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OPTIMUM ENERGY WASTE REDUCTION FOR LIGHTING ENERGY CONSUMPTION IN FACULTY OF ELECTRICAL ENGINEERING (FKE), UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM): A CASE STUDY

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Abstract— Electrical energy waste may be defined as electricity consumption that does not perform any useful or productive action to the consumer. Energy waste and losses can cause higher electricity and increase the cost of electric utilities. This paper presents a case study to estimate how much wastage of energy due to unnecessary lighting is occurring in the buildings under the Faculty of Electrical Engineering (FKE) in Universiti Teknikal Malaysia Melaka (UTeM). The study consists of an energy survey for all the current usage of all lighting fixtures in FKE. Then, by identifying the potential waste of energy, an operation scheduling of lighting fixtures is proposed, followed by data analysis to determine the potential energy savings and, hence, electricity cost. From the results, by reducing approximately 15% of the existing current lighting energy usage, FKE could save an estimated savings of about 242.34kWh per day, equivalent to RM2,268.26 monthly saving in electricity bills. Thus, this information can be used by the faculty and the university as part of the information to create more awareness in promoting energy-saving and reducing energy waste and loss, and supporting the energy efficiency plan, whether at the national or international level.

I. Introduction

From 2000 to 2018, the total energy consumption in Malaysia has increased from 53 billion (kWh) to 132 billion (kWh). This value is expected to grow from 48% in 2015 to 66% of the overall consumption by 2023 [1]. Energy-efficient, energy-saving and low-carbon energy strategies for buildings play an essential role in significantly reducing carbon dioxide emissions toward a sustainable nation [2].

Energy-saving has been identified as an essential strategy in today's modern civilization to handle developing concerns such as rising fuel costs, market competition, tightening regulation, climate change, and an impending energy crisis due to decreasing fossil fuel resources.[3] According to the World Bank's energy sector studies, one of the most cost-effective strategies to promote energy saving of existing power and energy sectors is to moderate energy demand, adopt more efficient technology, and reduce electrical energy waste. [4]. One of Malaysia's national energy policy's objectives is to promote efficient energy utilization and eliminate wasteful and non-productive energy consumption patterns [5]. Electrical energy waste may be defined as electricity consumption that does not perform useful or productive action. One form of energy waste is, for example, energy losses which are mainly caused by the heating of electrical cables and transformers. Another form of energy waste is caused by excessive use of electricity more than it needs. For example, the use of lighting when there's ample natural light, unnecessary switching on air conditioner without any room occupants and many more[6]. This type of energy waste is the focus of this study.

Energy waste and losses can cause higher electricity and increase the cost of electric utilities. Reducing energy losses can reduce overall operating costs for building a new power plant. Studies show that 1% of energy waste reduction or losses can save approximately RM200 million to RM300 million a year in Malaysia [7]. Besides that, the cost of energy loss and the cost of investment in reducing energy loss can affect the consumer's electricity tariff in Malaysia. Under incentive-based regulation (IBR) [8], evaluation of overall performance is done to determine cost savings and cost of energy loss (2014-2017). Cost savings incur higher profits to TNB, which bring consumers in a reduced tariff. For an effective energy-saving program, it is vital to know the magnitude, location and sources of energy waste that occurs in the system. With comprehensive and accurate energy waste information, corrective and preventive solutions for energy waste reduction can be planned and executed correctly and in a timely and effective manner.

A study shows that buildings consume the most energy globally, accounting for roughly 25% to 30% of total energy consumption and producing a similar amount of greenhouse gas [9]. A review study shows that the global contribution from buildings towards energy consumption, both residential and commercial, has steadily increased, reaching figures between 20% and 40% in developed countries, and it will continue to grow, as long as a resource and environmental exhaustion or economic recession allows it [10]. In the UK, building energy use associated with non-domestic buildings accounts for approximately 19% of the total CO_2 emissions [11].

Among all types of appliances, studies show that lighting is one of the most energy-intensive uses of electricity in a typical commercial building, accounting for 5 to 15% of total energy consumption [12],[13]. Thus, indoor or outdoor building lighting is also one of the most critical components to consider to reduce energy waste. In an energy efficiency study a chancellory building in Universiti Utara Malaysia (UUM), shows that 20% of its energy comes from lighting [14].

