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Energy Audit and Energy Efficiency Improvement Proposal For Pejabat Pembangunan dan Penyenggaraan (PPP), UTHM

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Abstract

Since Malaysia's building industry contributes significantly to the country's energy consumption, energy efficiency is a top national concern. The Sustainable Energy Management System (SEMS) is presently being implemented by Universiti Tun Hussein Onn Malaysia (UTHM) in order to enhance its energy performance. This study focuses full on carrying out an energy audit at the Pejabat Pembangunan dan Penyenggaraan (PPP) building, where issues with inefficient and unmonitored energy usage have been found. This study evaluates the energy consumption patterns of the PPP building and investigates major inefficiencies across key systems, including lighting, and MVAC system. The data were collected through a walkthrough audit and the UTHM energy monitoring system known as ENERGY SCADA. The walkthrough audit provided information on equipment type, operating conditions, and usage behavior, while the ENERGY SCADA system supplied real-time measurements of cost, and energy trends throughout the year. Analysis of the data collected helps to reveal the building's energy consumption and overall energy performance. The result from the audit indicates opportunities for improvement and the unnecessary energy consumption. This study supports PPP's efforts to improve operational efficiency by identifying consumption trends, inefficiencies, and possible low-cost or high-impact alternatives. The total annual electricity consumption of the PPP building was recorded at 137,456 kWh kWh, with an associated average per month of approximately 11,454.70 kWh. The cost of electricity approximately RM 54,175.34. The results show that the ACMV system accounts for 77.40% of the total energy consumption, followed by office equipment 16.54% and lighting systems 6.06%. The PPP Building Energy Index (BEI) is 74.20 kWh/m2/year below than the standard of MS 1525:2019. This indicate PPP energy consumption is not exceed the standard. The findings of PPP BEI also support UTHM's larger sustainability objectives in reducing energy consumption systematically and act as a baseline for upcoming energy audits in UTHM.

1. Introduction

Energy audit is a methodical process of examining a building's or facility's energy usage to identify areas where consumption can be reduced and energy efficiency improved. As of the growing reliance on artificial lighting, MVAC systems, and electrical appliances, building energy consumption keeps rising[1]. Universities in particular contribute significantly to institutional energy demand since they run several facilities that run for extended periods of time[2]. In order to attain the 3-star Energy Management Gold Standard (EMGS), Universiti Tun Hussein Onn Malaysia (UTHM) has implemented the Sustainable Energy Management System (SEMS), which highlights the necessity of systematic and ongoing monitoring of campus energy performance.

The Pejabat Pembangunan dan Penyenggaraan (PPP) building lacks a current systematic energy audit, despite being one of the major administrative structures in charge of overseeing university infrastructure. The building operates a variety of energy-intensive systems, such as lighting systems, office equipment, and mechanical ventilation and air conditioning (MVAC). This lack of analytical oversight leads to unrecorded excessive usage, resulting in operational waste and diminished system longevity. To serve as a baseline and exemplar for the rest of the campus, the PPP building requires a data-driven assessment to identify and mitigate these unmonitored inefficiencies. Nevertheless, despite its significance, the PPP building has never before received a methodical and organized energy audit. With energy audit, it helps them identify sections that use the most energy. Putting it into practice will assist the PPP building in achieving its sustainable energy goals.

Energy audits are widely acknowledged as a successful method for identifying energy inefficiencies and enhancing building performance[3]. Research on non-residential buildings consistently indicates that the MVAC system is the dominant contributor to total electricity consumption, particularly in tropical climates. Commercial and institutional buildings in Malaysia frequently suffer from significant energy wastage due to unmonitored energy use, ageing equipment, and poor operational practices [4]. According to study, inefficient air conditioning systems can account for as much as 60% of a building's overall energy use, particularly in tropical regions like Malaysia [5]. The Building Energy Index (BEI) is a regularly used way to quantify how efficiently a building consumes energy.

This study's primary goal is to perform a Level 2 energy audit in compliance with MS 1525:2019 for the PPP building at UTHM. The purpose of this study is to analyze the building's electrical energy consumption patterns, pinpoint the main energy-consuming systems and inefficiencies, and assess the building's energy performance using the Building Energy Index (BEI).

