had to be increased in some areas. However, the result of this research found that lighting quality was passed in most of areas, excepted at entrance gate and chiller room because of natural light was used at entrance gate and normal operation of chiller room would be turned off lighting for saving energy. Table 2 shows the lighting quality of each area.

Table 1 Reduction of lighting power demand.

Floor	Power demand of Lighting system		
	Installed	Actual	Reduction
1st	16.24	3.25	80.0%
2nd	68.37	13.67	80.0%
3rd	74.51	14.90	80.0%
4th	15.88	3.18	80.0%
Total	175.00	35.00	80.0%

Table 2 Lighting quality of each area in the library building

Area	Illumination (LUX)		Result
	Standard [16]	Actual	
Parking	50	75	Pass
Entrance Gate	500	300	Not Pass
Office of Director	500	692	Pass
Chiller room	200	178	Not Pass
Bookshelves	200	850	Pass
Walk way	300	370	Pass

The lighting power density (LPD) of electronics library building was measured into 2 methods, count from construction drawing and survey of actual usage, for comparing of the lighting power density between design data and actual state. Table 3 shows the lighting power density of electronics library building.

Table 3 Lighting power density (LPD) of electronics library building

Data	Quantity		Remark
Total area (exclude parking)	3,229	m^2	
Actual lighting demand	35.00	kW	
Installed lighting demand	175.00	kW	
LPD_{actual}	2.65	W/m^2	Pass
$LPD_{installed}$	13.23	W/m^2	Pass

Remark: Standard regulation value is 14 W/m^2 for university [16].

The power demand of electric energy of the electronics library building was recorded for a week, 3 – 9 February 2017, and repeated again, 16 – 23 February 2017, to confirm the trend of profile. This research found that the profiles were similarity then this profile could be represented to annual profile of power demand of the electronics library building. The load profile of electric power in the electronics library building was represented in Figure 8.

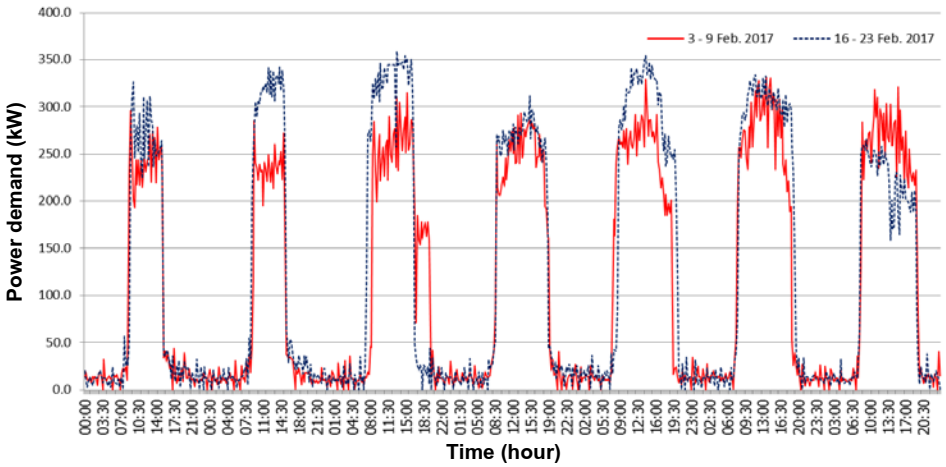

Figure 8 Load profile of electric power in the electronics library building

The average maximum power demand at on peak period and off peak period whole measured period was about 321.5 and 26.5 kW, respectively. The average daily power demand, whole on peak and off peak, was about 174.0 kW. The quantity of electric energy consumption was recorded in 24 hours a day throughout 2 weeks and, then, multiply by working day of the library. The average electric energy consumption on working day was 3,075.4 kWh/day and holiday was 2,027.8 kWh/day. The average monthly electric energy consumption of the electronics library building was about 77,729.05 kWh a month. Table 4 and Table 5 shows electric power demand and electric energy consumption, respectively.

Table 4 Electric power demand of the electronics library building.

Day	Power demand at peak (kW)		Power demand at off peak (kW)	
	3-9/02/2017	17-23/02/2017	3-9/02/2017	17-23/02/2017
Monday	315.0	359.1	19.0	13.7
Tuesday	293.4	311.5	13.7	18.1
Wednesday	329.5	354.4	25.5	52.3
Thursday	331.4	334.5	20.5	21.2
Friday	320.9	265.6	38.9	25.3
Saturday	296.5	326.5	38.9	25.3
Sunday	285.1	342.3	27.4	30.4
Average	**321.5**		**26.5**	
	174.0			

Table 5 Electric energy consumption of the electronics library building.