A study in [5] shows that the electricity bills may sum up to 40% of the total cost of operation and maintenance in a public university, as shown in Figure 1. A study in UK reveals that, the electricity consumption in the administration buildings of a typical higher education campus in the UK accounts for 26% of the campus annual electricity consumption[15]. A study in South Africa shows that more energy is used during non-working hours (56%) than during working hours (44%). This arises mainly from occupants' leaving lights and equipment on at the end of the day [16].

A study in University Tun Hussein Onn Malaysia (UTHM) finds that lighting use patterns varied among all the investigated lecture rooms and, 31% of lighting load was wasted and 13% of lighting load misused by the building users were recorded [17]. A study also shows that, apart from lighting, some office equipment which not turned OFF after office hours contribute to significant energy waste[18]. Nevertheless, there are strategies for reducing electric lighting without sacrificing the comfort of use, such as improvements in lamp, ballast and luminaire technology, use of task/ambient lighting, improvement in maintenance and utilization factor, reduction of illuminance levels and total switch-on time, use of manual dimming and switch-off occupancy sensors [19], [20]. An on-site survey to determine current energy consumption patterns in Korean university campus buildings reveals that a potential of between 6% to 30% energy savings could be achieved with a proper energy conservation strategy [21].

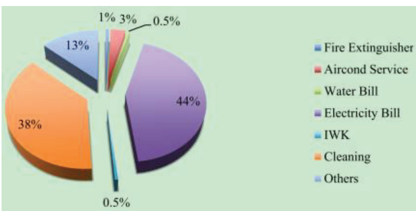

Figure 1: Distribution of operation and maintenance expenses in a public university

Universiti Teknikal Malaysia Melaka (UTeM) is one of Malaysia's many higher learning institutions. Its growing population and educational activities have contributed to Malacca's (in Malaysia) growing total demand for energy supply in the power delivery system. Due to the construction of additional campuses and increased load demand in recent years, UTeM's monthly electricity bills have risen to almost RM500,000. This amount is a significant portion of UTeM's total expenditure, and it is likely to increase in the future. However, due to rising operational costs and tight/limited government funding, UTeM must seek ways to save electrical energy costs, including investigating the possibility of reducing energy waste. Implementing energy-saving practices will significantly contribute toward a reduction in electricity costs.

According to UTeM's Development Office, the Faculty of Electrical Engineering (FKE) contributes to the highest electricity usage compared to other faculties' buildings, based on the data obtained from the IoT meters installed at FKE. As losses increase with load thus, FKE may have the highest probability percentage of energy waste and losses. To date, nobody knows how much energy waste is occurring in the

FKE building, which motivates the pursuance of this study.

From preliminary general observation in the campus of UTeM, it is common to see that some lights in some of the classrooms are kept on while there are no occupants inside. One probable reason is building occupants' lack of awareness and consciousness to switch off the light after they leave the room. Just reducing a small number of hours could bring substantial savings. For example, assume one hundred (100) nos of 36 Watt fluorescent lights fixtures were unnecessary switched on for 3 hours each day. Then, there will be approximately RM3.94 worth of electricity waste per day or RM118.26 per month, assuming a tariff rate of 36.5 cents/kWh [17]. Thus, it was crucial to analyze the lighting system's energy usage in UTeM to identify potential energy reduction and cost savings whenever possible.

Given the above discussions, we conducted a study to investigate and quantify the quantity and circumstances of lighting-related energy waste in different locations in several faculty buildings over a 5-days class session. This study mainly aims to identify the source of energy waste and propose a strategy for a new lighting schedule that could reduce energy waste and give electricity cost savings.

II. Methodology

This study selected six (6) building blocks of the Faculty of Electrical Engineering (FKE) of UTeM. The general procedure for this study is illustrated in Figure 2. In general, the study aims to investigate on the overall lighting energy consumption located at all six (6) buildings blocks, i.e. A, B, C, D, E and F. As shown in Figure 3, which includes administrative office, lecture/seminar rooms, laboratories and many more. Initially, data on the numbers, types and power rating of each lighting fixture need to be collected manually since there are no inventories on how many fixtures are installed.

