

A Case Study on Energy Efficiency at Universiti Pertahanan Nasional Malaysia (UPNM) Building

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Abstract—In efforts to minimize harmful greenhouse gas (GHG) emissions and mitigate climate change, energy efficiency has become a global priority. Commercial buildings, including university facilities like Universiti Pertahanan Nasional Malaysia (UPNM), play a significant role in this effort. Commercial buildings have been identified as major contributors to GHG emissions, due to its' energy consumption for air conditioning, lighting, and other operational needs. In alignment with the Paris Agreement 2016, the Malaysian government has implemented various energy-saving initiatives to reduce carbon emissions and achieve Energy Efficient Building Star Ratings. This study analyses five years of energy consumption at UPNM using the desktop audit method. Data collected from January 2018 to December 2022 includes the Nett Floor Area (NFA), energy consumption, and maximum demand of the UPNM buildings. The analysis covers energy consumption and expenditure, maximum demand, Building Energy Intensity (BEI), carbon footprint, and building energy labelling in accordance with the National Building Energy Labelling Standard. The findings indicate that UPNM has achieved a 5-star rating in 2020 and 2021, compared to a 4-star rating in 2018, 2019, and 2022. The BEI of UPNM buildings from 2018 to 2022 met the Energy Commission (EC) requirement of being below 135 kWh/m²/year. This study also has identified recommendations for further improving UPNM Building energy efficiency, such as regular maintenance of electrical appliances and conducting energy efficiency awareness campaigns.

Keywords— Energy efficiency; maximum demand; Building Energy Intensity (BEI); national building energy label; carbon footprint; energy consumption

Manuscript received 15 Oct. 2020; revised 29 Jan. 2021; accepted 2 Feb. 2021. Date of publication 17 Feb. 2021. International Journal on Informatics Visualization is licensed under a Creative Commons Attribution-Share Alike 4.0 International License.



I. INTRODUCTION

The world is currently facing a significant climate change problem directly linked to carbon emissions. Carbon emissions, primarily in the form of carbon dioxide (CO₂) from building operations are one of the contributors to greenhouse gas (GHG) concentrations in the atmosphere. Addressing the climate change problem related to carbon emissions requires substantial efforts to reduce GHG emissions and transition to a low-carbon economy. On these days, building energy consumption contributes to up to 40% of total world energy consumption, with demand predicted to reach 50% by 2030 as stated in Jemat *et al.*, [1]. Commercial, residential, and transportation applications are the most significant consumers of energy in everyday activities as accordance to Ahmad *et al.*, [2]. Commercial buildings contribute significantly to GHG emissions, due largely use of energy for cooling, lighting, and other operating needs [3].

The university building is one of the commercial buildings that contribute to this problem as stated by Muhammad and

Hilmi [4], Bakar *et al.*, [5], and Subramaniam *et al.*, [6]. Institution consumes a lot of electrical energy due to the massive building area and the high number of consumers, and it led to high carbon emission as taken from González-Torres *et al.*, [7]. This is certainly one of the most crucial problems that institutions must tackle. In address these issues, energy efficiency management has been a major priority to all Malaysian universities including Universiti Pertahanan Nasional Malaysia (UPNM). One of the major financial budget spending in UPNM has been identified as the payment for the electricity usage around RM5 million yearly and this is due to the high energy consumption which contributes to the carbon footprint approximately 5000 tonnes of CO₂ yearly. Hence there is a need for study in finding suitable strategies for the usage of electricity energy efficiently in UPNM.

There are almost fifty buildings in UPNM that need to be focused. Some of the building in UPNM are commonly required for important activities such as academic buildings, laboratories, administration building and others. In UPNM, there are also several buildings or space that need to operate

frequently such as dormitory, server room and others. The energy consumption is very high at those building because it uses a lot of electrical equipment and utilities such as machine and air conditioner.

In order to overcome this problem, the data collection of building energy consumption is collected for the purpose of studying the pattern and maximum demand of the UPNM building usage in order to improve the efficiency of energy used by the UPNM building. It is important to determine the exact energy usage of the UPNM building in order to analyse the Building Energy Intensity (BEI), carbon footprint and STAR rating as stipulated by the national building energy label. Hence, the suitable recommendation such as frequent maintenance of electrical equipment and awareness campaign can be implemented to improve energy efficiency of the building.

