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Research paper

Energy Consumption and Low Carbon Initiatives in an Academic Building: A Case Study in Malaysia

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Abstract

Climate change due to the enormous energy consumption and emission of CO_2 has become major issues in the aspect of political and scientific. In Malaysia, energy consumption in building sector contributes almost half of the electricity generated hence increasing the CO_2 emission. Through the Energy Efficiency Projects on Energy Efficiency (EE) programmes (2016 – 2020) initiated in RMK11, several buildings in Malaysia have started many ways to improve energy-efficiency and saving in building such as nearly Zero Energy Building (nZEB), apparatus standard, and labeling. Less attention and awareness to energy audits and in-depth monitoring in Malaysian public universities correspondingly leads to higher energy usage. By monitoring the energy consumption pattern, the conservation can be strategies and implemented. Through this study, a preliminary investigation on the energy consumption and Building Energy Use Index (BEI) in one of the selected academic buildings in Malaysian public universities has been carried out. From an initial data collection or walk-through audits, several energy-saving suggestions were made at identified areas that can be improved towards energy saving. Several works of literature have been reviewed to gathered additional information related to energy policies and regulations on Malaysia's perspective.

Keywords: *Energy Consumption; Energy efficiency; Building Energy Use Index (BEI); Energy policy*

1. Introduction

Building sector is one of the highest energy consumption equated to other sectors with approximately 30% to 45% of the entire global energy demand [1]. Compared with other sectors, building sector is the most potential sector to reduce the GHG emissions within the range of 6-29% [2, 3]. Non-domestic buildings such as institution, commercial and offices buildings are recognized amongst the highest energy consumption [3]. From the literature, several factors contributing to the higher energy consumption such as heating and cooling system, quality of the building structure, building management system, building floor area, the advancement of energy efficiency, economic growth and per-capita income [4]. Therefore, many countries through their governance legislative are striving for the energy saving and efficiency towards the development of sustainable building sector [5].

Malaysia has shown hike percentage in the energy consumption pattern due to the transition and development of Malaysia's policy from agriculture country to the developing country analogous with its National Transformation 50 (TN50) vision and mission [6]. Due to that transformation, the intensification of the energy consumed at the buildings sector in particularly has raises the concern on the air quality issues, electricity supply sustainable and the greenhouse gasses (GHG) accretion at the atmosphere [7]. These has been an enormous agenda since the involvement of Malaysia in Kyoto protocol in 1997, United Nations Framework Convention on Climate Change (UNFCCC) and the Conference on Climate Change United Nations (COP) [8]. Under the COP21, by year of 2030, Malaysia is committed to reduce the emission of GHG up to 45% from the 2005 gross domestic product (GDP) baseline [9].

The most potential solution on these issues are by employing the green technology and green living. An agreement has been signed between Malaysian Public Works Department (JKR) and United Nation Development Program (UNDP) Building Sector Energy Efficient Project (BSEEP) in realizing their initiative of having a nearly Zero Energy Building (nZEB) particularly focusing on the low carbon and sustainable building. The key driver for nZEB in Malaysia was initiated by Low Carbon Cities Framework (LCCF) towards sustainable development and GHG emission conservation in cities. The framework is focusing on four (4) elements which are buildings, urban environment, urban transportation and urban infrastructure [10]. The fact is while the buildings is at its operating phases, the tendency of CO_2 emissions is high. Hence, to achieve nZEB, several practical approaches need to be improvised and implemented such as building design, consumers behavior on the electricity usage, energy audit, energy management system and current building management regulatory/policy. Many cases revealed that approximately half of the total energy used in the building are consumed after working hours ended which occupied the unnecessary usage of lighting, air condition, ventilation and other electrical equipment [11-13]. Currently, European Union (EU) listed as one of the utmost example through its buildings directive which actively implementing the nZEB at their buildings parallel with their 20-20-20 EU mission [14]. Environmental management system has been implemented in many university in EU for sustainability aspiration [15].

In promoting energy efficiency buildings in Malaysia, several strategies have been structured incorporating the relevant policies and framework designed by the government which focusing at the supply side management and demand side management. Detail of the strategies are being describe in Table 1 below. These strategies are in line with Malaysia Energy Efficiency Action Plan (MEEAP) that concentrated on the energy efficiency development towards energy sustainability and its competitiveness [16].