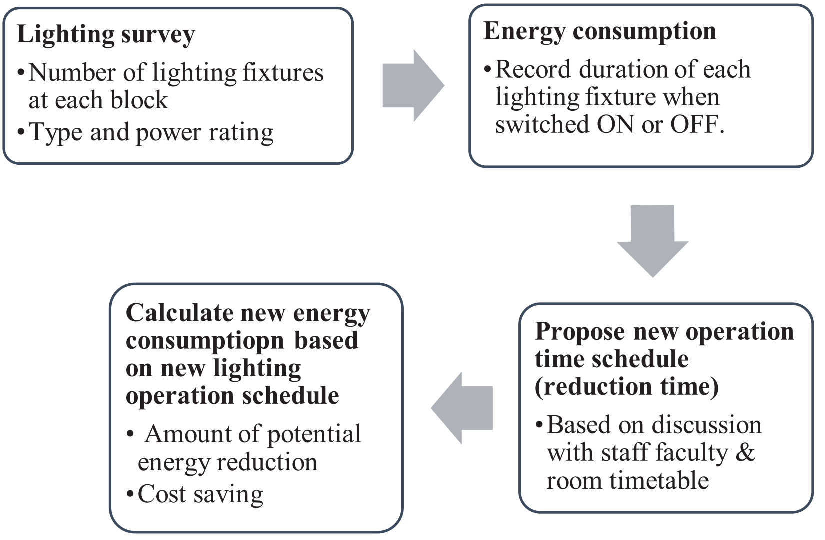

Figure 2: General procedure

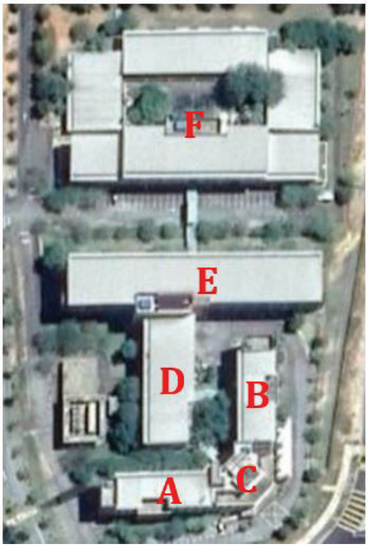

Figure 3: Aerial view of buildings in FKE

At each block, a lighting operation survey is conducted at each FKE block to estimate the duration of which each lighting fixture are turned ON or OFF. All the lighting is checked at a fixed time interval, starting from 8 am to 5 pm, for 5-working days when the semester is running and students have their classes daily. Lighting energy during the weekend is not considered as part of this survey. Another assumption is that the usage of lighting is also based on the current class schedule of the semester. Therefore, it cannot be inferred directly for the other semesters as different semesters will have different class schedules.

In this survey, the duration of energy consumption due to lighting is calculated based on the difference between the ON and OFF times. This, it is assumed that the lighting fixtures are ON the entire duration and no intermittent switching occurs. Figures 4 and 5 show two-room samples with different classes scheduled to be used as a reference to determine the optimum lighting schedule, so no light fixtures are turned ON whenever there's no activity planned for the room.

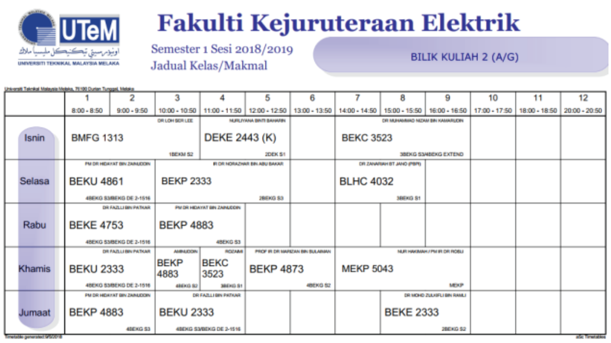

Figure 4: A sample room time table with high utilization

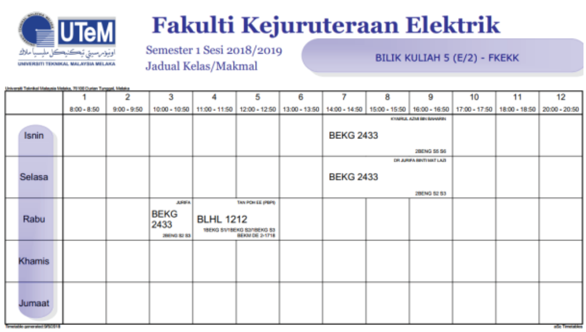

Figure 5: A sample room timetable with less utilization

Next, the survey data is then presented to the faculty to obtain inputs to identify where and when the waste lighting activities are and to get a proposal of optimum and efficient lighting schedule. Finally, a comparison is conducted using spreadsheet software based on the lighting schedule to determine the potential energy-saving, hence electricity cost. The following are some examples of discussion items with the faculty in coming up with the proposed lighting schedule:

1. Which room or areas need to be lit at all times?
2. Is there any security issue if the light fixtures are turned OFF at night?
3. How to optimize the lighting schedule in areas such as the hallway and stairways on the buildings, considering security personnel's need to perform round clock inspection?