The rest of the paper are organized as follows: The first section tells the Energy Audit Framework for Pejabat Pembangunan dan Penyenggaran (PPP) Building. It will cover the building information such as the wings, floor area and etc. Then, the paper continued with energy audit framework. It tells about the function of the Energy Scada and what data collects from the walkthrough-audit. The next section presents results from the energy audit framework and data analyzation. The paper end with conclusion of the study.

2. Energy Audit Framework for Pejabat Pembangunan dan Penyenggaraan (PPP) Building

The PPP is in responsible of managing the infrastructure, buildings, and maintenance tasks on campus. The PPP building is one of the campus's electricity users since it is in charge of the UTHM. This study aims to conduct a systematic energy audit to assess the energy consumption of the Pejabat Pembangunan dan Penyenggaraan (PPP) building. The objective is to identify patterns of energy usage in building, particularly air-conditioning and lighting. The study begins with an understanding of the PPP building through a walkthrough audit, followed by the analysis of energy consumption trends. Figure 1 shows the PPP building from the side view. Figure 2 show the layout buidling of PPP building with gross area of 1852.35 per meter square. The building consists of a single level and is divided into two main sections, namely the left wing and the right wing. In addition to office spaces, the building is equipped with several supporting facilities such as a pantry room for staff to store food and beverages, two Musolla for prayer activities, and four toilets. The building also built with four meeting rooms of different sizes to accommodate discussions, briefings, and official meetings. Refer to the figure 2 to have clear picture of the building structure and design. The university's main entrance substation is immediately connected to the PPP building's electrical supply. The lighting system, the air conditioning (MVAC) system, and other office equipment comprise the three primary categories of the electrical distribution system. This configuration guarantees that every system gets enough power to meet its operational needs.

Research Progress in Mechanical and Manufacturing Engineering Vol. 7 No. 1 (2026) p. 171-179