II. MATERIALS AND METHODS

A flowchart is used to illustrate the project's methodology for achieving the objectives. This project's flowchart is shown in Figure 1. Initially, the project requires performing research and gathering literature reviews from a number of publications, journals, and other sources related to energy efficiency management. The purpose of this phase is to collect all of the information and knowledge needed to complete the project. The following phase is to determine the project's problem statement, objectives, and scope of the work. This is essential in order to determine a clear project purpose and specify the project's scope. The flowchart then proceeds by collecting continuous data on the UPNM building's energy consumption and patterns. The electrical data will be interpreted and analysed to see the pattern of energy usage.

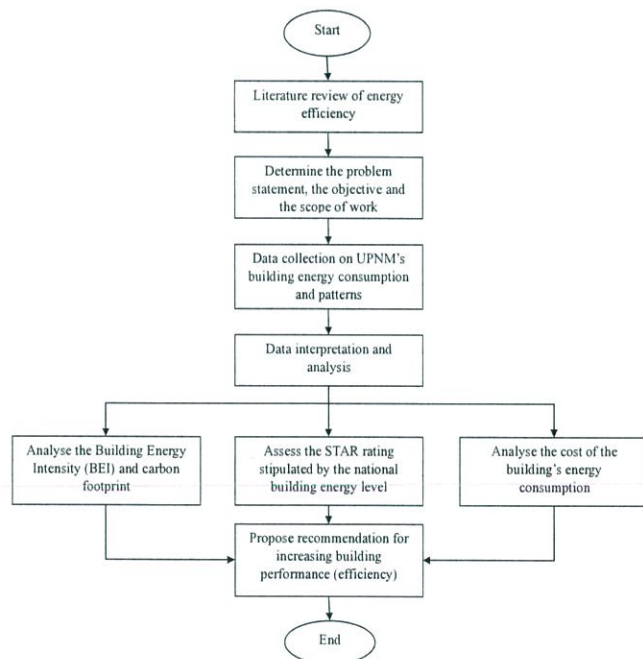


Fig. 1 Overall flowchart of the project

The next step of this project are divide by three distinct analyses which are the cost of the building's energy consumption, the

Building Energy Intensity (BEI) and carbon footprint, and the STAR rating specified by the national building energy label. This analysis will be based on the continuous data that will be interpreted and analysed throughout the project's initial stages. The final part of this project is to propose recommendations for increasing UPNM's building performance (efficiency).

A. Data Collection

The gathering data of energy consumption for UPNM building is the next step in these studies. Energy consumption data is obtained from the Development and Maintenance Department (JPP) starting from January 2018 until December 2022. This data will be used to analyse the pattern of energy consumption and peak demand. Electricity demand is the rate at which electrical energy is consumed for a certain output rating, measured in kW, whereas energy consumption is the amount of electrical energy spent during a given period, measured in kWh [8].

Data analysis is conducted using information gathered during data collection. Analysed data is displayed more clearly for better comprehension. In this study, the data obtained from JPP was analysed using a desktop audit approach. A desktop audit is an assessment that seeks and analyses energy from building information, data and documentation collected without an actual visit.

B. Building General Description

Universiti Pertahanan Nasional Malaysia (UPNM) was established on June 1, 1995, as Akademi Tentera Malaysia (ATMA), or the Malaysian Armed Forces Academy [9]. UPNM is a military university in Kuala Lumpur, Malaysia, located in Sungai Besi Camp as stated by Syafuan *et al.*, [10]. This is Malaysia's first university dedicated to the requirements and growth of the Malaysian Armed Forces.

ATMA was elevated to university status on November 10, 2006, which led to the current UPNM. The Prime Minister, Datuk Seri Abdullah Ahmad Badawi, announced the formation of the university during the Budget 2007 reading in Malaysian Parliament. The university's establishment cost RM 500 million, which was entirely funded by the Malaysian government. UPNM is a university with 48 main buildings on 694,646.95 m² of land or 171.651 acres. Other than that, UPNM have nett floor area (NFA) of 96,382.50 m². Other than that, this building is categorized as commercial building. This commercial sector use energy for heating, cooling, lighting, machinery, workstation, etc [11].

