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Energy Saving Potential for Tun Fatimah Residential College: A Case Study of UTHM Residential College

Azmil Asraf Hadri[1], Azian Hariri[1]*

[1]Department of Mechanical Engineering, Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, MALAYSIA

*Corresponding Author Designation

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Abstract: Inefficiency of energy usage has become main concern among the building owners. To ensure proper energy consumption of the building, it has become a practice to conduct building energy performance study. In Universiti Tun Hussein Onn Malaysia (UTHM), there are many residential colleges for student. Tun Fatimah residential college (KKTF) and Tun Dr Ismail residential college (KKTDI) are located close to each other and both has the same building structure. However, in term of energy consumption, KKTF has higher energy consumption compared to KKTDI. Therefore, a study was carried out to investigate the energy saving potential at KKTF. This study aims to identify energy consumption in KKTF, user behavior, and to identify any potential energy saving that can be applied at KKTF. This study was carried out firstly by identifying characteristics of the building, KKTF electrical bill for one-year, electrical equipment used, and user behavior through field observation and questionnaire. From the result, it is observed that general equipment has highest energy consumption (34%) followed by air conditioning and mechanical ventilation (ACMV) system (32%), and lighting system (31%). Therefore, three type of potential saving method or Energy Conservation Measures (ECMs) were proposed later in this study which focused on no, low/medium and large investment measures. With these proposed measures, KKTF is estimated to reduce the energy consumption by 28% in the future.

Keywords: Energy Saving, Energy Conservation Measures (ECMs), Residential college

1. Introduction

Energy is the ability to do work, where work is done when a force moves an object. Energy is available in all different from such as heat, light, motion, chemical and electrical. Electrical energy is an energy that is stored in charged particles within an electric field [1]. Electrical energy is one of the most commonly used forms of energy in the world. It can be easily converted into any other energy form and can be safely and efficiently [2]. As Malaysia moves towards the status of a developed nation, energy requirement will become more intensive parallel with Malaysia's objective of achieving a developed nation. Malaysia shows that building sector is the major energy consumers where it consume

*Corresponding author: azian@uthm.edu.my

48% of the total electricity energy [3]. Based on that problem, MS1525:2007 which is Renewable Energy Efficiency Code and the Use of Renewable Energy for Non-residential Buildings were introduced to achieve energy efficiency for building sector. According to MS1525:2007 standard, recommended Building Energy Index (BEI) in Malaysia is 135kWh/m²/yr [4]. But, most of the building in Malaysia does not meet this standard. This is because building owners or building user are not aware whether their building achieved or not with this requirement. In Malaysian universities, energy wastage tends to occur mainly because of inefficient use of energy and lack of awareness among building users.

Same goes to UTHM, when rapid growth takes place in UTHM, it will automatically lead to increase of electrical energy usage. Tun Fatimah residential college (KKTF) and Tun Dr Ismail residential college (KKTDI) are two building that located close to each other and both has the same building structure. However, in term of energy consumption, KKTF has higher energy consumption then KKTDI. Therefore, a study to investigate the potential of energy saving at KKTF was carried out. The objectives of this study are to identify the building power consumption, user behavior, and saving measures by find out any potential energy saving that can be applied at KKTF. By the end of this study, the anticipated result of this project is that saving target can be achieved through suggested Energy Conservation Measures (ECMs) by using either no, low/medium or large investment measures.

2. Materials and Methods

This chapter discusses the method/process of conduction this case study in more details starting from identification of the area of study until all the necessary data and result were obtained. The purpose of this chapter is to help a better understanding on methods used in this case study by providing clearer guidelines and explanation/discussion for every method used in this research.

2.1 Electrical equipment identification

In KKTF, the electrical equipment used varies depend on the type of user. There are electrical appliances provided by the college itself and there are electrical appliances brought by the residents of the college especially student and cafeteria workers. Observation and questionnaire have been made in order to identify electrical equipment in KKTF.

2.2 Tariff

Tenaga Nasional Berhad (TNB) has 27 types of tariff applicable for different type of buildings. Tariff is selected according to energy and function of the building. For KKTF, type of tariff that are suitable to use to calculate the electrical cost is called commercial tariff C1. The details of the tariff are shown in Table 1.