Fig. 1: PPP Building Office

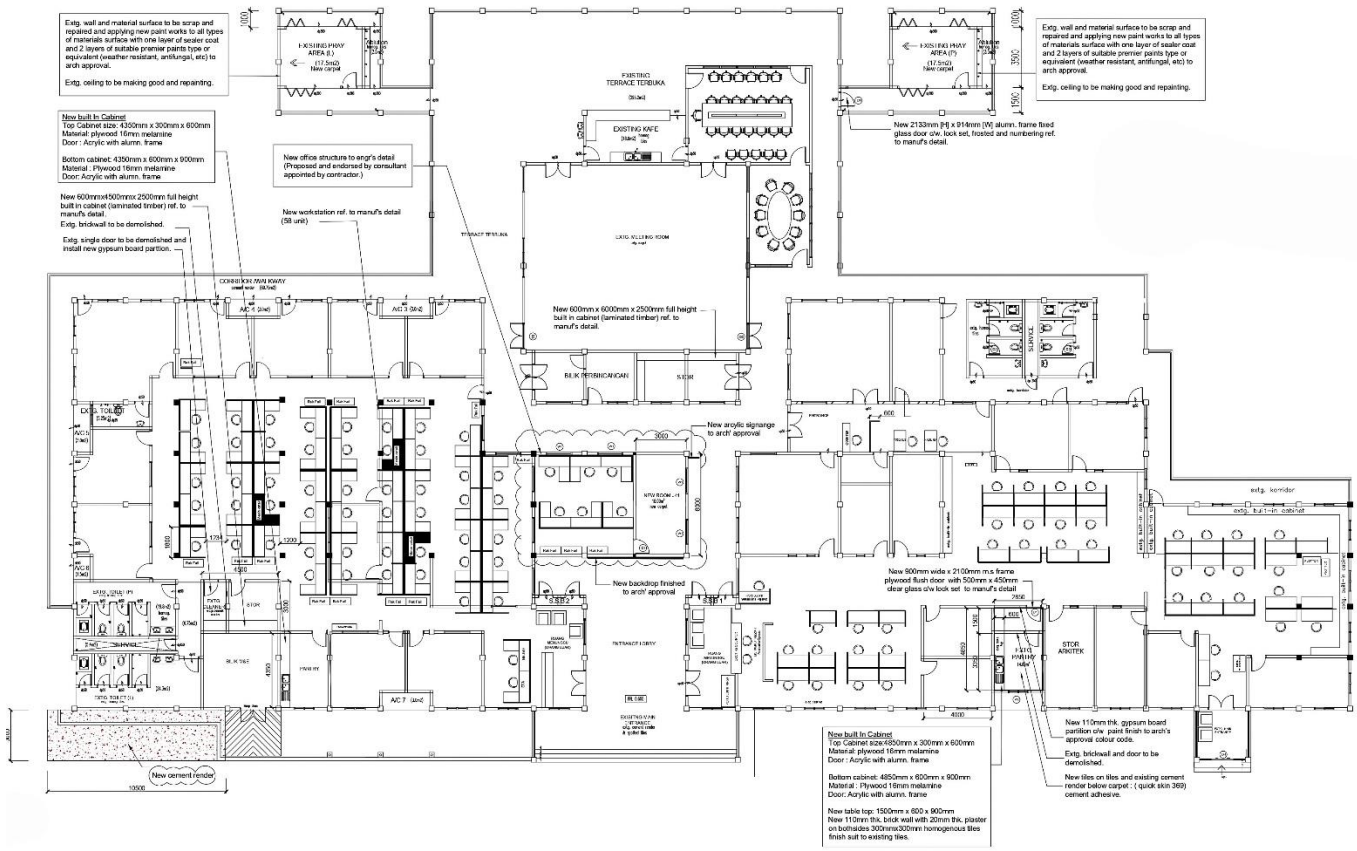

Fig 2: PPP Layout Building

3. Energy Audit Framework

3.1 Energy Scada

Universiti Tun Hussein Onn Malaysia (UTHM) established the energy monitoring and management system known as Energy Scada. The software and hardware system known as Supervisory Control and Data Acquisition, or SCADA, is used to track, gather, and evaluate real-time data from building systems. The system helps to monitor the energy consumption of PPP building and provides information of electricity costs It can be utilized to compare parameters from time-to-time. This enables identification of consumption patterns over time. The system enables to identify of the electric consumption daily, weekly, or annually. The study evaluates the energy consumption and electricity from January 2024 to December 2024. The given datas' unit for the energy consumption and electricity are kWh and Ringgit Malaysia (RM). Figure 3 shows the interface of the Energy Scada

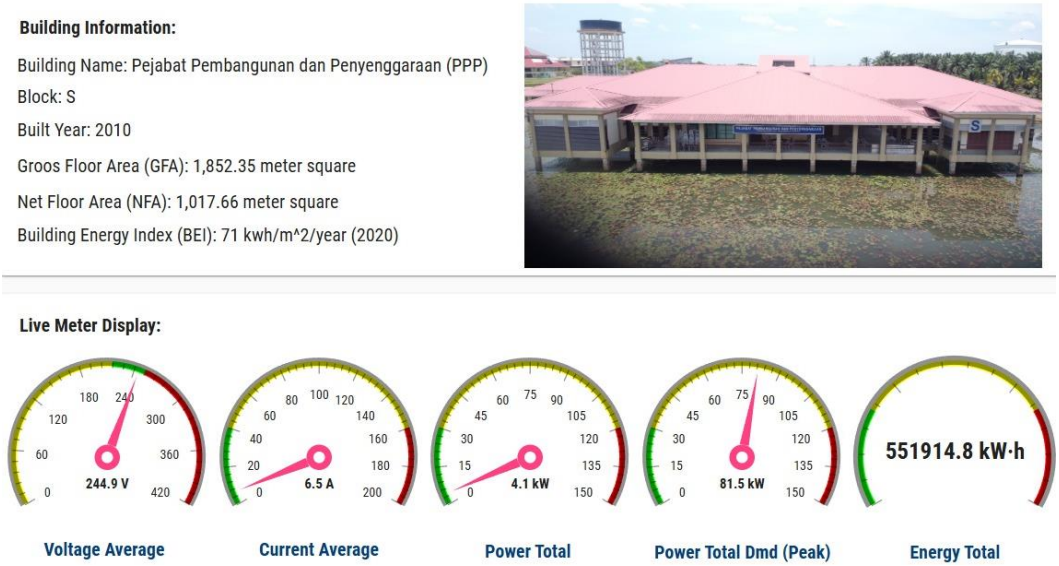

Fig 3: Energy Scada Interface

3.2 Walkthrough Audit

The audit is the Level 2 process energy audit based on MS1525:2019[6] .The process of and analyzing the office's section of the building. The walkthrough-audit focus in data collection, system identification, and performance assessment. Its cover on lighting system, mechanical ventilation and air-conditioning (MVAC) system, and lighting illuminance system. It covers the types, power-rating, hours of operating, and it energy consumption for each system.