C. Energy Consumption Cost Of UPNM

The energy consumption cost of the UPNM's building will be determined by this study. According to Tenaga Nasional Berhad (TNB) [12], the energy tariff for UPNM is category C1, which is a medium voltage general commercial tariff.

TABLE I
ENERGY TARIFF FOR UPNM [13]

Type	Tariff C1- Medium Voltage General Commercial Tariff Components	Current rate
A	Energy consumption	RM 0.365/kWh
B	Maximum Demand	RM30.30/kW
C	Renewable Energy Fund (RE Fund)	1.6% from total bill
D	Imbalance Cost Pass-Through (ICPT)	±RM/kWh (rebate/surcharge)
E	Discount for Higher Educational Institution (HEI)	10%

From Table 1, the energy consumption cost of the UPNM building may be determined using Eq. (1).

$$Total\ Cost = A + B + C + D - E \quad (1)$$

The electricity consumption cost of the UPNM building may be determined using Eq. (1) based on Table 1. It is commonly referred to as the total cost of energy consumption, maximum demand, RE Fund, Imbalance Cost Pass-Through (ICPT), and HEI discount. RE Fund is a fund collected by the Government through consumer's electricity consumption. The fund will be used to promote growth of electricity generation from renewable energy resources. As stipulated in the RE Act 2011, the RE Fund is collected through a surcharge of consumers' electricity consumption at the rate of 1.6% [13].

The ICPT and discount for HEI also will be included in the cost to calculate the total cost for UPNM's buildings. ICPT is a mechanism that allows the utility to reflect changes (either increase or reduction) in fuel and other generation-related costs in the electricity tariff every six months in the form of rebate or surcharge according to Fatin et al., [14]. Table 2 shows the ICPT charge from January 2018 until December 2022. As an example, the government has decided that the ICPT charge rate before January 2022 is a rebate of RM 0.02/kWh but from January 2022 to December 2022 the charge rate is surcharge of RM 0.037/kWh.

TABLE II
ICPT CHARGE RATE FOR 2018 UNTIL 2022 [15]

Duration	Tariff (RM/kWh)	ICPT (RM/kWh)
2018 JAN-JUN	0.3945	-0.0152
JUL-DEC	0.3945	0.0135

2019	JAN-JUN	0.3945	0.0255
	JUL-DEC	0.3945	0.0255
2020	JAN-JUN	0.3945	0.0200
	JUL-DEC	0.3945	0.0000
2021	JAN-JUN	0.3654	-0.0200
	JUL-DEC	0.3654	-0.0200
2022	JAN-JUN	0.3654	0.0370
	JUL-DEC	0.3654	0.0370

Other than that, for HEI discount, all government and private institutions of learning which are fully or partly funded by the government and normally administered by Ministry of Education are eligible to a 10% discount on their monthly bills.

D. Building Energy Intensity (BEI)

BEI is a method that is used as a baseline for measuring the energy performance of any building. According to the Malaysian Standard, MS1525, the benchmark for Building Energy Intensity (BEI) of a non-residential building that meets this standard is 135 kWh/m²/year that in line with Jamaludin *et al.*, [16], Singh *et al.*, [17] and Mohd Jaffri *et al.*, [18]. The Malaysian Standard equation for BEI benchmark is determined as Eq. (2).

$$BEI_{benchmark} = \frac{Annual\ Energy\ Consumption\ (kWh)}{NFA\ (m^2)}\ kWh/m^2/year \quad (2)$$

Where NFA indicates nett floor area of the building in m². Other than that, to obtain the BEI the annual energy consumption in kWh/year also uses. The index is calculated by taking the ratio between annual energy consumption and NFA.

E. National Building Energy Label

The BEI of the building determines the building's rating. The building categories, such as university, office, school, and hospital, are the first section of the label. The second part of the label refers to the energy intensity of the building (BEI). Finally, the star range is the final part of the label. The star rating range, as indicated in the Table 3, began with one star, which denotes a severely inefficient building, and ended with five stars, which denotes the most efficient building [19,20].