Table 1: Details of tariff C1

Tariff Category	Unit	Rates
Tariff C1-Mediuym Voltage General Commercial Tariff		
For each kilowatt of maximum demand per month	RM/kW	30.3
For all kWh	sen/kWh	36.5
Minimum monthly charge	RM	600

2.3 Energy Efficiency Index (EEI)

Energy Efficiency Index (EEI) is one of the Key Performance Indicator (KPI) to track the performance of energy consumption. The formula for EEI is as shown in Eq. 1.

$$\text{Energy Efficiency Index} = \frac{\text{Energy Input (kWh)}}{\text{Gross Floor area of building (m}^2\text{)}} \quad \text{Eq. 1}$$

The energy input is basically the electricity bills. There are several factors that related to energy consumption, but in this case study the recommended factor to be used for KKTF is the floor area of building as the factor that related in energy consumption.

2.3.1 Baseline EEI

Baseline EEI can be calculated by summing up all 12 values of energy consumption or electricity bills like from January 2019 until December 2019. Then, the value will be divided by 12 months to get the average monthly energy consumption. The average was then divided by gross floor area to get the EEI baseline.

2.3.2 Target EEI

After the value for the baseline has been obtained it will be drawn on the graph with a green line while the red line represents the energy saving target. For this case, the target for KKTF is around 10% reduction of energy.

2.4 Energy Conservation Measures (ECMs)

Energy Conservation Measure is a project conducted or technology implemented that reduces the consumption of energy in a facility. The types of projects implemented can be in a variety of forms but usually are designed to reduce utility costs in order to achieved that target EEI line. The energy conservation measures need to be prioritized according to three types which is no, low/medium and large investment.

2.5 Energy Reduction Estimation

After the energy conservation measure has been analysed and selected, then based on the proposed measures, the energy reduction estimation will be analysed in order to know whether the target to achieved target EEI line is possible to be achieved or not.

3. Results and Discussion

The results and discussion section present data and analysis of the study. Analysis of data is a process where the data collected is being analyzed according to the objective of the study. The result obtained were discussed accordingly.

3.1 KKTF and KKTDI energy consumption at 2019

Table 2 shows electricity bills for KKTF and KKTDI at 2019. From the figure, it shows that electricity bills for KKTF is higher than KKTDI. Apart from that, the data also shows that every month KKTF will consume energy slightly higher than KKTDI.

Table 2: Electricity bills for KKTF and KKTDI at 2019

	KKTF					KKTDI				
2019	kWh			%	Cost	kWh			%	Cost
	0800 - 2200	2200 - 0800	Total	0800 - 2200	RM	0800 - 2200	2200 - 0800	Total	0800 - 2200	RM
Jan	37,253	31,750	69,003	54.0%	25,186	30,503	24,903	55,406	55.1%	20,223
Feb	31,823	26,747	58,570	54.3%	21,378	26,259	22,594	48,852	53.8%	17,831
Mar	61,449	50,747	112,195	54.8%	40,951	58,681	48,433	107,114	54.8%	39,097
Apr	54,268	44,072	98,341	55.2%	35,894	50,242	40,677	90,919	55.3%	33,186
May	59,731	51,374	111,105	53.8%	40,553	57,809	50,281	108,090	53.5%	39,453
Jun	43,547	36,314	79,861	54.5%	29,149	41,434	34,074	75,508	54.9%	27,561
Jul	25,979	21,313	47,293	54.9%	17,262	22,597	19,993	42,590	53.1%	15,545
Aug	18,044	14,196	32,239	56.0%	11,767	10,375	10,452	20,827	49.8%	7,602
Sep	49,739	40,448	90,187	55.2%	32,918	44,987	35,843	80,829	55.7%	29,503
Oct	54,699	45,399	100,098	54.6%	36,536	50,486	41,816	92,301	54.7%	33,690
Nov	61,060	48,831	109,891	55.6%	40,110	58,102	47,000	105,102	55.3%	38,362
Dec	57,661	47,997	105,657	54.6%	38,565	56,273	46,375	102,649	54.8%	37,467
Total	555,250	459,188	1,014,438	54.7%	370,270	507,748	422,440	930,189	54.6%	339,519

3.2 KKTF total operation hour

There is no fixed operation hour for KKTF because it involved with students, staffs and workers. Hence, the total operation hours for KKTF can only be roughly estimated through observation and questionnaire. A survey and observation have been done for three weeks to determine the operation hours for all building at KKTF including main building and student building. Table 3 below shows the summary of the operation hours for KKTF.

Table 3: Summary of the operation hours for KKTF

No	**Section**	**Operation hour per month (hour/month)**
1	Management office	160
2	Meeting room	20
3	Cafeteria	480
4	Cooperative shop	160
5	Waffle shop	180
Student building section		
No	Appliance	Operation hour per month (hour/month)
1	Lighting	210
2	Ceiling fan	420
3	Laptop charger	150
4	Phone charger	150
5	Pedestal fan	420
No	Appliance	Operation times per month (times/month)
1	Home printer	20
2	Electric kettle	30
3	Iron	2
4	Rice cooker	8
5	Washing machine	4

3.3 KKTF total electrical equipment

From data collection phase, the number of electrical equipment has been recorded and tabulated along with their power (Watt) value as shown in Table 4 below.