Table 1: Malaysian building energy saving framework.

FRAMEWORK	*STRATEGIC PLAN*	*PLAN DESCRIPTION*	*REF.*
Supply Side Management	i. Large scale solar (LSS)	i. Implemented by the Energy Commission (EC). ii.Allocated quota 1000MW between 2017-2020 (800MW for peninsular Malaysia and 200MW for Sabah).	[17]
	ii. Net energy metering (NEM)	i.Implemented by Sustainable Energy Development Authority (SEDA). ii. Allocated quota 500MW between 2016 2020 (450MW for peninsular Malaysia and 50MW for Sabah).	[18]
Demand Side Management	i. Energy efficiency building (i.e. Low energy office, Green energy office, diamond office).	i.Model on non-residential and commercial building built in 2004, 2007 and 2010 with incorporating usefulness of energy efficiency and renewable energy design.	[19]
	ii. Efficient Management of Electrical Energy Regulations(EMEER).	ii.Electrical energy manager, energy audit, monitoring and periodic reports are required for consumer used 3 million kWh within 6months.	[20]
	iii. Sustainability Achieved via Energy Efficiency (SAVE).	iii.Conservation on electricity billings and reduction of GHG emission.	[21]
	iv. Standard and labeling.		[22]
	v. Minimum Energy Performance Standard (MEPS).	iv. EC provide the energy rating on the electrical equipment from 2 to 5 stars to reduced electricity consumption and billings.	[22]
	vi. Energy Performance Contracting (EPC).	v.Encouraging the collaboration between government and private sectors for advance strategic industries towards energy efficiency enhancement.	[23]

Withal, several significant efforts have been initiated to achieve and improve sustainability and energy efficiency in the university building such as academic case study on the energy consumption, awareness campaign on electrical conservation amongst staffs and students, usage of smart metering, usage of energy saving instruments, integration distributed energy resources and revised administrative regulations [3, 17-19]. Therefore, towards the low carbon initiative presented in this paper, a large public university in southern region of Malaysia has been chosen as a pilot project. The study started with the energy management audit by analyzing the energy consumption profile, consumer's behavior and their effects towards the efficacy on the management operational costs.

2. Methodology

By implementing case study approaches, this research concentrated on the electrical energy consumption at one public university in the southern region of Malaysia. Recognized as vigorously engineering campus with 70-acre area, the campus has been chosen as pilot project based on inspiration obtained from the Malaysian Energy Commission and RMK11 initiatives. Various deliberate meetings were held with the technical representatives to comprehend the condition and daily operation events in the campus. Based on the gathered information, the idealistic of parameters and operational arrangement are described in Table 2. The parameters described is imperative to evaluate the building performance, consumption profile and consumers behavior. With that, the systematic energy management process and potential of energy saving method life cost cycle analysis on the equipment and building can be performed. Rationally, the building performance and efficiency is inversely proportion with the construction year.

The utilities authorities in Malaysia are strongly encourage their customers to minimizing the sudden arising of Maximum Demand (MD) to avoid penalties charges by applying the demand side management such as customers controlling their electricity demand during daytime peaks [20]. The amount of payable MD charged is shown in equation 1 which is based on the highest kW (HkW) recorded in a month for 30 minutes interval multiplied by the fix customers tariff (T) rates set by the utilities authorities in Malaysia. By referring to the guideline, university building is under commercial tariff category [21].

$$MD = HkW \times T \quad (1)$$

While equation 2 is Building Energy Use Index (BEI) used as a measurement indicator of the total energy used. This equation is a general equation.

$$BEI = \frac{Total\ Energy\ Consumption\ \left(\frac{kWh}{year}\right)}{Gross\ Floor\ Area\ (m2)} \quad (2)$$

Table 2: Building parameters and operational arrangement

BUILDING PARAMETER	*DATA MEASUREMENT CRITERIA*
Campus zone	5 number of zones have been identified within the campus area for accessible energy management and audit as shown in Fig.1
Space consumption	Lecture hall, classroom, laboratory, cafeteria, student's hotel, health center, offices, toilets, corridors, stairs
Operational time	Normal lecture hours and office started from 8am to 6pm (Sunday to Thursday). Post graduate distance learning classes conducted during weekend at non-centralized chiller building.
Cooling equipment	Chiller and Split unit air condition (4 units of chillers are available with 2 units are simultaneously operate starting at 7.30am and the other 2 retreats as reserve)
Lighting	Florescent
Shading mechanism	Blind and curtain
Building age	3 Years.
Occupancy	Number of students and staffs accumulated is 3000 persons

