



## ENERGY AUDITING ASSESSMENT BY ISO 50001 ENERGY MANAGEMENT STANDARD IN UNIVERSITY BUILDING

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### ABSTRACT

*This research focuses on studying energy auditing potential in university buildings following the ISO 50001 Energy Management standard. The sample area is the Faculty of Animal Science and Technology Building, Maejo University. The area's scope is a lecture building (building A) and conference building (building B). For energy indicators analysis is divided into three levels: organization level, system level, and equipment level. The results found that the sample building used 100% electricity or about 166,041.66 kWh/year. The significant energy use (SEU) area was the air conditioning system that consumed the highest energy use approximately 38.33%, following by the lighting system, other systems, lift system, ventilation system and pump system which their proportion are 30.76%, 28.32%, 1.43%, 0.95%, and 0.21, respectively. The energy utilization index (EUI) before the study is equal to 5.49 kWh/m<sup>2</sup>-year higher than after the study assessment that is equal to 3.75 kWh/m<sup>2</sup>-year from four recommended measures for example; lighting bulb reducing in the brighter area than standard, changing the fluorescent bulb to LED bulb, changing air conditioning to use a high-efficiency air conditioner, and reducing time ventilation fans in the air-conditioned room. If the sample building will improve following recommended measures, the expected result is a great saving than the current situation. The energy performance index (EPI) of will be decreased by about 31.63%. The electricity will be saved of 32,239.38 kWh/year or equivalent to 125,088.78 Baht/year which the investment cost is about 682,075.00 Baht and get a payback period of 5.45 years.*

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## INTRODUCTION

At present, the demand for energy in Thailand is increasing steadily. Especially in the industrial and service sectors due to the expansion of business and many factory buildings, as a result, the need to use more energy as well. Therefore, the government has the Department of Energy formulate an Energy Efficiency Plan (EEP 2015) (Ministry of Energy, 2015), which aims to reduce energy intensity by 30% by 2036. The ISO 50001 Energy Management System is used to promote energy conservation to propel Thailand's energy management. The ISO 50001 is an energy management standard approved by the International Organization for Standardization released on 15 June 2011 (Ministry of Energy, 2016). The objective of ISO 50001 proposes to enable the improvement of energy performance in organizations (ISO, 2018). Comply with standards framework of ISO 50001 bases on the Plan Do Check Action (P-D-C-A) and can be integrated with other energy management standards such as energy management eight steps of Department of Alternative Energy Development and Efficiency and green building certification. For the related research, Pornchai & Wuttikon (2016) studied the sustainable energy conservation of Siam University following ISO 50001: 2011 to set a model building of community institutions. The building's significant energy use (SEU) was an electric power and energy baseline (EnBs) of the organization was 306,166.67 kWh/month. The energy reduction target would be reduced by about 5% compared with the energy consumption of the year 2015. Pelser et al. (2018) and Narciso & Martins (2020) studied the improvement method of energy management in the cement industry. The energy costs had increased in the year 2008 to 78% and improve continually in the future. When using the ISO 50001 standard for one year, it was found that the energy consumption could be reduced by about 22%, or equivalent to 8.61 ZAR/t. Yacout et al. (2014) and Ozturk (2005) studied the energy management for the textile industry according to ISO 50001:2011. They found that efficient lighting systems, identifying and arresting compressed air leaks, and recovery steam condensate. The monthly reduction of power consumption was 3.9% by applying the measures, which achieved a saving of 919,500 EGP/year. Al-Saadi et al. (2017) and Al-Mulla et al. (2013) studied the reduction of energy in a library building with a total floor area of 2,756 m<sup>2</sup> in Oman's hot climate. To offer opportunities to reduce energy consumption, it was found that the average energy-user-intensity (EUI) was 507 kWh/m<sup>2</sup>/year. Several energy management opportunities (EMOs) were explored using the calibrated model. The top four significant recommendations for EMOs were 1) switch off the HVAC systems outside the occupancy hours 2) increase the thermostat setpoint 3) reduce the air infiltration by using sealant around the window frames and doors, and 4) reduce the lighting intensity and use LED lights instead of the current fluorescent lights. When the EMOs proceed, the energy consumption could be reduced as much as 38.5% (Sudhakara Reddy, 2013). From the above, it is obvious that ISO 50001 is widely used in both industries and buildings; however, there is less of an educational building that attends ISO 50001 standard such as Maejo University. Many years ago, Maejo University needed to enhance a green university; therefore, it is appropriate to establish an energy management system following ISO 50001 to upgrade energy conservation. This research aims to study the potential of energy management in university buildings by ISO 50001 Energy Management System application.