Table 4: KKTF total electrical equipment

No	Equipment	Power (W)	Quantity (pcs)
Lightning Equipment			
1	Recessed type fluorescent 2 light fitting (1200m)	36	340
2	Recessed type fluorescent 1 light fitting (1200m)	18	2009
3	Recessed compact fluorescent downlight	18	2110
4	Street light	80	26
5	Spotlight (NIKKON)	400	12
6	Exit sign C/W 3 hours battery backup	18	13
7	Emergency light C/W 3 hours battery backup	18	383
ACMV Equipment			
1	Ceiling fan	75	1045
2	Wall fan	60	16
3	Air Conditioner	1160	17
4	VRV indoor unit	4140	11
5	Wall mount ventilation fan	34	128
General Equipment			
1	Desktop computer	105	36
2	LCD television unit	200	3
3	Commercial printer	50	7
4	Home printer	5	14
5	LCD projector	300	3
6	Vending machine	11000	3
7	2 chiller 1 freezer 3 door	6380	4
8	Electric waffle maker	1500	2
9	Washing machine	500	8
General Equipment (Based on questionnaire)			
1	Laptop charger	60	1200
2	Phone charger	6	1200
3	Home printer	5	20
4	Pedestal fan	55	420
5	Iron	1200	170
6	Electric kettle	1200	150
7	Rice cooker	700	15

3.4 KKTF estimation energy consumption

After all the necessary data has been collected, the analysis to estimate the total energy consumption for KKTF can be done in order to identify user trend in KKTF. The estimation of total energy consumption will be divided into three types which is lighting system, ACMV system and general equipment. The power (Watt) for each part can be calculated by multiplying the number of units with their respective power consumption and hours of usage or how many times it has been used. The main formula used as shown in Eq. 2.

$$\text{Energy consumption} = \text{No of unit} \times \text{Power consumption (Watt)} \times \text{usage hours (hours)} \quad \text{Eq. 2}$$

The energy consumption for KKTF can be categorized into 9 categories. The categories are office section, meeting room section, cafeteria section, cooperative shop section, waffle shop section, surau section, student room section, house of fellow section and general space section respectively.

3.5 Energy Efficiency Index (EEI)

Find the EEI for each month by using EEI formula (2.1) above. Below is example calculation for January 2019.

$$\text{EEI for January 2019} = \frac{69{,}003\ \text{kWH}}{30{,}600\ \text{m}^2} = 2.26$$

3.5.1 EEI baseline

Then, the total value of EEI divided by 12 to get the average of EEI or EEI baseline.

$$\text{EEI baseline} = \frac{33.15}{12} = 2.76$$

3.5.2 Target EEI baseline

After the EEI baseline has been obtained. The energy saving target can be decided and the target for KKTF is 10% energy saving, means that the target EEI is around 2.48 as shown in calculation below. Figure 1 below shows bar chart of EEI for KKTF during 2019 including EEI baseline and Target EEI.

$$\text{Target EEI} = 2.76 - (2.76 \times 10\%)$$
$$= 2.76 - 0.276$$
$$= 2.48$$

No	Criterion	Power Consumption (kWh)	Estimated cost (RM)	Percentage (%)
1	Lighting system	33,708.71	12,303.68	31.18
2	ACMV system	34,983.06	12,768.82	32.36
3	General Equipment	36,483.60	13,316.51	33.74
4	2 Houses of fellow	2,942.00	1,073.83	2.72
	Total	**108,117.37**	**39,462.84**	**100**