TABLE III
STAR RATING RANGE [19]

STAR	BEI Range
1-Star	BEI > 250
2-Star	160 < BEI ≤ 250
3-Star	130 < BEI ≤ 160
4-Star	100 < BEI ≤ 130
5-Star	BEI < 100

The Energy Commission (EC) introduced this labelling, which may be used by any commercial building such as an office, hospital, university and school. The important aim of this labelling is to motivate people to improve building energy efficiency by rating buildings from 1 to 5 stars based on their energy efficiency. This label also provides information about the energy performance of the building.

F. Carbon Footprint

The value of a building's carbon footprint can vary greatly based on a variety of factors, including the size of the building, its energy efficiency, operational practices, and the energy sources used to power the building's operations according to Karen and Maria [21], and Jiandong et al., [22]. To tackle these issues, the United Nations Framework Convention on Climate Change (UNFCCC) established the Paris Agreement in 2016 among 195 nations that agreed to deal with climate change and GHG emissions as taken from Mathur *et al.*, [23]. The average emissions factor for Peninsular Malaysia, Sabah and Wilayah Persekutuan Labuan, according to research conducted by Malaysian Green Technology and Climate Change Corporation (MGTC) titled "Study on Grid Connected Electricity Baselines in Malaysia," is 0.68 tCO₂/MWh [24]. The emission of carbon at the UPNM building may be determined using Eq. (3).

$$\text{Carbon}_{\text{emission}} = \text{Total energy consumption (MWh)} \times 0.68 \text{ ton} \quad (3)$$

III. RESULTS AND DISCUSSION

In this section, the result that has been achieved from the case study will be presented and will be discussed. This section made up by six main results which are the energy consumption, maximum demand, cost of electrical consumption, Building Energy Intensity (BEI), STAR rating and carbon footprint of UPNM building

A. Energy Consumption of UPNM Building

Figure 2 shows the yearly comparison of energy consumption (kWh) for UPNM building between 2018 until 2022. The highest energy consumption is in 2019 with 11,978,088 kWh and the lowest energy consumption energy is on 2020 with 8,761,675 kWh. The total consumption of electrical energy in 2018 and 2019 is high due to no changes of equipment in 2018 and starting of equipment changes in 2019 to reduce the energy consumption. Next, the energy consumption from 2019 reduce to 8,761,675 kWh in 2020 and 9,039,010 kWh in 2021. This reduction is due to COVID-19 and the Movement Control Order (MCO) which limits the movement of students and staff. During this period, all students attend online learning classes and staff work from home. However, the installation of energy-efficient devices such as Light Emitting Diode (LED) lighting keeps going from 2020 to 2022.

Next, the energy consumption increases by 25% from 2021 to 2022 when the movement control order is relaxed and university activities can be carried out normally which allows buildings at UPNM to operate in full. Therefore, residents and building operations at UPNM has begun to increase which contributes to the increase in energy in the year 2022. Despite the installation of numerous energy-efficient devices, the rise in energy usage for 2022 is also related to the addition of new buildings at UPNM.

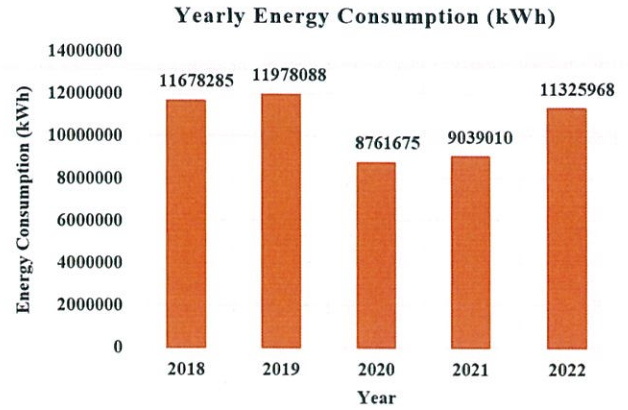


Fig. 2 Energy consumption of UPNM building

B. Maximum Demand of UPNM Building

In this section, this project will discuss on the maximum demand of UPNM building. Figure 3 indicates the comparison of maximum demand for UPNM building between 2018 until 2022. Referring to the Figure 3, the maximum demand appears with two peaks showing the higher demand above 37000 kW which is in 2018 (37050 kW) and 2019 (37223 kW). The higher demand can be attributed to the use of energy inefficient appliances that have not been replaced. Next, the maximum demand from 2019 is decrease in 2020 (30780 kW) and 2021 (27611 kW). Despite the occurrence of COVID-19 and MCO, some places in UPNM still need to operate for example the server room and so on. Further, the maximum demand for UPNM building is increasing 30% from 27,611 kW in 2021 to 35,864 kW in 2022. Even though the replacement of energy efficiency appliances has been made, the increase in demand is due to the addition of a new building which is Jauhari building.