## RESEARCH METHOD

### A. Sample Building

The area study is the location of the Faculty of Animal Science and Technology, Maejo University. In this research, the study's scope focuses only on a building zone that had many building users. Building A is a lecture building and Building B is a conference building, as shown in Figure 1. The total useful areas of both buildings are 5,048.17 m<sup>2</sup> and 3,522.30 m<sup>2</sup>, respectively.

### B. Research Procedure

The research procedure. It consists of collecting data of building, energy auditing, energy baselines analysis, calculation of energy indicators, and energy-saving assessment.

The preliminary data of sample building is collected according to ISO 50002 by ASHRAE Preliminary Energy Use and ASHRAE Level 1 Walk-Through Forms, such as building usage, operating time electricity consumption per month and the area of the building. After that, surveying and measuring the energy consumption of many systems within the building is collected. To calculate Energy Utilization Index (EUI) and Energy Performance Index (EPI) as equation 1 and 2 (Ministry of Energy, 2016), respectively.

$$EUI = \frac{\text{Energy Consumption}}{\text{Building Area}} \quad (1)$$

$$EPI = \frac{EUI_{\text{Present}} - EUI_{\text{Base}}}{EUI_{\text{Base}}} \times 100 \quad (2)$$

Where EUI is an energy utilization index (kWh/m<sup>2</sup>), EPI is the Energy Performance Index (%). EUI<sub>Present</sub> is the energy utilization index for the current year (kWh/m<sup>2</sup>). EUI<sub>Base</sub> is the energy utilization index for the base year (kWh/m<sup>2</sup>)



Figure 1. Faculty of Animal Science and Technology, Maejo University.

Figure 2(a) shows the air conditioning system. The power consumption by digital power clamp meter (Model; UNI-T UT231, resolution ±0.01 kW, accuracy ±3%) is measured. The air temperature and the relative humidity of the supply air and return air is measured by an anemometer (Model; Lutron AH-4223, resolution ± 0.1°C, ±0.1 %RH, ±0.1 m/s, accuracy ±3%). The measurement data uses to calculate the Coefficient of Performance (COP) and Energy Efficiency Ratio (EER) as following equations 3 and 4 (Ministry of Energy, 2015), respectively.

$$COP = \frac{Q_{\text{Evap}}}{E_{\text{Comp}}} \quad (3)$$

Where E<sub>Comp</sub> is the power of the compressor (kW). Q<sub>Evap</sub> is heat input to the refrigerant in the evaporator (kW).

$$EER = 3.412 \times COP \quad (4)$$

Where EER is Energy Efficiency Ratio (Btu/hr.W)

For the lighting system, the number of bulbs, the type of lamp, and the average light intensity in each area using lux meter (Model; Center 337, resolution ±0.01 Lux, accuracy ±3%) has shown in Figure 2(b). In addition to the standard value, the Light Power Density: LPD and Lighting Efficacy Ratio: LER calculate as following equations 5 and 6 (Ministry of Energy, 2015).

$$LPD = B/A \quad (5)$$

LPD is Light Power Density (W/m<sup>2</sup>), B is the power of lighting system (W). A is the area of the room or using space (m<sup>2</sup>).

$$\text{LER} = \text{lumens}/B \quad (6)$$

Where LER is Lighting Efficacy Ratio (lumens/W), Lumens is the luminance of light (lumens).



(a) Air conditioning system. (b) Lighting measurement.