Period	Working Day (kWh/day)					Holiday (kWh/day)	
	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.
3-9 Feb. 2017	2,832.0	2,798.0	3,098.0	3,153.0	3,095.0	1,905.0	1,759.0
17-23 Feb. 2017	2,822.0	2,994.0	3,746.0	3,555.0	2,660.5	2,033.0	2,414.0
Average	**3,075.4**					**2,027.8**	
	77,729.05 kWh/month						

Table 6 represents the specific energy consumption and energy utilization index of the electronics library building. The specific energy consumption was shown in 3 categories which it were based on total area, air condition area and person, about 16.67 MJ/m^2, 21.25 MJ/m^2 and 21.15 MJ/person, respectively. The energy utilization index of the electronics library building was about 0.44. Hence, the value was positive which expressed the “pass” of the standard criterion.

Table 6 Specific energy consumption and energy utilization index of library building.

Description	Quantity	
Average energy consumption	77,729.05	kWh/month
Total area	16,784	m^2
Air condition area	13,229	m^2
Number of officers	25	persons/day
Day of working	30	day/month
Average number of users	39,420	Persons/month
Temperature	25	°C
Specific Energy Consumption (total)	16.67	MJ/m^2
Specific Energy Consumption (air condition area)	21.15	MJ/m^2
Specific Energy Consumption (person)	6.97	MJ/person
Standard Electricity Utilization (SEU)	124,602.17	kWh
Energy Utilization Index (EUI)	0.44	

8. Conclusion

The electric energy consumption of the electronics library building at Pibulsongkram Rajabhat University was divided into 3 categories which maximum value was used by air condition system and it was be tracked by lighting system. The most of electric energy consumption for lighting system was used by 2nd and 3rd floors which energy consumption in both floors were similar because of they were provided for reading which having more users. The trend of power demand at the electronics library building was generality which it was used at working time and shut down at night time. However, the specific energy

consumption could be controlled by control of air conditioning capacity to maintain maximum demand due to energy was consumed by chiller. Moreover, control of lighting quality by limit to turn on quantity of lighting figures would be assistance to maintain the specific energy consumption as well. However, the energy utilization index of the electronics library building was been positive which it would be expressed that pass the standard. Nevertheless, the energy conservation measure would be necessarily implemented to sustain and improve of energy efficiency in the building.

References

[1] Wongkot W. Performance Tracking of Thailand's energy management system under Energy Conservation Promotion Act. Energy Procedia 2016;100:448-51.

[2] Parida M, Wongkot W, Det D. Analysis of Energy Utilization Index in Thailand sanitary ceramics sector. Energy Procedia 2017;141:170-4.

[3] Department of Alternative Energy development and efficiency. Thailand Energy Efficiency Situation [Internet]. 2016 [cited 2017 Feb 5]. Available from: http://www.dede.go.th.

[4] Energy Policy and Planning Office. Cabinet meeting report [Internet]. 2012 [cited 2014 Feb 5]. Available from: http://www.eppo.go.th.

[5] Nakrak T. Management and improvement the power energy consumption of Thammasat University [desertation]. Pratumthani. Thammasat University; 2011.

[6] Nattanee T, Wongkot W, Det D. Energy Performance Study in Thailand Hospital Building. Energy Procedia 2017;141:255-9.

[7] Orrawan R, Busarin E, Siwimol C, Sansanee S, Narun L. Status of total electric energy consumption in university. Energy Procedia 2015;197:1166-73.

[8] Chung W, Hui YV, Lam YM. Benchmarking the energy efficiency of commercial buildings. Applied Energy 2006;83:1-14.

[9] Orrawan R, Sansanee S, Narun L, Siwimol C, Busarin E. Study of the electric energy consumption of the science center building. Suan Sunandha Science and Technology Journal 2015;2:7-10.

[10] Pochkao A. Saving electricity energy in private educational building: a case study of The Vongchavalitkul University building [dissertation]. Bangkok: Vongchavalitkul University; 2005.

[11] Luo R, Han Y, Zhou X. Characteristics of campus energy consumption in North China University of Science and Technology. Procedia Engineering 2017;205:3816-23.

[12] Jing R, Wang M, Zhang R, Li N, Zhou Y. A study on energy performance of 30 commercial office buildings in Hong Kong. Energy and Building 2017;144:1117-28.

[13] Sait HH. Auditing and analysis of energy consumption of an educational building in hot and humid area. Energy Conservation and Management 2013;66:143-52.

[14] Khoshbakht M, Gou Z, Dupre K. Energy use characteristics and benchmarking for higher education buildings. Energy and Building 2018;164:61-76.

[15] Illuminating Engineering Association Thailand. Guideline for Indoor Lighting Design [Internet]. 2014 [cited 2017 Feb 5]. Available from: http://www.tieathai.org.

[16] Ministerial Regulations B.E.2552. Definition of type or sizing of building and standard, rule and method to design of building for energy conservation. Energy Conservation and Promotion Act (No.2) B.E.2550, Kingdom of Thailand

[17] Energy Policy and Planning Office. Energy conservation in government sector: Fiscal year 2013 [Internet]. 2013. [cited 2014 Feb 5] Available from: http://www.e-report.energy.go.th.

[18] Ministerial Regulations B.E.2549. Standard in administration and safety management occupational health and working environment in heat, light and sound. Building Control Act (No.4) B.E.2550, Kingdom of Thailand.

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