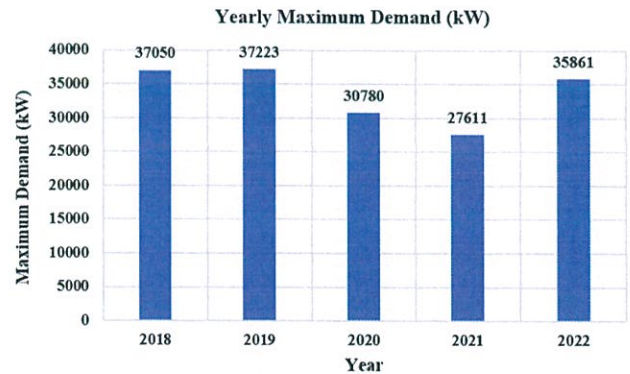


Fig. 3 Maximum demand of UPNM building

C. Electricity Cost of UPNM Building

According to Tenaga Nasional Berhad (TNB), the energy tariff for UPNM building is C1 type. The calculation for cost of electrical consumption for UPNM building was calculated. The cost of consumption for UPNM building is affected directly by the energy consumption, the maximum demand and the Imbalance Cost Pass-Through (ICPT). The result for cost of electrical consumption is presented in Figure 4.

The highest cost of energy consumption is in 2019 with RM5,906,691. Even though the tariff remains the same which is RM0.3945/kWh from 2018 to 2020, the highest cost of

electricity in 2019 is due to higher consumption of energy and a human error, which is a five-month penalty for late bill payment. Compared to 2021 and 2022, the tariff is reduced to RM0.3654/kWh. Next, even though after the replacement of energy efficiency appliances and reduction of tariff, the cost for 2022 is also high which is RM5,088,293 that due to new building develop in UPNM but in September 2022, UPNM has joined the Merdeka Incentive and got energy cost savings electricity amounting to RM18,286.12 given in the bill. Based on the research, the electricity tariff and Imbalance Cost Pass-Through (ICPT) also affect the electricity cost. The charge of ICPT is are unstable and change according to government regulations.

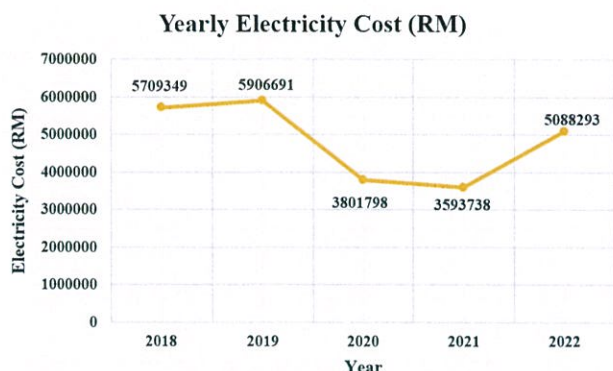


Fig. 4 Electricity cost of UPNM building

D. Building Energy Intensity of UPNM Building

The next part of this project will discuss the calculation and finding based on the analysis of the energy consumption of UPNM building. The Building Energy Intensity (BEI) calculated using Equation 2 to get the building's performance index. Based on the analysis and calculation, **Error! Reference source not found.** states that the highest BEI of UPNM building is in 2019 with the value of 124.28 kWh/m²/year. Next, the BEI value for 2020 and 2021 decrease from 2019 due to Movement Control Order (MCO) and COVID-19 cases. Furthermore, the increasing value of BEI in 2022 is due to the relaxation of the MCO which allows buildings at UPNM to operate in full from May 2022. According to the Malaysian Standard (MS1525), the recommended amount of energy consumption for commercial buildings is 135 kWh/m²/year. The BEI value of UPNM building from 2018 until 2022 are all meet the MS1525 so UPNM building can be considered as an energy efficiency building.