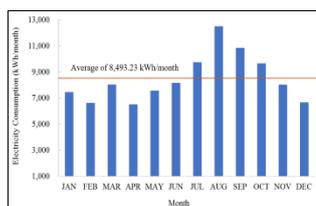
Figure 2. Energy measurement

For the other systems such as the lift system, ventilation system, and pump system, their power is collected for the power consumption analysis. After the energy auditing step, all data is used as the Energy Baseline (EnB). And find the proportion of energy consumption that will be analyzed by a discussion of the Significant Energy Use (SEU) by the Pareto graph. For the energy performance indicators (EnPIs) considering, three levels are discussed as following the organization level (EUI, EPI), system-level (LPD), equipment level (LER, LUX for lighting, and COP, EER for air conditioning system). Finally, all information is summarized and used to present energy conservation measures and calculate energy savings.

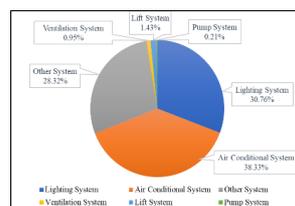
## RESULTS AND DISCUSSION

### A. Energy Consumption

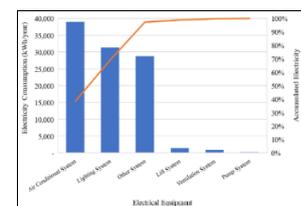
The survey measured the energy in the building. In 2018, the Faculty of Animal Science and Technology consumed 661,336.02 kWh equivalent to 2,565,983.76 Baht or an average electricity cost of 3.88 Baht/kWh. The Energy Baseline (EnB) of electricity consumption of Building A and Building B in 2018, as shown in Figure 3(A), was a total of 101,918.80 kWh or equivalent to an average of 8,493.23 kWh/month. It found that electricity was highest in August because it was the middle of the first semester with many activities and experiments. The value of the Energy Utilization Index (EUI) of the building was 5.49 kWh/m<sup>2</sup>-year.



(A) Energy consumption of Building A and Building B



(B) The energy consumption proportion



(C) The significant energy use by Pareto Chart

Figure 3. Energy consumption data in 2018

In figure 3(B) shows the energy consumption proportion in both buildings in 2018. It was found that the air conditioning system mostly used the electricity with a ratio of 38.33%, followed by the lighting system, other systems, lift system, ventilation system, and pump system with 30.76%, 28.32%, 1.43%, 0.95%, and 0.21%, respectively. When considering the Significant Energy Use (SEU) by the Pareto chart in Figure 3(C), it was found that the SEU systems were the air conditioning system, lighting systems, and other systems, respectively. Their summation of proportionality was over 80%.

### 1. Lighting System

Table 1 presents the results of the energy auditing of the lighting systems of both buildings. The electricity consumption of the lighting system was equal to 31,350.22 kWh/year. Building A has 74 rooms, which used 1,096 bulbs of fluorescent T5. It is equivalent to 71.03% of the total number of fluorescent bulbs. The second type is followed by fluorescent T8 (18 W and 36 W) and compact fluorescent lamps, in which a total of 434 bulbs accounted for 28.13% and 0.84%, respectively. Building B has 13 rooms that used fluorescent T8 and T5 in proportions of 41.05% and 39.30%, respectively, and the compact fluorescent bulb inside the conference room had 56 bulbs.

For the luminance investigation of each room, it was found that 62 rooms of Building A and 11 rooms of Building B had passed the standards value 300-400 Lux (Ministry of Energy, 2015), or accounting for 83.78% and 84.62%, respectively. The luminance from measurement varied from 96.60-1,126.30 Lux. Although many standard rooms still using low-efficiency tubes. For the Lighting Efficacy Ratio (LER) investigation, it was found that the only five standard rooms of Building A and Building B were passed, with the average of LER was 53.52 lumens/W and 11.63 lumen/W, respectively. The LER is lower than the standard in which the standard is set to be greater than 75 lumens/W (Siap et al., 2019; D'Amico et al., 2019). For the Light Power Density (LPD) Of Building A with an average of 12.23 W/m<sup>2</sup> and Building B with an average of 103.20 W/m<sup>2</sup> with 49 standardized rooms from a total of 87 rooms, the LPD expected value, not more than 14 W/m<sup>2</sup> (Ministry of Energy, 2015).