Lighting is one of the biggest contributions to electricity usage in most office buildings, including the PPP complex. A decent lighting system is crucial because it impacts worker comfort, visibility, and energy usage. In commercial buildings, lighting usually accounts for a large percentage of overall electricity consumption, particularly when inefficient fixtures are installed. To calculate their overall energy contribution, the types of illumination, wattage, and operating hours were determined in the study. Many Malaysian buildings still employ antiquated lighting technologies, which use more energy than contemporary LED systems, according to earlier studies [7].

The MVAC system is one of the biggest energy-consuming system in non-residential buildings. The system can contribute up to 40–60% of the total electricity usage in Malaysian office and university buildings. This indicates the importance of analyzing the air-conditioning units in the PPP building to identify inefficiencies in use or operation schedules. The analysis included identifying the types of air-conditioning units, their rated capacity, and operating hours. Air conditioning energy savings are strongly influenced by equipment efficiency, temperature control, and occupant behavior [8]. The evaluation method used in this study follows the principles of emphasize proper inspection and performance assessment of the systems to ensure acceptable indoor comfort at the lowest energy cost [9].

The BEI for the PPP building is determined by dividing its annual energy consumption by its total floor area. This gives the energy used per square meter per year. The formula for BEI is presented below:

$$BEI = \frac{Total\ energy\ consumption\ in\ a\ ear, kWh}{Total\ gross\ floor\ area, m^2} \quad [1]$$

4. Results and Discussion

There are two focuses on the results which are energy consumption and major energy inefficiencies. These focuses were selected based on the data we can understand pattern of the energy. The overview taking place from JAN 24 until DEC 2024. As of that, the electric cost of the PPP building can be identified and analyses. By understanding the energy pattens especially on energy consumption, BEI can be calculated and identified. The study also, touch the lighting system and MVAC system as its both can be classified as major energy usage at PPP building.

4.1 Energy Consumption

The energy usage of PPP buildings in 2024 is displayed in Figure 4. The measurements and data were taken between January and December of 2024. A bar chart illustrating the trends is shown in Figure 4. The amount of energy used in 2024 is around 137,456 kWh. The average annual energy usage is 11,454.70 kWh. In summary, the PPP building uses between 10,000 and 15,000 kWh of energy on average to run.

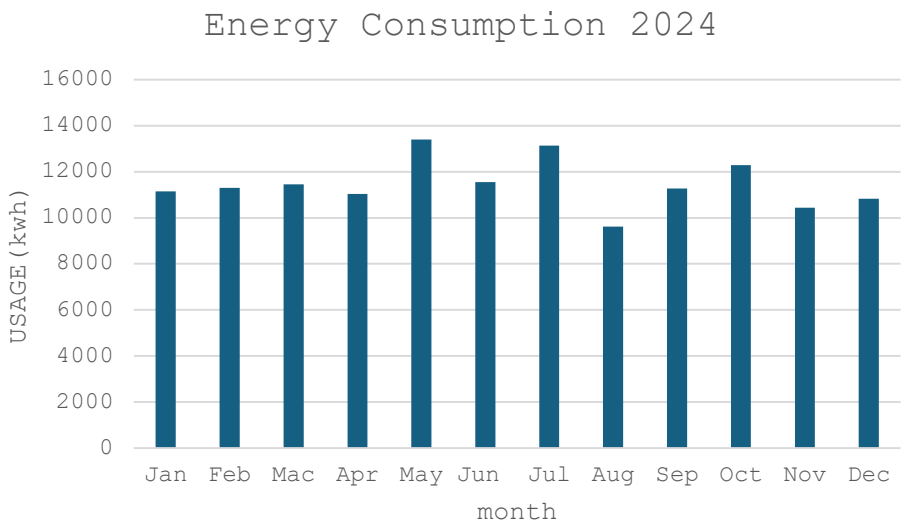

Fig. 4 Energy Consumption

According to Jabatan Metreologi Malaysia, May and July had the highest energy use due to hot weather and heatwaves [10] .Due to the Northeast Monsoon season, the energy usage at the end of the year is less than 11,000 kWh. the time of year when it rains a lot, particularly in Johor. "The first phase of the Northeast Monsoon, which runs from November to December 2024, is expected to bring heavy rain events to Kelantan, Terengganu, Pahang, Johor, Sarawak, and Sabah [11].