TABLE IV
BEI OF UPNM BUILDING

Year	Annual Energy Consumption (kWh)	Nett Floor Area (m ²)	BEI (kWh/m ² /year)
2018	11678285	96382.5	121.17
2019	11978088	96382.5	124.28
2020	8761675	96382.5	90.91
2021	9039010	96382.5	93.78
2022	11325968	96382.5	117.51

E. STAR Rating of UPNM Building

In this section, this project proceeds with STAR rating of the building based on the National Building Energy Label and the result is shown in **Error! Reference source not found.** Based on the Building Energy Intensity (BEI), the UPNM building in the year of 2018 and 2019 has a range from 100 to 130 kWh/m²/year which indicate 4-star rating while for the following year which is 2020 and 2021, the BEI of UPNM building increase to 5-star rating. In 2022, the decreasing of BEI is in range of 100 to 130 kWh/m²/year and it also leads to decreasing of star rating in 2022 to 4-star rating.

TABLE V
STAR RATING OF UPNM BUILDING

Year	UPNM BEI (kWh/m ² /year)	BEI Range (Kwh/ m ² /year)	STAR Rating
2018	121.17	100 < BEI ≤ 130	4-Star
2019	124.28	100 < BEI ≤ 130	4-Star
2020	90.91	BEI < 100	5-Star
2021	93.78	BEI < 100	5-Star
2022	117.51	100 < BEI ≤ 130	4-Star

F. Carbon Footprint of UPNM Building

Figure 5 shows the yearly carbon footprint (tons CO₂/MWh) for UPNM building between 2018 until 2022. According to research conducted by Malaysian Green Technology and Climate Change Corporation (MGTC), the total average emission factor is 0.68 tCO₂/MWh. The carbon footprint is linearly proportional to the energy consumption. The increase in energy consumption also increases the carbon footprint. As shown in Figure above, the highest carbon footprint by UPNM building is on 2019 with 8145.10 tons CO₂/MWh because the energy consumption of that year is the highest among other years. Other than that, the lowest carbon footprint of UPNM building is in 2020 with 5957.94 tons CO₂/MWh. Due to worst COVID-19 cases and MCO in 2020, the energy consumption in 2020 is the lowest among the other years. After the replacement of energy efficiency appliances, even the university operated in normal condition and have addition of new building, the carbon release is reduced compared to 2019.

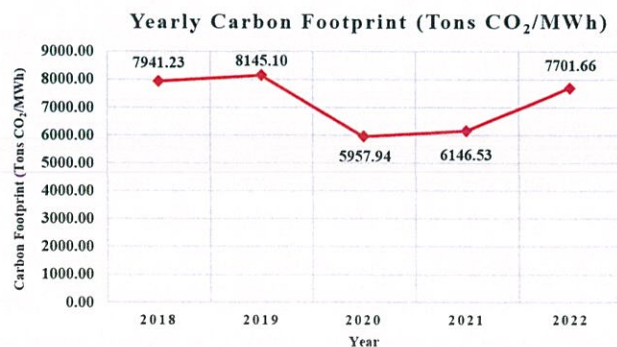


Fig. 5 Carbon footprint of UPNM building

G. Recommendation for Energy Efficiency Management

In this section several strategies and solutions have been suggested for this problem. At the end of this analysis, recommendations that would help the UPNM building to lowering the energy usage and maximum demand, save the electricity cost, reduce the carbon footprint and improving the BEI and STAR rating have been made as presented in Figure 6. There are several strategies and solutions such as awareness campaign, implementation of air conditioner split unit (ACSU), frequent electrical equipment maintenance, more energy efficiency equipment such as Light Emitting Diode (LED) lighting retrofitting and the installation of sensors or timers for electrical equipment in the building.

Firstly, the strategies that need to be implemented is the continuous awareness campaign for all students, staff and lectures in UPNM. After doing some observations, there are still some places where lights, air conditioners and other electrical appliances are left open when there are no occupants. Therefore, serious actions such as continuous reminders and appropriate labels can be placed on electrical devices such as switches and plug points as accordance to Taib *et al.*, [25]. Next is implementation of air conditioner split unit (ACSU). Based on the observation, the air conditioner for classes at 2nd and 3rd floor of Bestari building is still centralized. The centralization of air conditioner will only cause energy waste because the air conditioner will still operate even when there are no occupants.