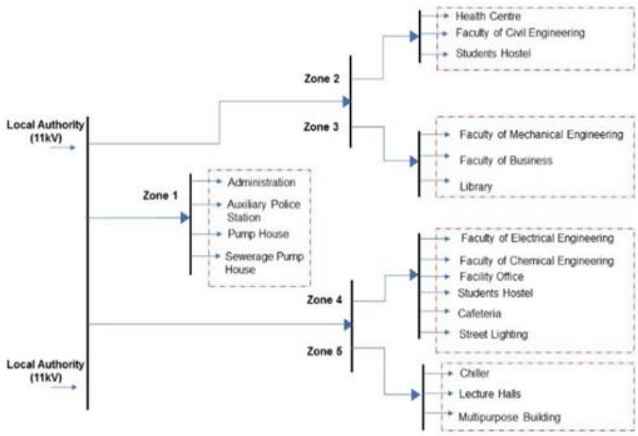

Fig.1: Single Line Diagram for Campus Zone Division.

Three phase power recorder - Fluke 1750 is used to capture and record automatically all parameter and event of electrical consumption such as voltage, current, power factor, power quality related measurements etc. at each outgoing feeder load connected [22]. In pursuance of comprehend the electrical energy consumption patterns, the data is collected at 3 distinctive periods defined as lecture week (LW) from 14/03/2016 to 20/03/2016, study week (SW) from 21/03/2016 to 27/03/2016 and examination week (EW) from 28/03/2016 to 3/04/2016 at ten-minute interval. The load profile will describe the characteristics of electrical usage whereby at the predominant peak hours, the demand patterns can cause huge impact on the overall system load profile.

In this study, several steps were conducted such as reviewing electricity bills of the previous months, developing trend on electricity consumption considering maximum demand (MD) at the said distinctive period, identification of parameter variables effecting energy used, identification of significant consumer, and potential of energy savings such as restructure the occupancy timetable and eliminating the unnecessary usage of lighting, air conditioning, ventilation and other electrical equipment.

3. Results and Discussions

Since university's operational budget is required to pay for the electricity bills, hence the understanding of the pattern for energy consumption in this research is essential to develop the potential opportunities on the energy conservation. Starting in February 2016 the management of university has initiated the preliminary action for energy conservation by strictly enforcement of no classes after 6pm to reduce the usage of chiller, lighting and other electrical equipment. It is important to ensure the compliances of BEI calculation as in Eq. 3.1. Through the parameter obtained, the BEI for this research subject is 67.38 kWh/m^2/year, thus complying with MS 1525:2007 standard [23, 24]. The value calculated are used further to analyze the behavior of electrical usage at the overall building in this pilot project.

Next, the understanding of energy consumption in this pilot university was done by analyzing the average monthly electrical load profile and its MD as depicted in Fig.2. The respective load profile is to demonstrate and distinguish the pattern of electricity consumption between 2015 and 2016. From the graph shown in Fig.2, higher energy consumptions were marked at the month of June until October and December until April at year 2015 and 2016. This is due to the full occupancy of campus residences since the academic semester is running at this month. Observed that during month of March and August, the energy consumption has reached to its peak due to summer season that affecting the amount of solar radiation received and heat, hence, increasing the usage of cooling system. Furthermore, due to the restructure of occupancy timetable, the operating time of coolant chillers were reconfigured and shortened about 3 hours from its daily usage. As for consequences, observed that starting February 2016, there were significant reduced of monthly energy consumption by 12% after the said action executed. In most cases, the number kW of MD recorded in Fig.2 is approximately 20% higher than the average total monthly usage.