Table 1. The data of the lighting system.

Issue	Building A	Building B
Number of survey rooms	74	13
Number of bulbs	fl T8 (36 W)	385
	T8 (18 W)	49
	T5 (28 W)	1,096
	pcl	13
The luminance from measurement (Lux)	96.70-1,126.30	177.33-835.00
Number of rooms that passing standard	62	11
The average Lighting Efficacy Ratio (LER) (lumens/W)	53.52	11.63
Number of rooms with passing LER Standard	4	1
The average Light Power Density (LDP) (W/m <sup>2</sup> )	12.23	103.20
Number of rooms with passing LPD Standard	48	1

Remark: fl is a fluorescent bulb, pcl is a compact fluorescent bulb.

### 2. Air Conditioning System

Table 2 shows the data from the energy auditing of air conditioning systems with electrical energy consumption of 39,065.48 kWh/year. Most sizes of the air conditioners in Building A and Building B was 25,000 Btu/hr with 37 units. The next following type was 30,000 Btu/hr, with 14 units installed in lecture classrooms, meeting rooms, and offices. For the most laboratories did not have air conditioners. Building B has two large central air conditioners with 150,000 Btu/hr size in the conference room. However, from the study, most air conditioners' COP and EER values are within the standards by the COP not less than 3.22, and EER not less than 11 Btu/hr·W (Ministry of Energy, 2015). The average COP and EER from the measurement were 3.58 and 12.20 Btu/hr·W<sub>e</sub>. However, even if the air conditioners have the average COP values and EER will pass the standards. But air conditioners have a life of more than ten years, resulting in high demand for electrical energy. As the compressor has a long cutting period.

### 3. Other Systems

For the other systems, the electrical equipment in Building A was mainly used in the lecture rooms and dean offices, such as computers, photocopiers, audio, and other convenience electrical appliances. The equipment was used in the specific operation in each field study. Building B used the electrical devices in the meeting room, such as computers, stereos, and projectors. Both buildings consumed electricity of about 28,863.40 kWh/year. The measurement is that it was unable to evaluate the energy savings because the users had unstable usage behavior. Therefore, the recommendation to adjust the energy saving should be conducted by the building's energy policy.

### B. Energy Conservation Measures

From the energy survey, there are two main energy-consuming systems, air conditioning and lighting. Table 3 shows three energy measures that would be suggested for energy management improvement.

From the building survey data, it was found that the lighting illumination was higher than the standard value. Most of the light bulbs are about 92.23% fluorescent lamps, resulting in high electrical consumption. Therefore, measures were proposed two suggestion measures were reducing the lighting bulb and changing the fluorescent bulb to high efficiency LED bulb which power is 18 W per bulb. Therefore, the lighting systems will save energy consumption of about 24,989.21 kWh/year or equivalent to 96,958.14 Baht/year. The investment cost was 350,775.00 Baht and the simple payback period was 5.62 years, in Table 3.

Table 2. The data of the air conditioning system.

Issue	Building A	Building B
Air conditioners size (Btu/hr)	9,000 (3 units) 25,000 (31 units) 30,000 (14 units) 40,000 (2 units)	25,000 (6 units) 150,000 (2 units)
The lifetime of air conditioners (years)	8-18	18
Power consumption of compressor (W)	0.76-3.54	2.21-17.5
Coefficient of Performance	2.56-4.58	2.63-3.92
Energy Efficiency Ratio (Btu/hr·W <sub>e</sub> )	8.75-15.61	8.96-13.39

Table 3. The suggestion measures from energy auditing.

Measures	Savings		Investment (Baht)	Payback Period (year)
	Electrical Energy (kWh/year)	Cost (Baht/year)		
1. Lighting bulb reduction	8,898.44	34,525.95	-	-
2. Changing fluorescent bulb to LED bulb	16,090.77	62,432.19	350,775.00	5.62
3. Changing an old air conditioner to use a high- efficient air conditioner	7,096.83	27,535.70	331,300.00	12.03
4. Reducing the operation time of ventilation fan	153.34	594.94	-	-
<b>Total</b>	<b>32,239.38</b>	<b>125,088.78</b>	<b>682,075.00</b>	<b>5.45</b>

Remark: An average electrical cost of a building is 3.88 Baht/kWh.