4.2 Electricity Cost

The Figure 5 shows the PPP building's yearly electricity consumption in 2024. The largest charge is RM 4571.77 in May. In August, the lowest electricity bill was RM 3455.76. Nonetheless, the typical cost of power is between RM 3,000 and RM 5,000. Due to variables including weather variations and cycles of appliance use, the overall connection between demand and consumption is non-linear over extended periods of time [12] .Because they can capture the complex, real-world variations in power demand that linear models cannot, they provide more accuracy.

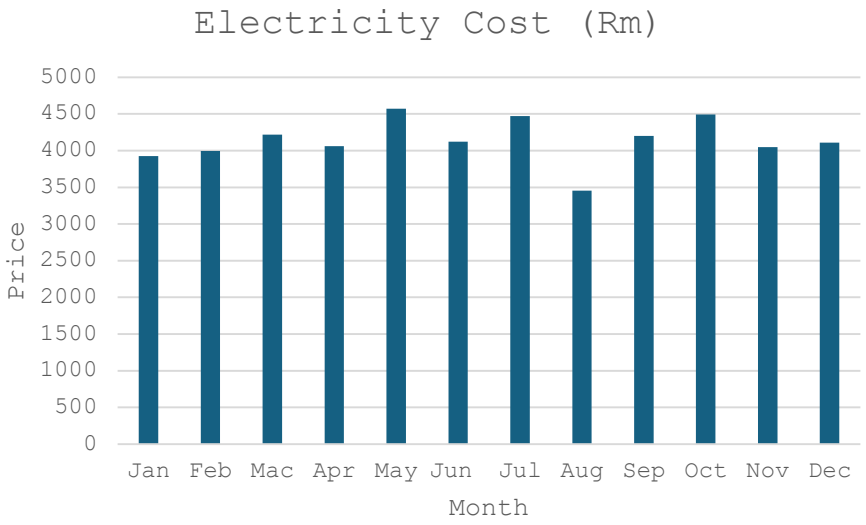

Fig 5. Electricity Cost

4.3 Illuminance Analysis

The majority of the PPP building's spaces do not reach the lux levels required by the MS1525:2019 requirements, according to an analysis of illumination in the meeting room, left wing, and right wing. The result for illuminance analysis for the left wing, right wing, hallway, and meeting room presents in the table 4.1 below. The results indicated that office rooms at left wing exhibited low lux levels, which could potentially impact the health of the occupants. On the right wing, the only section that adhere standard is only at pantry. The result on the hallway and meeting rooms shows most of the area does not the minimum standard.

Table 4.1: Illuminance Analysis

Area	MS1525:2019 Level	Measured Level	Standard Remark
General Office	300-400	Under	Not Suitable for office work
Meeting Rooms	300-400	Under	Not Suitable for work
Rooms	300-400	Under	Not Suitable for office work
Pantry Area	150-300	Adhere	Suitable for occupant comfortability
Corridors	100	Adhere	Suitable for occupant comfortability

4.4 Identification Of Major Energy-Consuming Areas

According to figure 6 below, the mechanical ventilation and air-conditioning system accounts for 77.40% of the PPP building's total energy consumption from the total average of 11,454.70 kWh. This suggests that the main causes of electricity use are ventilation and cooling, which is common for office buildings in Malaysia's tropical environment[13]. Approximately 6.21% of the energy used is contributed by the lighting system[14]. This

comparatively low proportion indicates that the PPP building's lighting system is typically energy-efficient, either as a result of its short operating hours or use of LED lighting. Computers, printers, photocopiers, networking devices, and pantry equipment are examples of office equipment that provide roughly 16.39%.