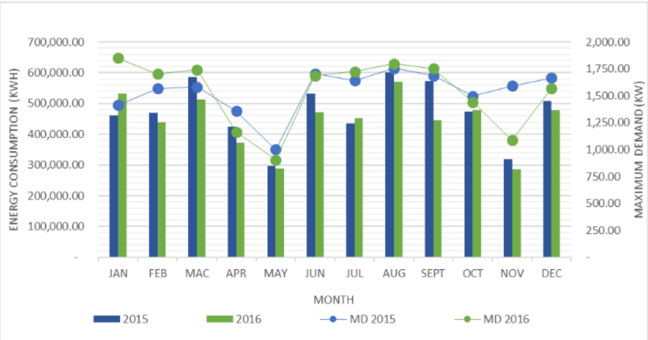

Fig.2: Monthly load profile for energy consumption (kWh) and MD between 2015 and 2016.

Further analysis was executed by monitoring the average electrical load profile by sectioning the transformer into five (5) zones starting from 14/03/2016 until 3/04/2016. Fig. 3 shown the average daily load profile on the actual electrical consumption with the occurrence of MD at every respective zone. The information regarding room occupancies, activities and building descriptions as depicted in Table 2 are crucial to be considered in this analysis.

Form the information of MD shows in Fig.3 at the next page, the division of total energy consumption at every zone considering MD value is depicted in Table 3. Observed that zone 5 denoted as the highest usage of electricity with total of 86,784.27 kWh with the MD value recorded is 801 kW. This may be attributed by the operational of the chillers as major energy required for space cooling. This finding has been supported from research done by Saidur et al. that operational of chiller consumed almost 40% of energy in industrial and commercial buildings. The next lion share underwrote by Zone 4 with 21% of total energy consumption (MD value is 798.73). As described above, this zone is supplying to large number of consumers. Minor kWh usage at Zone 1 is recorded due to its distinct time of room activities and occupancy.

Table 3: Division share of total energy consumption at every zone considering MD

Zone	*Amount of Energy Consumption (kWh)*	*Amount of MD (kW)*	*Energy Consumption + MD (kWh)*
1	35,816.01	296.07	36,112.08
2	63,623.92	263.71	63,887.63
3	53,639.99	149.20	53,789.19
4	77,262.97	798.73	78,061.70
5	86,784.27	801.00	87,585.27
Total (kWh)			319,435.87

Table 4 summarizes additional major finding analogous with harmonic limitation and total harmonic distortion (THD) encountered at each zone. The readings for harmonics and THD events captured are in complied with the limits practice by IEC 61000 and IEEE 519 respectively. Within the period of monitoring, it was observed that MD occurred on 15/03/2016 at 8.30 am. Hence during the period, total MD taken from zone 1, zone 2, zone 3, zone 4 and zone 5 were amounted 1,743 kW. From the guideline [25], Malaysia local authority supplies an alternating current (AC) system electricity with the supply frequency value of 50 Hz ± 1%. The typical low voltage levels of 400 V for three-phase and 230V for single-phase configuration systems with specified ranges between +10% and -6% for the allowable percentage variation.

Data captured shown that the average power factor is within the allowable range stipulated by the local utilities authorities (≥0.85) [26]. By zone division perspective, slightly lower reading of power factor is recorded at the thoughtful view of zone 1 and zone 5. These may be contributed by the operational of large induction motor at the pump house (zone 1) and simultaneously operation of two (2) chillers with power rated each at 262.8 kW (zone 5). To maintain an efficient level of electricity usage, the power factor surcharge will be imposed when measured power factor index is less than 0.90 for electricity supply 132 kV and above or less than 0.85 for electricity supply below 132 kV. Therefore, the consumers are required to maintain their load power factor to avoid any surcharge imposed.

Table 4: Electrical Events Limit

Zone	*Power Factor (pf)*	*Harmonics*	*THD*
1	0.83		
2	0.91	Complied	Complied
3	0.85	with IEC	with IEEE
4	0.89	61000 [35]	519 [36]
5	0.77		