III. Result and Discussion

Table 1 to 6 shows the detailed data of the lighting facilities, total installed lighting capacity, the usage survey data, and the proposed schedule for the lighting operation. It can be seen that the energy consumption for lighting fixtures in Block A,B, C and D are approximately between 100 to 200kWh/day. However, there is more usage in Block E and F, where the use is approximately between 400kwH/day to 700kWh/day.

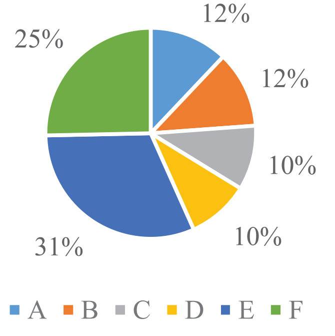

Figure 6: Percentage breakdown of lighting energy usage at all blocks in FKE

Figure 6 shows the distribution of lighting energy usage for all blocks in FKE. It was found out that, from the energy survey, Block E (which consists of mainly lecture room and laboratories) contributes highest to the total energy, which is about 31% of the total lighting energy consumption, followed by lighting in Block F (at 25%). The rest of the blocks have almost similar usage, which is around 10% to 12%. When zooming in Block E, it was also found that most of the lighting energy comes from the lighting in the laboratories, which contributes to almost half of the total lighting energy consumption in the block (see Figure 7).

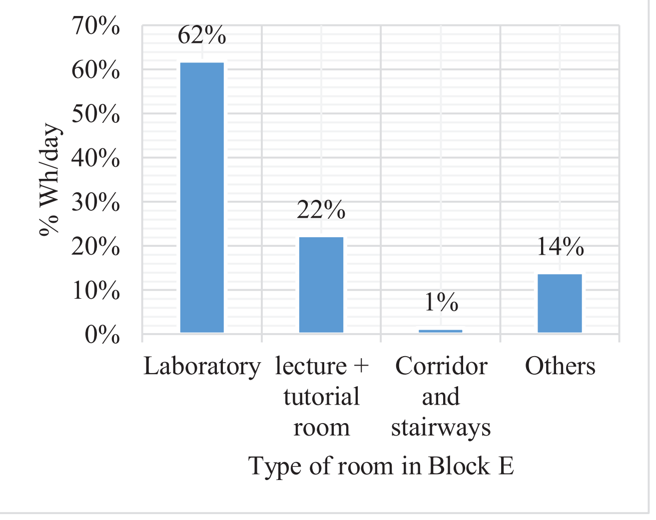

Figure 7: Percentage of lighting energy usage at Block E based on the type of rooms/areas

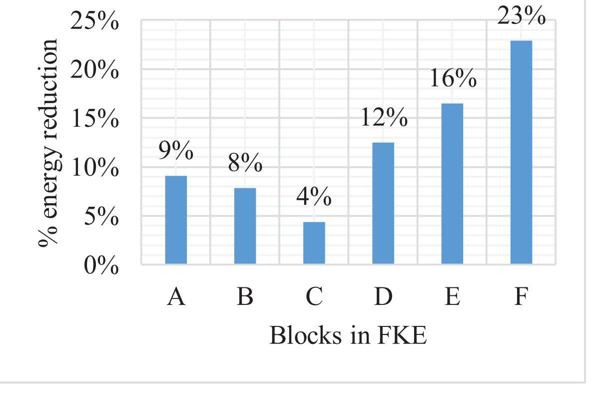

Figure 8: Percentage of lighting energy usage at Block E based on the main type of room