Other than that, the maintenance of electrical equipment should be done regularly referring to manufacturer's recommendation or do the inspection regularly. As an example, the energy use to operate the air conditioner is high because a dirty filter caused by improper maintenance will make the air flow difficult to enter the system and make the motor of the fan to work harder thus consumed more electrical energy. Next, more energy efficiency equipment should be applied. From the observation, the application of LED lighting at UPNM building is still minimal. The LED lighting can result in significant energy savings, reduction of utility costs and reducing energy consumption that also contribute to reduction of the GHG [26].

Furthermore, the installation of sensors or timers for electrical equipment in the building should be implemented that in line with Paramati *et al.*, [27] and Thanakodi *et al.*, [28]. Based on the observation, there are still electrical equipment that still operate when there no occupant such as lighting system at meeting room and restroom. As an example, the installation of occupancy sensor in infrequent areas can be done. When no one is around, these sensors will switch off lights and that will eliminating excessive energy use [29].

In addition, there are several recommendations that can reduce the expenditure of UPNM building such as the installation of battery bank and implementation of green tariff. The installation of battery bank should be considered because it can provide power during peak demand periods and reducing the need to draw electricity from the grid. By utilizing stored energy during times of high demand, the building can reduce its reliance on utility power, leading to lower energy consumption and potentially lower electricity bills [30].

Finally, the implementation of green tariff for UPNM. A green tariff is a pricing structure or program offered by utility companies that allows customers to choose renewable energy sources for their electricity consumption. The utility company will ensure that a portion or all of the electricity supplied to the

customer comes from renewable energy generation and not reliance on fossil fuel-based power generation. In this type of tariff, the ICPT component will not be charge on the bills so this also reduce the electricity bills and carbon footprint.

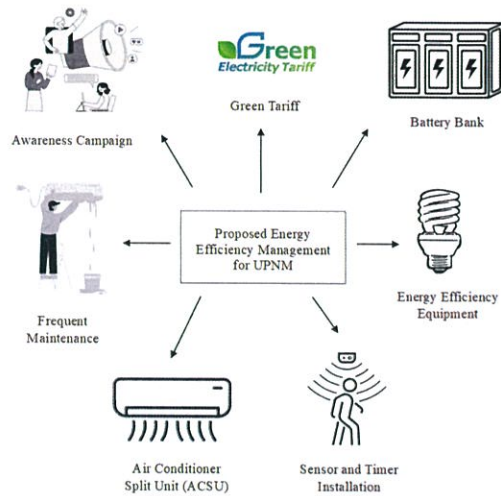


Fig. 6 Proposed Energy Efficiency Management for UPNM

IV. CONCLUSION

This research was conducted on energy consumption of UPNM buildings for five years which are from 2018 until 2022 using desktop audit method. Through discussion and data collection of energy consumption by UPNM buildings from Department of Development and Maintenance (JPP), the data obtained for five years can be analysed and observed. From this study, it is concluded that the BEI of UPNM building from 2018 until 2022 achieve the good benchmark setup by Suruhanjaya Tenaga (ST). However, it cannot be considered for the years 2020 and 2021 because COVID-19 occurred throughout that period and activities at UPNM were not entirely functional.

Following that, the STAR rating of the UPNM building also good which are 4 and 5 stars. Other than that, the initiatives to install energy-efficient devices from 2019 until 2022 reduce the energy consumption, maximum demand, cost of electricity and carbon footprint of the UPNM building. As a result, we can conclude that the UPNM building also contributes to the SDG goal of zero emissions. Last but not least, the concern about increasing utility costs and GHG emissions caused by excessive energy consumption, various recommendation such as awareness campaign and frequent electrical equipment maintenance to improve building energy efficiency and reduce climate change have been proposed.

ACKNOWLEDGMENT

The authors would like to thank all of the staff members from the Department of Jabatan Pembangunan dan Penyelenggaraan (JPP) at Universiti Pertahanan Nasional Malaysia (UPNM) for their guidance and full cooperation in completing this study. Apart from that, authors would like to express special gratitude to Mr. Ts. Steve Anthony Lojuntin of the Sustainable Energy Development Authority (SEDA) Malaysia for his guidance on carbon emissions.

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