From air conditioning systems, it was found that COP and EER of most air conditioners were lower than the standard value because it also had a total lifetime of 8 units more than 10 years that were resulting in low performance. Therefore, the suggestion measures changed an old air conditioner (on-off type) to use a high-efficiency air conditioner (inverter type). This measure's energy saving was approximately 7,096.83 kWh/year or equivalent to 27,535.70 Baht/year. The investment cost was 331,300 Baht and the simple payback period was 12.03 years. Some air-conditioned rooms had ventilation fans often used while the air conditioner was on, so the cooled air was leaked to the outside and increased the compressor's workload. In this issue, the suggested measure could reduce the period time of ventilation fan by about %50. The energy-saving would be predicted of 153.34 kWh/year or equivalent to 594.94 Baht/year. The air conditioning systems analysis would save a total of 7,250.17 kWh/year or 28,130.64 Baht/year.

From the suggestion of building energy-saving measures. Will save energy to reach a total of 32,239.38 kWh/year or equivalent to 125,088.78 baht/year with a payback period of 5.45 years, as shown in Table 3.

### C. Energy Performance Indicator

For Energy Performance Indicator (EnPI) analysis presents as following Table 4 with three levels assessment. The results show that for the organization level, EUI, after the discussion was 3.75 kWh/m<sup>2</sup>·year that decreased equal to 1.74 kWh/m<sup>2</sup>·year and Energy Performance Index (EPI), would be reduced by about 31.63%.

For system-level, LPD after assessment of building B was equal to 39.26 W/m<sup>2</sup> higher than building A was equal to 635. W/m<sup>2</sup> due to Building B is a conference room and has many light bulbs per room. For the equipment level, the LER of the lighting was 100 W/lumen, COP, and SEER of air conditioners were between 5.93-4.99 and 20.25-17.03 Btu/hr·W<sub>e</sub> greater than before the study.

Table 4. Assessment of energy performance indicators before and after the improvement of the measures.

Level	Issue	EnPI	Before		After		
Level 1	Organization Level	EUI (kWh/m <sup>2</sup> ·year)	5.49		3.75		
		EPI (%)	-		31.63		
			Building		Building		
			A	B	A	B	
Level 2	System Level (Lighting System)	LPD (W/m <sup>2</sup> )	12.23	103.2	6.35	39.26	
Level 3	Equipment Level	Lighting	LER (W/lumen)	91.33	51.71	100	100
		Air Conditioning	COP	2.56-4.58	2.63-3.92	4.99-5.93	5.67
			EER	8.75-	8.96-13.39	17.03*	19.33*
			(Btu/ hr·W <sub>e</sub> )	15.61		20.25*	

Remark: \* measuring the efficiency of inverter type air conditioners depends on the compressor load according to the operating load conditions such as room temperature and an outside temperature in each season. Therefore the efficiency will be reported in a term of Seasonal Energy Efficiency Ratio (SEER).

### CONCLUSIONS

In this study, the energy auditing assessment demonstrated along with ISO 50001 procedures in the Faculty of Animal Science and Technology Building, Maejo University. It found that the most proportion of energy consumption was air conditioning. After study assessment, four energy measures were suggested, such as lighting bulb reduction, changing fluorescent bulb to LED bulb, high-efficiency air conditioner using, and reducing the operation time of ventilation fan which the electrical energy was save of 32,239.38 kWh/year or equivalent to 125,088.78 Baht/year. The energy

utilization index (EUI) before the study is equal to 5.49 kWh/m<sup>2</sup>-year higher than after the study assessment that is equal to 3.75 kWh/m<sup>2</sup>-year after discussion decreased similar to 1.74 kWh/m<sup>2</sup>-year resulted in Energy Performance Indicator (EPI) decreased about 31.63%. If the sample building uses the study results, the actual result will happen in the future. However, the environmental impact assessment from all measures should be analyzed for green university promotion in the future.

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