Impact of Electrical Energy Consumption and Occupancy in University Building

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Abstract. Energy wastage tends to occur in Malaysian Universities mainly due to inefficient use of energy and lack of awareness among the building occupancy. Most of the energy consumption are contributed from the operation of HVAC and lighting system. However, the energy consumption remains the same during final exam week and semester break even though the occupancy in the college is low. This mainly due to the lack of ignorance and awareness in managing the electrical energy consumption of the buildings. Coupled with the hike in electricity bills to the University, therefore it is important that swift actions can be taken to reduce the bills via energy efficiency measures. This paper highlights preliminary results of the electrical energy consumption for 3 blocks in College of Engineering (COE), Universiti Tenaga Nasional (UNITEN). This paper also identifies potential areas of energy saving in those blocks. Finally, suggestions on the ways to improve electrical energy usage in those buildings. This study indicates that by implementing no cost initiatives into COE buildings, the university can potentially save up to 11.9% of its monthly electrical bills by switching off lightings for one hour.

INTRODUCTION

Energy is the lifeblood of modern societies. One of the important energies in human daily life nowadays is electricity. In the past decades, the world's energy consumption and associated CO_2 emissions have increased rapidly due to the increases in population and comfort demand of people [1]. Study by [2] indicates that the main drivers that cause increase in energy demand are economy (i.e., GDP) and population. In fact, initiatives towards a sustainable university in Malaysia are being bound by various limits, including low need of natural issues on the grounds, and absence of coordination between and among advocates and key constituencies [3]. There are five major factors identified which affect the energy consumption in a building, there are equipment (include the number of split unit air-conditioners, lighting and electrical appliances in use), outside temperature, people, operating hour and building structure [4, 5]. Generally, electrical energy consumption increases when more air conditioners and lightings are turned on and more electrical devices are in use. Nevertheless, energy wastage due to poor occupants' behaviour will increase energy consumption unnecessarily.

One of the major function of building is to provide an acceptable indoor environment, which allows occupants to carry out various activities in comfortable environment. University building is one of commercial buildings that consume high energy since the area of university is large. Study in [6] revealed that 93% of the energy consumption in the schools was electricity. University buildings are characterised by a very high multiplicity of activities such as classrooms, libraries, offices, conference rooms, laboratories, cafeterias, sports gyms, lecture hall and etc. with various occupancy profiles. Increase numbers of activities in the lecture hall and classroom will definitely use more energy in the building while undergoing teaching and learning in any university. Meanwhile, university which has alternating schedules of semester and semester break (holidays), may have some saving in electrical energy consumption if the implementing energy efficiency measure can be carried out.

As highlighted in [7], study shows that energy performance monitoring is important for an effective energy management system such as occupants' activities and behaviour towards electrical energy consumption because it will help to understand better the building's operational behaviour under different conditions and helps to identify undesired wastage of energy under specific conditions. However, study in [8] indicated that improving and implementing building energy efficiency is one of the best strategies in reducing energy consumption of the university buildings, while maintaining the comfort and well-being of the building occupants. Implementing energy efficiency can helps in increasing lighting performance, keep comfortable temperature, reduce the high cost of electric power, minimise dependence on electricity, and improved ventilation and indoor air quality. The study highlighted that effective energy management practices are necessary and awareness program to reduce energy consumption and uses energy wisely and efficiently are important. This will help address buildings' operational issues, and decrease their energy use in the long-term.

In term of energy saving, study in [9-12] identified there are two measures to achieve energy saving in university buildings namely, technical solutions and operational solutions Technical solutions include enhancing building envelope, purchase high efficiency equipment such as heating, ventilating and air-conditioning (HVAC) system and the use of efficient electrical equipment and application of passive technology in buildings are categorized as structural energy. While operational solutions are control strategies on mechanical and electrical (M&E) equipment and occupant behavioural change towards energy saving including public awareness, energy codes, regulation and other supporting elements are termed also known as non-structural energy conservation measures [12]. Among these two solutions, the operation-focused solutions are more suitable and practical for university buildings, due to the limited responsibility of faculties and students for energy saving because the university members may not have direct responsibility to reduce utility costs. Hence, it is obvious that operational solutions are more cost-effective than technical solutions.