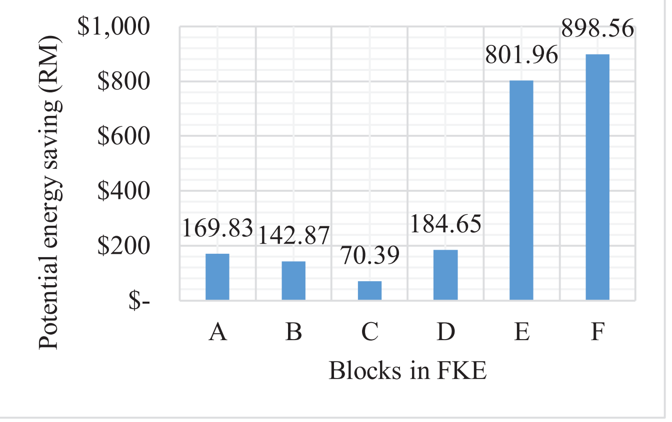

Figure 9: Percentage of lighting energy savings

Table 7 summarizes the lighting energy consumption analysis for all blocks in FKE and the potential energy savings (per month) if the proposed new lighting schedule is implemented. Overall, it can be seen that a total of approximately RM 2,268.26 can be saved every month just by reducing the wasted lighting energy of around 242.34 kWh/day out of the total lighting energy (a reduction of about 15%). Suppose projected yearly, considering that there are 2 semesters every year, and each semester takes about four months. In that case, therefore, the faculty could save approximately RM18,146.12 per year just by considering performing slight modifications of the lighting energy consumption.

Figure 8 shows the percentage of potential energy-saving if the proposed lighting schedule is implemented, and consequently, the amount of energy savings in terms of electricity cost savings (see Figure 7). It can be seen that, overall, the reduction of lighting usage is between 5% to 23% from its current use. However, from Figure 9, even for about a 16% reduction of usage in Block E, FKE could save a significant amount of electricity cost.

Table 1: Lighting inventory and consumption in Block A FKE UTeM

						Existing schedule		New schedule	
No	**Room/Area**	**No of rooms/area**	**Rated power per unit (W)**	**Total no of unit**	**Installed capacity (watt)**	**Duration (hour/day)**	**Usage (Wh/day)**	**Duration (hour/day)**	**Usage (Wh/day)**
1	Lecturers room	58	36	348	12,528	9	112,752	9	112,752
2	Lecture Room 2	1	36	24	864	9	7,776	7	6,048
3	Seminar room (student)	1	36	20	720	9	6,480	5	3,600
4	Seminar room 2 (staff)	1	36	22	792	7	5,544	7	5,544
5	Corridor	4	16	104	1,664	24	39,936	24	39,936
6	AHU room	1	36	6	216	24	5,184	24	5,184
7	Toilet	4	16	42	672	15	10,080	4	2,688
8	Stairs	1	16	32	512	24	12,288	12	6,144
Total				**598**	**17,968**	**121**	**200,040**	**92**	**181,896**

Table 2: Lighting inventory and consumption in Block B FKE UTeM

						Existing schedule		New schedule	
No	**Room/Area**	**No of rooms/area**	**Rated power per unit (W)**	**Total no of unit**	**Installed capacity (watt)**	**Duration (hour/day)**	**Usage (Wh/day)**	**Duration (hour/day)**	**Usage (Wh/day)**
1	Lecturers Room	58	36	348	12,528	9	112,752	9	112,752
2	Lecture Room 1	1	36	24	864	9	7,776	7	6,048
3	Discussion Room 1	1	36	20	720	5	3,600	5	3,600
4	Discussion Room 2	1	36	20	720	5	3,600	5	3,600
5	Corridor	4	16	104	1664	24	39,936	24	39,936
6	Ahu Room	1	36	6	216	24	5,184	24	5,184
7	Toilet	4	16	42	672	15	10,080	4	2,688
8	Stairs	1	16	32	512	24	12,288	12	6,144
Total				**596**	**17,896**	**115**	**195,216**	**90**	**179,952**