$$\boldsymbol{MVAC} = \frac{\mathbf{8,867.66\ kWh}}{\mathbf{11,454.70kWh}} \times \mathbf{100}$$

$$= \mathbf{77.40\%}$$

$$\boldsymbol{Light} = \frac{\mathbf{711.33\ kWh}}{\mathbf{11,454.70kWh}} \times \mathbf{100}$$

$$= \mathbf{6.21\%}$$

$$\boldsymbol{Others} = \frac{\mathbf{1,875.71\ kWh}}{\mathbf{11,454.70kWh}} \times \mathbf{100}$$

$$= \mathbf{16.39\%}$$

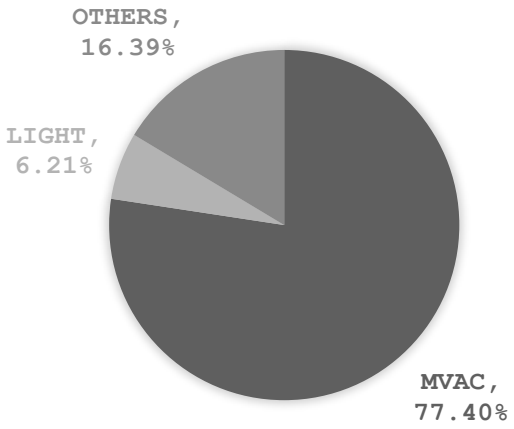

Fig.6 Energy Consumption Areas

4.5 Building Energy Index (BEI)

In 2024, the total energy consumption was 137456.39 kWh, with a gross area of 1,852.35 square meters.

$$PPP\ building\ BEI\ 2024 = \frac{Total\ energy\ consumption\ in\ a\ year, kWh}{Total\ gross\ floor\ area, m^2}$$

$$PPP\ building\ BEI\ 2024 = \frac{137{,}456.39}{1{,}852.35}$$

$$= 74.20 \frac{kWh}{m^2}/year$$

According to MS1525:2019 published by the Energy Commission of Malaysia, the recommended benchmark value for the Building Energy index (BEI) of non-residential building is 135 kWh/m^2/ year. The calculation indicates that the BEI value of the PPP building in 2024 was 74.20 kWh/m^2/year. These values fall short of the Energy Commission's criterion, which met the suggested value.

5. Conclusion

Using the ENERGY SCADA system and walkthrough evaluations, this study successfully carried out a Level 2 energy audit of the Pejabat Pembangunan dan Penyenggaraan (PPP) building at UTHM. According to the analysis, the building used about 137,456 kWh of energy in 2024, with an average of 11,454.70 kWh each month. Due to increasing cooling demands, the hot months of May and July had the highest energy consumption, while the Northeast Monsoon season at the end of the year saw the lowest. According to the audit, the building's energy demand is mostly caused by the HVAC and lighting systems. Based on the calculated BEI, the result of the PPP building achieves goal of Suruhanjaya Tenaga Malaysia as in under 135 kWh/m^2/year. The value of the BEI of PP building is 74.20 kWh/m^2/year. However, improvement can be done by change all the non-LED to fully LED light which will lower the energy demand. The change can help to reduce the energy consumption to 685.44 kWh/year. Additionally, awareness among the staff of PPP also should implement, as during conducted audit, the air-conditioner, electronic appliance, and light system keep on running while not in use. The cost of the approach can help to save Rm 1,084.53 This can cause the effect of wastage of energy. The wastage is not aligned with the UTHM energy goals, as its aim to become Sustainable Energy Management System and serve EMGS goal. Ultimately, the results serve as a guide for future audits to reduce operational expenses and improve environmental sustainability.

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Conflict of Interest

The authors affirm that they have no conflicts of interest with regard to the paper's publication.

Author Contribution

The authors confirm contribution to the paper as follows: study conception and design: Ikhwan Hanif Bin Mohd Asri, Ramhuzaini bin ABD Rahman; data collection: Ikhwan Hanif Bin Mohd Asri; analysis and interpretation of results: Ikhwan Hanif Bin Mohd Asri; draft manuscript preparation: Ikhwan Hanif Bin Mohd Asri, Ramhuzaini bin ABD Rahman. All authors reviewed the results and approved the final version of the manuscript.

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