Energy efficiency plays an important role in the energy and climate strategies that promise carbon reductions [13]. One of the benefits of energy efficiency for a building is it helps to improve building operation and occupant comfort. It can be achieved by optimize electrical energy usage in the university area. There are many technological and other solutions exist to improve building energy efficiency. This can be seen in the numerous green building projects being developed around the world. The greatest challenges in improving energy efficiency are human—educating, disseminating and making decisions to utilize existing and new solutions.

Therefore, energy efficiency and conservation implementation is one of the affordable and swift solutions to overcome the energy consumption of a university. Study in [14] highlighted that efficiency and energy conservation implementation can be audited through energy audit. An energy audit is the key to a systematic approach to decision-making in the area of energy management. The primary function of an energy audit is to identify all of the energy streams in a facility in order to balance total energy input with energy use. The main goal of the energy audit is to understand about current status of the building, its systems and indoor climate, the investments that will be needed to implement the procedures, and how profitable they will be. Generally energy audit can be classified into preliminary audit and detailed audit. As per ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standards there are three types of audits. Level 1 is walk-through analysis and also known as preliminary audit. Preliminary energy audit is relatively quick exercise, it estimates the scope for saving using the existing or easily obtained data and helps identify the areas for more detailed study. Level 2 is energy survey and analysis included more details on building survey, breakdown of energy use and calculation and financial analysis of proposed energy efficiency measures. Level 3 are detailed of capital intensive modifications, which involve more detailed field analysis, rigorous engineering analysis, and cost and savings calculations with a high level of accuracy.

Thus, this paper analyses the historical of electrical energy consumption and its relationship with the number of occupancy in COE buildings for each academic calendar. This paper also presents a simple impact study with no cost imitative and calculate the potential electrical energy consumption saving that it can achieve. Finally, electrical energy saving measures and strategies are recommended in this paper.

METHODOLOGY

This research study focuses on the College of Engineering (COE). COE consists of three (3) building blocks namely, BL, BM and BN. Each building block had four floors. BL is the building used for laboratories and support staff offices. The building mainly equipped with computers and all electrical and mechanical machines for engineering students laboratories works. Meanwhile, teaching and learning are the main activities in BM block, it consist of lecture halls, classrooms with varies room capacities and free & easy corner for student to hang out. Finally, BN block is where all the academic staff and support staff offices are located between 1st floor and 3rd floor and 4th floor is mainly used for classrooms.

The historical electrical energy consumption data and students occupancy were extracted, collected and gathered for these 3 blocks (BL, BM and BN) between year 2016 and 2018. These data was obtained from UNITEN's Facility Development & Management (FDM) department and COE's Online Portal. Energy audit level 1 was carried out in this study. It involved preliminary energy use analysis, walk through survey and identification of no cost recommendations. A brief action plan is proposed to FDM for their action. Figure 1 show the process flow chart in carrying out energy audit level 1.

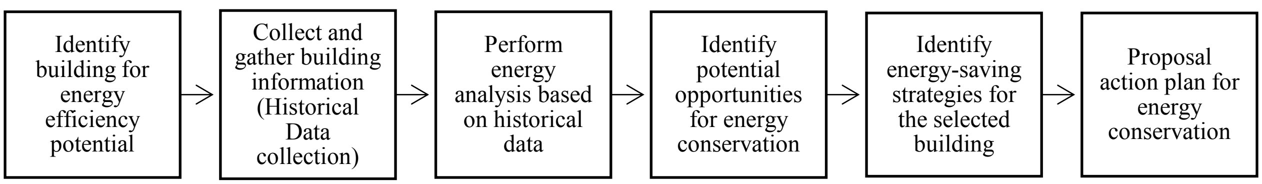


FIGURE 1. Process flows of energy saving in COE building, UNITEN

Tariff type C2 is applies in COE building which is based on the Time-of-Use (ToU) tariff as shown in Table 1.

TABLE 1. Tariff C2 and ToU Period.