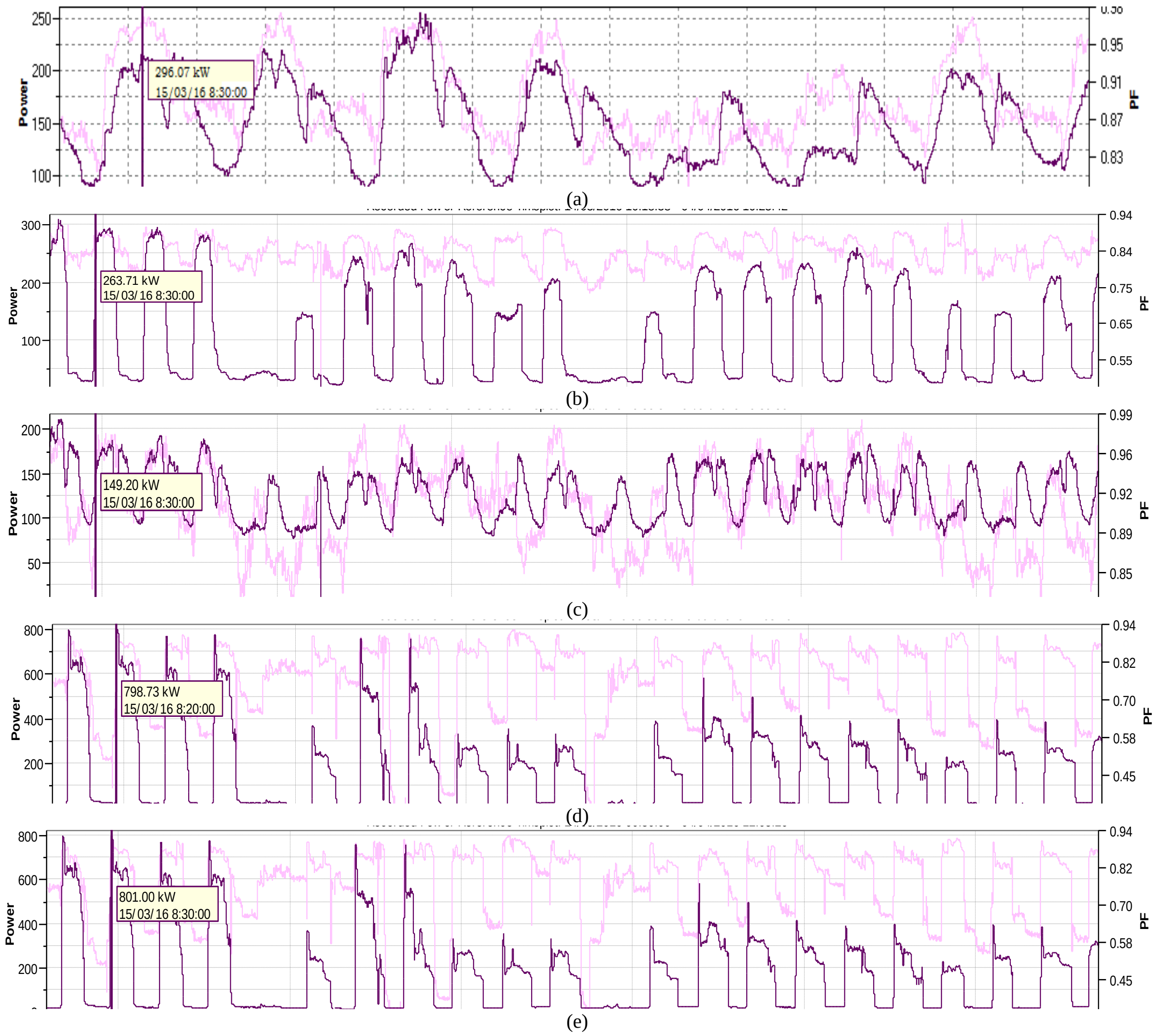

Fig.3: Typical load profile monitored during the occurrence of MD: a) Zone 1, b) Zone 2, c) Zone 3, d) Zone 4, e) Zone 5

From a micro perspective, further comparisons were made at different zone and period as depicted in Fig.5. A daily sample were taken on Wednesday during LW, SW and EW to understand the cluster pattern of LP. Zone 1 has a very similar pattern during these three (3) weeks because of the transformer is supplying to the administration and auxiliary police office that run its operation constantly from 8 am to 5 pm daily. Heavy usage of electricity is recorded during LW at zone 5 since teaching activities were still conducted and the consumption of chillers need to operate at its full swing thus contributing to the challenges of energy conservation. Apart of zone 1, the other zones recorded the highest usage during LW and least during SW. Obviously during SW, no lecture will be conducted and most of the students are more incline to do revision at their own place. The occupancy of the lecture hall and multipurpose buildings is lower during examination week since only written examinations were conducted at that time.