Table 3: Lighting inventory and consumption in Block C FKE UTeM

						Existing schedule		New schedule	
No	**Room/Area**	**No of rooms/area**	**Rated power per unit (W)**	**Total no of unit**	**Installed capacity (watt)**	**Duration (hour/day)**	**Usage (Wh/day)**	**Duration (hour/day)**	**Usage (Wh/day)**
1	Lobby	1	16	126	2,016	24	48384	24	48384
2	Academic Administration Office	1	36	12	432	9	3888	9	3888
3	Pigeonhole Room	1	16	8	128	9	1152	9	1152
4	Admin office	1	36	114	4,104	13	53352	13	53352
			16	24	384	13	4992	13	4992
5	Meeting Room	1	36	36	1,296	5	6480	5	6480
			16	38	608	5	3040	5	3040
6	Library + Prayer Room +Corridor + Tutor Room	1	36	72	2,592	9	23328	9	23328
7	Corridor	1	15	54	810	13	10530	13	10530
8	Toilet	4	16	34	544	15	8160	4	2176
9	Stairs	1	16	32	512	15	7680	12	6144
10	Communication rack	1	36	4	144	2	288	2	288
11	Server	1	16	12	192	2	384	2	384
12	Store	1	36	2	72	2	144	2	144
13	Electrical Room	1	36	6	216	2	432	2	432
Total				**574**	**14,050**	**138**	**172,234**	**124**	**164,714**

Table 4: Lighting inventory and consumption in Block D FKE UTeM

No	Room/Area	No of rooms/area	Rated power per unit (W)	Total no of unit	Installed capacity (watt)	Existing schedule		New schedule	
						Duration (hour/day)	Usage (Wh/day)	Duration (hour/day)	Usage (Wh/day)
1	Power Electronic and Control Lab	1	36	260	9,360	4	37,440	3	28,080
2	SAFEE Room	1	36	96	3,456	9	31,104	6	20,736
3	Electric Technology Lab	1	36	220	7,920	5	39,600	5	39,600
4	Component Store	1	36	40	1,440	2	2,880	2	2,880
5	Post-Graduate Room 1	1	36	48	1,728	9	15,552	9	15,552
6	Corridor	4	16	156	2,496	12	29,952	12	29,952
7	Gazebo	1	36	4	144	2	288	2	288
8	Stairs	1	16	8	128	12	1,536	12	1,536
	Total			**832**	**26,672**	**55**	**158,352**	**51**	**138,624**

Table 5: Lighting inventory and consumption in Block E FKE UTeM

No	Room/Area	No of rooms/area	Rated power per unit (W)	Total no of unit	Installed capacity (watt)	Existing schedule		New schedule	
						Duration (hour/day)	Usage (Wh/day)	Duration (hour/day)	Usage (Wh/day)
1	Laboratory	16	36	1280	46080	7	322,560	6	276,480
2	Lecture Room 3	1	36	48	1728	9	15,552	8	13,824
3	Lecture Room 4	1	36	48	1728	9	15,552	7	12,096
4	Lecture Room 5	1	36	48	1728	9	15,552	8	13,824
5	Lecture Room 6	1	36	48	1728	9	15,552	7	12,096
6	Lecture Room 8	1	36	24	864	9	7,776	5	4,320
7	Lecture Room 9	1	36	24	864	9	7,776	6	5,184
8	Lecture Room 10	1	36	24	864	9	7,776	7	6,048

9	Lecture Room 11	1	36	24	864	9	7,776	7	6,048
10	Lecture Room 12	1	36	24	864	9	7,776	5	4,320
11	Lecture Room 13	1	36	24	864	9	7,776	5	4,320
12	Lecture Room 14	1	36	24	864	9	7,776	6	5,184
13	Tutorial Room 6	1	36	12	432	-	0	-	0
14	Tutorial Room 7	1	36	12	432	-	0	-	0
15	Post-Graduate Room 2	1	36	48	1728	9	15,552	9	15,552
16	Prayer Room(Female)	1	36	12	432	9	3,888	9	3,888
17	Prayer Room (Male)	1	36	24	864	9	7,776	9	7,776
18	Toilet	9	16	50	800	15	12,000	4	3,200
19	Stairs	3	16	16	256	15	3,840	12	3,072
20	Corridor	4	16	16	256	15	3,840	12	3,072
21	Store	1	36	22	792	3	2,376	3	2,376
			16	7	112	3	336	4	448
22	Ahu Room	1	36	6	216	24	5,184	24	5,184
23	Gazebo	1	36	4	144	3	432	3	432
24	PSM ROOM	1	36	80	2880	9	25,920	9	25,920
Total				**1,949**	**68,384**	**220**	**520,344**	**175**	**434,664**