Description	Unit	Tariff Rates	Period
For each kilowatt of maximum demand per month during the peak period	RM/kW	45.10	8am-10pm (14 hours)
For all kWh during the peak period	sen/kWh	36.50	8am-10pm (14 hours)
For all kWh during the off-peak period	sen/kWh	22.40	10pm-8am (10 hours)

The percentage of electrical energy saving will be calculated using (1) as below,

$$Electrical\ Energy\ Saving\ (\%) = \frac{(Normal\ Operation\ Bill - No\ cost\ initiative\ Operation\ Bill)}{Normal\ Operation\ Bill} \times 100\% \quad (1)$$

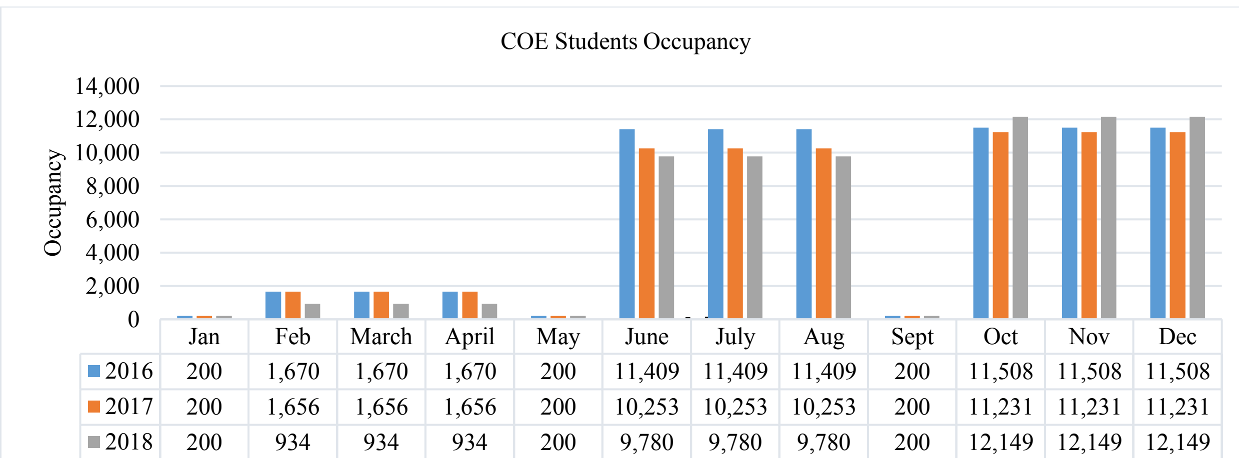
In this paper, the potential electrical energy consumption saving is determined from the no cost initiatives. In other words, energy conservation measures on lightings and its impact is analysed and discussed for COE buildings. Others electrical energy consumption are not discussed and evaluated in this paper. Assumptions used in this impact study are tabulated in Table 2. The potential electrical energy saving calculation is purely based on electrical energy consumption (kWh) and does not include other charges such as 6% service tax, maximum demand charges, power factor surcharge and 1.6% Renewable Energy Fund. It is also assumed that during weekend, there is a minimum electrical energy consumption (i.e., off-peak period) in all common areas and blocks such as in the corridors. For no cost operation, it is assumed that lightings are switch off for an hour during break between 1pm and 2pm and all staff leave their office after 6pm.

TABLE 2. Electrical Energy Appliances Assumptions

Description		Current Operation		No Cost Operation	
		Peak Period	Off-Peak Period	Peak Period	Off-Peak Period
Duration of Electrical Consumption		8am-10pm	10pm-8am	8am-10pm	10pm-8am
No. of Days		22	30	22	30
T5 Light Tube (14Watt)	BL	1890 units	480 units	1755 units	480 units
	BM	1578 units	480 units	1465 units	480 units
	BN	3334 units	1500 units	3044 units	1500 units

ANALYSIS AND DISCUSSION

Figure 2 shows COE building blocks students' occupancy between year 2016 and 2018. It indicates that the students' occupancy in COE building blocks is depending on UNITEN's academic calendar. Fig. 2 shows that during the month of January, May and September each year, these three blocks have a low students' occupancy and during this period, these blocks are occupied by existing support staff and academic staff who have permanent office space in the buildings.



	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2016	200	1,670	1,670	1,670	200	11,409	11,409	11,409	200	11,508	11,508	11,508
2017	200	1,656	1,656	1,656	200	10,253	10,253	10,253	200	11,231	11,231	11,231
2018	200	934	934	934	200	9,780	9,780	9,780	200	12,149	12,149	12,149

FIGURE 2. COE Students Occupancy data

The peak period of students' occupancy in these blocks can be observed in the first and second semesters of the university's academic calendar which running between June and August and between October and December respectively. This indirectly indicates that during these periods, these blocks are used by students to attend their classes and the usage of electrical energy consumption particularly lightings and HVAC maybe high.

