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Detailed Energy Audit and Energy Conservation Measures for a Goverment Primary Schools

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Energy efficiency in government primary schools is significantly important in supporting national sustainable development and reducing energy consumption. This paper presents a detailed energy audit conducted at Sekolah Kebangsaan Seri Binjai, Tongkang Pechah, Johor aims to evaluate energy performance, analysis the load apportioning and identify inefficiency .This study began with a preliminary audit assessment to assess energy usage and possibilities for the Energy Conservation Measures (ECM) in the school building. Next, a detailed energy audit that involved several processes was carried out in the school building, including collecting desktop and field data, analyzing energy performance, and identifying the breakdown of the energy usage and inefficiency within the school building. The finding reveals that Sekolah Kebangsaan Seri Binjai had varied energy utilization throughout 2024, which indicates that the school's academic calendar significantly influences school energy consumption. Moreover, the Building Energy Index (BEI) for Sekolah Kebangsaan Seri Binjai is 5.83 kWh/m²/year, indicating a lower level of energy performance compared to the MS5215:2019 standard. This finding also revealed that mechanical ventilation systems, particularly fans, are the biggest contributors to energy usage in the school building, followed by the lighting system, accounting for between 57% and 43% of total energy consumption in the school. Therefore, several Energy Conservation Measures (ECMs) are proposed that include LED retrofitting, optimization of fan operation, and energy awareness practices. This study has demonstrated that a detailed energy audit can effectively identify inefficiencies, optimizing the energy usage and supporting sustainable energy management in primary school buildings..

Keywords: Detailed Energy Audit, Energy Conservation Measures, Primary School, Energy Profile

1. INTRODUCTION

Currently, energy consumption in building sectors has become a critical global concern due to its significant contribution to overall energy demands and greenhouse gas emissions. In Malaysia, building sector accounts almost 40% of the total national energy consumption, making it among the largest energy users when comparing to industrial and transportation sectors [1]-[2]. As the urban areas expand rapily and increasing in the population grow causes rising in expectations for indoor comfort that increasing the energy demands in the buildings. This trend not only pressures present energy

resources, but also emphasizes the importance of developing efficient energy efficiency strategies to assist fulfill sustainable development goals and reduce environmental consequences [3]-[6].

Within the building sector, educational building represent an important category of public building that contribute to the national energy consumption. Government primary schools (Sekolah kebangsaan) building refers to a publicly funded educational building managed by the Ministry of Education (KPM), providing formal primary-level education to children and operating under the national curriculum with high occupancy levels. Government Primary School among the public sectors buildings represent the slightly portion of national electricity consumpotion eventhrough not classified as high-energy consumer compared to others building sectors [7]. It prolong operating hours, larger number of occupancy and various functional space contribure to the energy demand in the building sectors. In addition, Malaysia's tropical climate characterised by high temperature and humidity that playing the significant role in increasing the energy consumption causes from the excessive use of mechanical and electrical systems.

Despite their relevance, energy efficiency studies in educational buildings have predominantly focused on higher education institutions, while primary school buildings have received comparatively limited attention [8] . This gap is particularly concerning given that many government primary schools in Malaysia are ageing infrastructures that were not originally designed with energy-efficient features or modern building standards. As a result, these buildings often rely on outdated electrical systems, inefficient lighting technologies, and manual operational practices, which contribute to unnecessary energy wastage. Furthermore, the absence of systematic energy monitoring and auditing practices in many schools restricts the ability to accurately evaluate energy performance and implement data-driven improvements.

Previous studies have indicated that lighting systems account for approximately 25-35% of total building energy consumption highlighting it impact on overall energy performance[9]. The combined usage of mechanical ventilation systems and lights in school buildings increases the demand for energy during operating hours. However, without in-depth analysis of energy consumption patterns and load distribution, it is difficult to identify inefficiencies and making effective energy-saving solutions. Therefore, a comprehensive of energy consumption patterns in school building is important for enhancing energy efficiency and minimizing operational costs.

Energy auditing is a fundamental tool for assessing a building's energy use and identifying opportunities for enhanced efficiency. A detailed energy audit involves the systematic collection and analysis of energy data, including utility bills, on-site measurements, and equipment performance evaluation. This approach enables the identification of major energy-consuming systems, the analysis of load profiles, and the development of targeted Energy Conservation Measures (ECMs)[10-15]. Despite the significance of detailed energy audits, it application on the primary school building remains limited since the data-driven energy management practices are still evolving.

Therefore, this study aims to address the existing research gap by conducting a detailed energy audit in Sekolah Kebangsaan Seri Binjai, Johor. The objectives of this study are to evaluate the school's energy performance, analyse the breakdown of energy in the school system, identify key sources of energy inefficiency, and propose suitable Energy Conservation Measures (ECMs) to improve energy efficiency. This study enhances existing knowledge by providing a comprehensive assessment of a representative government primary school. It also provides valuable recommendations for enhancing energy management in educational buildings. The findings of this study are expected to enhance national efforts toward sustainable energy use and provide a reference for future studies on energy efficiency in primary school buildings.