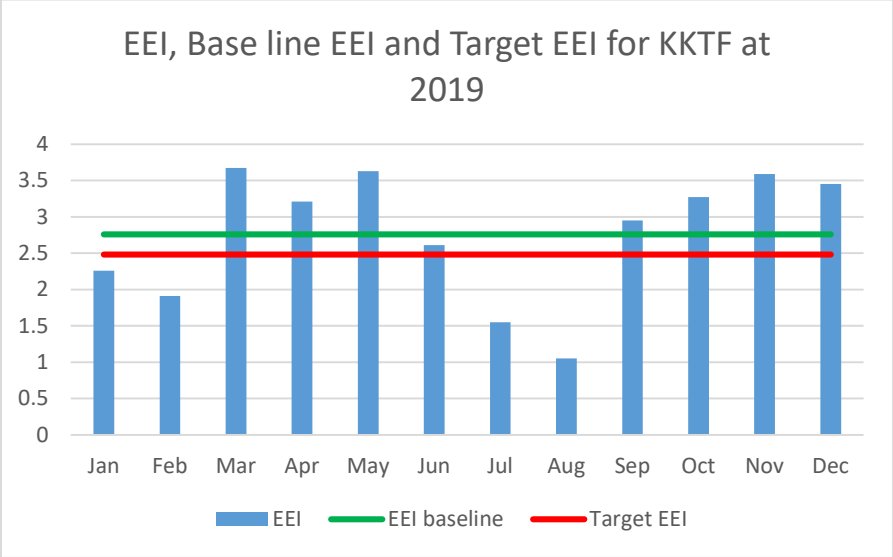

Figure 1: EEI, EEI baseline and Target EEI for KKTF at 2019

3.6 Select Energy target

Energy target drives energy management activities and promote continuous improvement. Setting clear and measurable target is critical for understanding the intended results, developing effective strategies and reaping financial gains. The target for KKTF is 10% reduction in energy consumption from the EEI baseline.

3.6.1 Proposed solution and recommendation

There are a few ways of solution and recommendation that were suggested in this topic. Recommendation that would bring some cost saving benefits to the building has been made at the end of this study. There are several EMCs that have been identified and it can be prevailed by having a plan which will be discussed in this chapter. The EMCs need to be prioritized according to three types. Below is the plan of EMCs that will help to reduce energy consumption at KKTF. The no or low investment measures can be implemented immediately follow with medium and large investment measures.

i) No investment measures:
    i) Announcement
    ii) Awareness training
    iii) Human control
    iv) Reduce number of lamps in student room

ii) Low or medium investment measures:
    i) Sticker or reminder sign placement

iii) Large investment measures:
    i) Timer installation for lighting system
    ii) LED lighting installation

3.7 Energy reduction estimation

Based on the proposed measures, target to reduce 10% of energy consumption is possible to be achieved. The following Table 5 summarizes the energy reduction estimation for one month. Based on table 5, it is clearly showing that if KKTF apply these solutions that have been proposed, it can help to save electrical energy usage at KKTF for each month which is around 28.47% compared to the previous energy usage. Plus, by applying these solutions also proved that it can achieved the target EEI that have been analyzed which is about 10% reduction from previous energy usage.

With around 28.47% energy reduction, it can estimate that monthly saving for KKTF is about RM 2,017.4. Meaning, if the monthly saving can be continued for up to 16 months, the total saving can already cover the investment cost which is around RM 31,611. Below shows calculation to cover the investment cost by using the saving cost that can be obtained from the ECMs results.

$$\text{Monthly saving} = \text{RM } 2{,}017.4$$

$$\text{Investment cost, (Target)} = \text{RM}31{,}611$$

$$\text{Total Monthly saving} = \text{Monthly saving} \times \text{Months}$$

$$= 2{,}017.4 \times 16 \text{ Months}$$

$$= \text{RM } 32{,}278.4 \text{ (Target Achieved)}$$

Table 5: Energy reduction estimation for one month

No	Type of ECM	ECMs	Investment (RM)	Estimated energy saving (kWh)	Monthly saving (RM)	Percentage of Monthly saving (%)
1	No	Announcement	0			
2		Awareness training	0			
3		Human control	0	N/A	N/A	N/A
4		Reduce number of lamps in student room	0	4,030.68	1471.12	11.96
5	Low/ medium	Sticker or Reminder sign placement	500	N/A	N/A	N/A
6	Large	Timer installation	574	2,095.32	764.79	6.22
7		LED lighting installation	30,537	3,431.812	1,252.61	10.20
		Total	**31,611**	**5,527.132**	**2,017.4**	**±28.47**
					Target	**10.00**

4. Conclusion

This study is considered success as the estimation of electrical energy consumption and cost of KKTF is successfully estimated and several potential saving measures or ECMs that can apply in KKTF has been proposed. By applying these ECMs at KKTF, it can help in reducing the usage of electrical energy by 28% in the future and can save around RM 2000 per month. With this result, it can be estimated that if the monthly saving can be continued for up to 16 months, the total saving can already cover the investment cost which is around RM 31,611.

With proper energy monitoring system, proper equipment provided and sufficient of time to conduct the research and collect all the necessary data without any problems arise like COVID-19, then the exact user trend that cause high electrical energy usage at KKTF can be determined. With the exact user trend at KKTF, a more effective potential saving solution can be determined.

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