Table 6: Lighting inventory and consumption in Block F FKE UTeM

No	Room/Area	No of rooms/area	Rated power per unit (W)	Total no of unit	Installed capacity (watt)	Existing schedule Duration (hour/day)	Existing schedule Usage (Wh/day)	New schedule Duration (hour/day)	New schedule Usage (Wh/day)
1	Lecture Room 15	1	36	24	864	9	7,776	7	6,048
2	Lecture Room 16	1	36	24	864	9	7,776	7	6,048
3	Tutorial Room (L1)	1	36	18	648	-	-	-	-
4	Tutorial Room 16 (L2)	1	36	12	432	-	-	-	-
5	Tutorial Room 13 (L2)	1	36	12	432	-	-	-	-
6	Tutorial Room 9 (2F)	1	36	12	432	-	-	-	-
7	Tutorial Room 15 (2F)	1	36	12	432	-	-	-	-
8	Industrial Power Lab	1	300	39	11700	3	35,100	3	35,100
9	Machine Control Lab	1	36	104	3744	9	33,696	9	33,696
10	Protection System Lab	1	36	104	3744	7	26,208	7	26,208
11	Generation And Transmission Lab	1	300	24	7200	3	21,600	3	21,600
			16	22	352	3	1,056		0
12	High Voltage Lab	1	300	8	2400	3	7,200	3	7,200
			16	10	160	3	480		0
13	Electric Machine Lab 1	1	36	80	2880	7	20,160	5	14,400
14	Electric Machine Lab 2	1	36	80	2880	4	11,520	3	8,640
15	Engineering Lab & CERIA Lab	1	300	21	6300	5	31,500	5	31,500
			36	112	4032	5	20,160		0
16	Electric & Electronic Lab 1	1	36	80	2880	7	20,160	5	14,400
17	Electric & Electronic Lab 2	1	36	80	2880	7	20,160	4	11,520
18	Mechatronic System Lab	1	36	80	2880	7	20,160	6	17,280

19	Instrumentation and DSP Lab	1	36	80	2880	7	20,160	4	11,520
20	Microprocessor Lab	1	36	80	2880	7	20,160	4	11,520
21	Toilet	4	36	32	1152	15	17,280	4	4,608
22	Corridor		16	284	4544	15	68,160	12	54,528
23	Ahu Room	1	36	3	108	24	2,592	24	2,592
24	Stairs	2	16	28	448	15	6,720	12	5,376
Total				**1,465**	**70,148**	**174**	**419,784**	**127**	**323,784**

Table 7: Summary of energy usage and potential energy saving based on proposed new schedule for lighting fixtures in FKE

Blok	**Existing total light operating hours (h)**	**Proposed total light operating hours (h)**	**Lighting operation time reduction(h)**	**Existing usage (kWh)**	**Proposed lighting schedule (kWh)**	**Energy saving (kWh)**	**Estimated bill based on existing schedule (RM/Month)**	**Estimated bill based on proposed schedule (RM/Month)**	**Estimated monthly energy saving (RM/month)**
A	121	92	29	200.04	181.90	18.14	1872.37	1702.55	169.83
B	138	124	14	195.22	179.95	15.26	1827.22	1684.35	142.87
C	138	124	14	172.23	164.71	7.52	1612.11	1541.72	70.39
D	55	51	4	158.35	138.62	19.73	1482.17	1297.52	184.65
E	220	175	45	520.34	434.66	85.68	4870.42	4068.46	801.96
F	174	127	47	419.78	323.78	96.00	3929.18	3030.62	898.56
Total	**846**	**693**	**153**	**1,665.97**	**1,423.63**	**242.34**	**15,593.48**	**13,325.21**	**2,268.26**

IV. Conclusion

This paper reported field survey results on lighting energy consumption in the buildings under FKE, UTeM. The study aims to assess the sources of energy waste and propose a new lighting schedule to reduce the waste of energy. The findings show that, by implementing the proposed lighting schedule in FKE buildings, the faculty could reduce its usage by approximately 15%, bringing savings up to RM 2,268.26 monthly saving in electricity bills. Nevertheless, implementing the proposed lighting schedule is a challenge as it requires cooperation from all users of the facilities, including students, staff members and contract workers working in the buildings. Alternatively, the faculty could propose to embark on a more sophisticated but costly system, such as installing an energy control and monitoring system, which can remotely control the energy consumption of lighting.

Conclusively, there are significant energy-saving potentials of the lighting system in the investigated teaching building resulting from this study. Therefore, changes in building users' behavior can contribute positively to FKE and UTeM for reducing energy usage and costs.

V. Acknowledgment

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VI. References

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