Figure 3 shows the historical electrical energy consumption between 2016 and 2018. It is logical to assume that, more rooms are occupied will tend to increase electrical energy consumption in the building. In other words, more students or staff activities will increase electrical energy consumption due to the usage of electrical appliances such as PCs, monitors, projectors, lighting and mechanical ventilation. However, it can be observed that the monthly electrical energy consumption patterns in COE building blocks throughout the years ranging between 140,337kWh and 238,514kWh irrespective to the students occupancy and university's academic calendar. This shows that even with alternating schedules of semester and semester break (holidays), there is no energy management in COE building blocks and energy was wasted despite low student's occupancy in all three blocks.

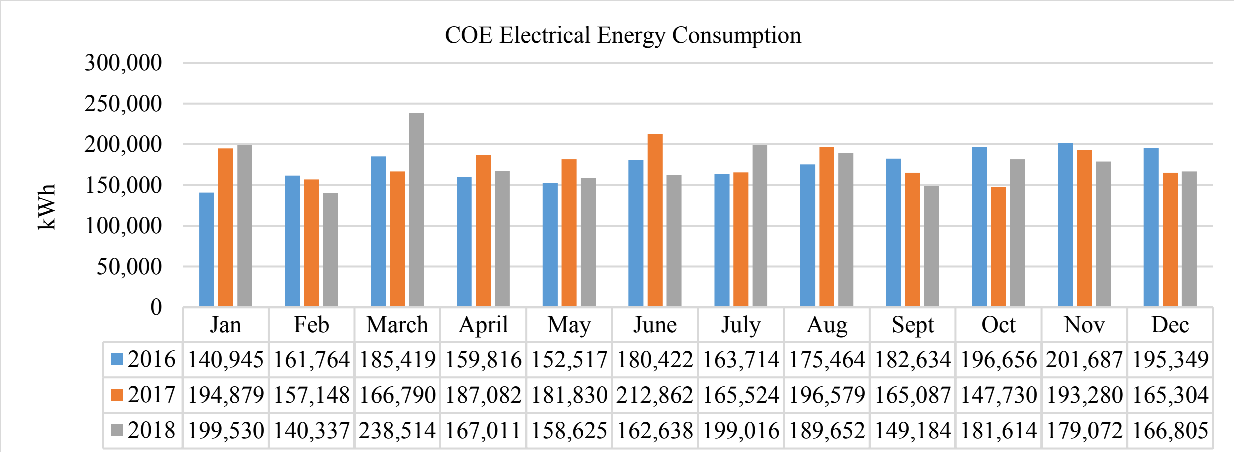


FIGURE 3. COE Electrical Energy Consumption

Fig. 3 also indicates that, from February to April each year between 2016 and 2018, when the teaching and learning activities are lesser in COE building blocks, HVAC, lightings and other electrical appliances was operating like in a normal semester. No reduction in energy consumption is reported in that period. In 2016, the minimum and maximum electrical energy consumption were reported to be 140,945 kWh (January) and 201,687 kWh (November) respectively.

Based on Fig. 3, June 2017 recorded the highest electrical energy consumption at 212,862 kWh and lowest electrical energy consumption are October at 157,148 kWh. However, in 2018, March recorded the highest electrical energy consumption at 238,514 kWh during the special semester and lowest in February at 140,337 kWh. This shown that COE building does not carry out any efficient energy management to save electrical energy consumption between 2016 and 2018. This study indicates that there is no clear relation between occupancy and electrical energy consumption in COE building in any semester.

Moreover the energy audit conducted in the rooms and by locations indicate that some of the illuminance measured are either too low or too high as indicated in Table 3. Lighting performance in COE gave various illuminance results. This indicates that the lighting in the rooms and by locations has not been following the MS1525 or JKR guidelines. Low illuminance measured is due to some light bulbs are burnt out but yet to be replaced. Meanwhile high illuminance measured is due to more lightings are fitted in a room. Most lightings are operating between 7am and 10pm.

Meanwhile HVAC in COE particularly BN building is operating automatically between 6am and 8pm for 14 hours on weekdays. However it is not operate during weekend and public holidays as the occupancy is low. In order to achieve energy saving in HVAC, the easiest way is to make changes on the setting so the starting/finishing time of HVAC system as per operating hours in COE depending to university's academic calendar.