The load profile is observed to possess a similar cluster pattern between each zone. Begin its operational activities at 8 am, the demand LP at zone 1, 3, 4 and 5 (administration building, auxiliary police office, faculties, library, facilities, lecture halls, multipurpose building and chillers) will continue to reach its peak value at noon and start decreasing after 5 pm. Contrasting event at zone 2 (health centre and students hostel) whereby the demand supply is most likely at its high consumption from 7 am onwards before slowly decrease for approximately 2 hours starting at 5 pm and drastically low from midnight to the next morning. Based on the load profile pattern, during LW period the electricity were consumed at its highest usage followed by EW period and SW period respectively.

Throughout the investigation, zone 5 hold the major shares of total energy consumption and highest MD compared with another zone due to the heavy usage of air-conditioning such as coolant chiller and several types of heavy electrical appliances available in laboratories. Factor of electrical motors efficiency involved at its rated loads (>90%) and lower rated loads (<50%) were considered at the beginning of data captured [27]. By comparing the findings with the recent similar research, it was observed that the electrical motors are the major contributors for energy consumption thus reflect to the electrical billings.

Several potential elements are narrated for energy conservation has be executed such as restructure the occupancy timetable and eliminating the unnecessary usage of lighting, air conditioning, ventilation and other electrical equipment. For future recommendation, the university might consider to deploy high efficiency motor or variable speed drive (VSD) for farther energy and bills savings as deployed in many researches.

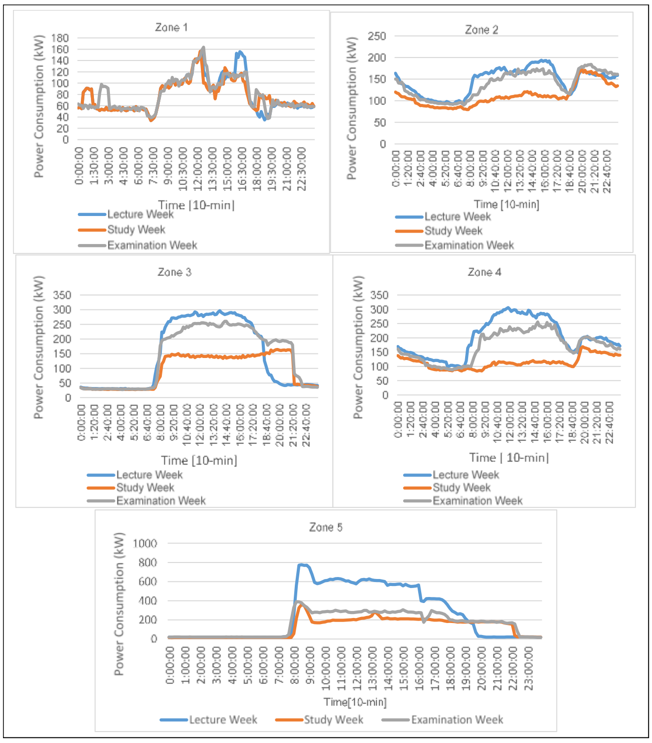

Fig.5: Daily load profile at different zones during distinctive week (lecture, study and examination week)

4. Conclusion

A preliminary study was conducted based on data collection with walk-throughs energy audit to assess the energy consumption at one of the public universities in Malaysia. The audit has been done towards energy conservation and low carbon initiative. The energy conservation in university building is decisive with reflect to its nature of services. Towards the low carbon initiative, the understanding of energy consumption profile is essential to investigate the effects that is contributed to the management operational costs. Hence, the LP obtained at each zone were scrutinized based on its distinctive period. These results have been used to promote the energy efficiency development of the existing buildings while understanding the potential circumstances for energy conservation and reduction of GHG emission at the building sector. Several potential elements are narrated for energy conservation has be executed such as restructure the occupancy timetable and eliminating the unnecessary usage of lighting, air conditioning, ventilation and other electrical equipment. For future recommendation, the University might consider to deploy high efficiency motor or variable speed drive (VSD) for farther energy and bills savings. However, this may imply additional costs which required management approval. Altogether, factors associated for the electricity used in this pilot study are analogously with Malaysia's continental climate, building occupancy and technical consideration such as building structure, floor area, age and the advancement of technology characteristics used.

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