TABLE 3. Lights Illuminance in COE Building Blocks

Room/Location	IES standard, MS1525 and JKR Guidelines illuminance (Lux)	Illuminance Measured (Lux)
Lecturer Room	150	100 - 700
Dean Room	150	200 – 300
Admin office	150	200
Lounge	100	432
Meeting Room	200	90 - 170
Pantry	100	70 - 200
Corridor/Passageway	100	100 – 400
Toilet	100 -150	100 – 300
Classroom	300 – 500	100 – 800
Lecture hall	300 – 500	300
Laboratory	250 - 300	200 - 500
Entrance halls/ Lobby/ Waiting halls	100 - 150	281

Table 4 indicates that the potential electrical energy saving can be achieved just by adopting a simple ‘switch-off’ action when the lightings are not in used for one hour is around 11.9%. Thus, this study shows that adopting simple energy conservation measures can help to reduce monthly electricity bill.

TABLE 4. Potential Electrical Energy Saving with No Cost Initiatives

	Current Operation		No Cost Operation	
	Peak Period	Off-Peak Period	Peak Period	Off-Peak Period
Total Electrical Energy Consumption (kWh)	29,331.46	10,332	25,081	10,332
Monthly Bill (RM)	10,705.98	2,314.37	9,154.59	2,314.37
Month Bill (Peak +Off-Peak) (RM)	13,020.35		11,468.95	
Potential Electrical Energy Saving (%)	11.9%			

Therefore, no cost initiatives are more practical to be implemented in the university building if budget is an issue for operation team to implement energy efficiency action plan. From this study, there are several targeted places that can make big changes in the electrical energy consumption bill of COE buildings. Table 5 lists the proposed initiatives on the potential electrical energy saving strategies that can be implemented and some of them have been implemented in the COE building.

TABLE 5. Initiative of energy saving strategies.

Targeted Place	Current Observations	No Cost Initiatives
Laboratories	1. Lights were leave on after the laboratory session. 2. Some of the lights were on when there are no laboratory session 3. LCD projector and computer was in sleep mode when there are no laboratory session 4. Split unit air-conditioner was leave on when students are leaving the laboratory	1. Switch off lights and all equipment when leaving the laboratory 2. Switch off lights when there are no laboratory sessions 3. Switch-off LCD projectors as well as computer when a class finishes 4. Switch-off split unit air-conditioners when leaving the laboratory
Lecture Hall and lecture room	1. Split unit air-conditioner was leave on when student are leaving the class 2. LCD projector and computer was in sleep mode when there are no class 3. Lighting were leave on when students are living the class	1. Switch-off spilt unit air-conditioners when leaving the class 2. Switch-off LCD projectors as well as computer when a class finishes 3. Switch off lights when leaving the class
Support staff and academic staff Office	1. Lights and computer were on when leaving the office 2. Lights were on during lunch hour and computer is on standby mode 3. Split unit air conditioner were on when no one in the office 4. All of the equipment and unnecessary light were on during lunch hour	1. Switch off lights and computer when leaving the office 2. Switch off lights and computer during lunch hour 3. Switch off split unit air conditioner when leaving the office 4. Switch off all unnecessary lights and equipment during lunch hour

Apart from switching off lightings, there are also others no cost initiative that can help to bring enormous energy saving potential in a university building. For example, changing the occupancy behaviour can also lead to savings; provide awareness and competition among departments by setting goals and targets for monthly electrical energy usage and give an incentives and rewards for the winning department. Furthermore, academic, support staff and students can participate in energy management program that involve energy efficiency awareness campaign such as place a posters, reminder, stickers and signage in the laboratories, offices, lecture halls, class rooms and other relevant places.

CONCLUSIONS

This study indicates that electrical energy consumption within COE buildings depend on the user behaviour. For example, turning off the AV equipment and lights after a lecture finishes, shutting down the PCs and monitors when not in use will help to reduce electrical energy consumption of the building. All these can be achieved by raising awareness via a good energy management planning and strategy. Apart from the no cost initiative highlighted in this study, further energy saving can also be achieved if a continuous energy saving monitoring is implemented. Implementing others no cost initiative such as setting buildings temperature at 24 degree Celsius, reduce run-time of air handling units based on the class timetable and switch off split unit air conditioner when not in use will help in reducing energy consumption. The analysis indicates that the potential electrical energy consumption saving can be achieved with no cost initiative is 11.9% by switching off for one hour. Nevertheless, details analysis need to be performed to determine pragmatic energy reduction potential with more practical energy efficiency and conservation measures.

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