2. MATERIAL AND METHODS

A detailed energy audit conducted at Sekolah Kebangsaan Seri Binjai involved several processes, including walkthrough audits, data collection through both desktop and field methods, analysis of energy consumption patterns, identification of the breakdown of energy usage within the school building, and calculation of the Building Energy Index (BEI) for the school builsing. The findings of this study will assist in developing strategies to enhance energy efficiency and optimize energy usage. By implementing these strategies, Sekolah Kebangsaan Seri Binjai could move toward a more sustainable future.

2.1. Building Description

Sekolah Kebangsaan Seri Binjai, located in Tongkang Pechah, Johor, has been selected as a representative model of a Malaysian government primary school. This primary school consists of classroom blocks, administrative offices, labs, and

other educational facilities, as illustrated in Figure 1. The total gross floor area (GFA) of Sekolah Kebangsaan Seri Binjai is 4,074.91 m², which excludes parking and open spaces in the school areas. This GFA is important in obtaining the BEI for energy efficiency performance in schools, as it provides a basis for evaluating the energy consumption relative to the size of the educational facilities.

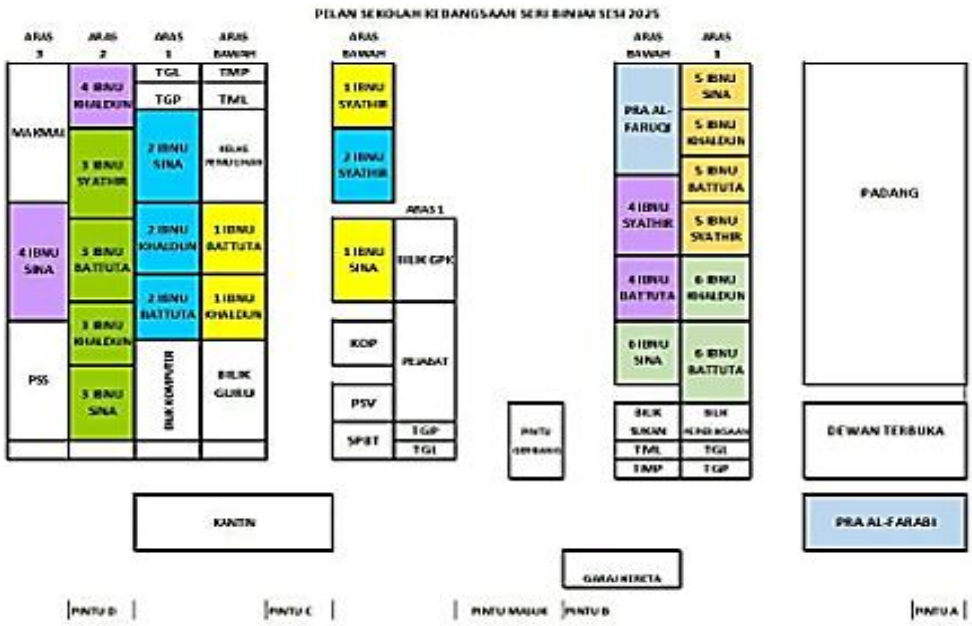

Figure 1. Building Layout of Sekolah Kebangsaan Seri Binjai

2.2. Data Collection

Desktop and field data collection are two distinct approaches used to gather energy audit data for Sekolah Kebangsaan Seri Binjai. Desktop data collection aims to minimize the need for field data collection by compiling all available building information, including electricity bills, building layouts, and specifications for mechanical and electrical (M&E) equipment. In contrast, field data collection serves to verify and cross-check the data obtained from desktop sources. This method is essential for understanding the school's operations and identifying areas of energy inefficiency within the building. In this study, field data collection includes a walkthrough audit for on-site inspections and power logging activities, which provide the physical measurements necessary to develop the school's energy profile.

2.2.1. Data Collection Equipment

The scope of work in obtaining the field data collection requires several measurement and monitoring devices to obtain the accurate data for the energy analysis. Table 1 represents the list of equipment used in this study for field data collection.

Table 1. Equipment Used in Data Collection

NO	Equipment Used	Description	Diagram

1	3-Phases Power Logger	Used to perform power logging for measuring the school load profile. Units: kWh	
2	Digital Lux Meter	To measure lighting lux level in every room and space of the school building. Units : Lux (lx)	

2.3. Analysis of Energy Profile & Load Apportioning

The energy usage pattern in Sekolah Kebangsaan Seri Binjai can be analyzed using desktop and field data collection. This analysis helps identify the breakdown of energy usage within the school building and enables the determination of the school energy profile. Below is the process used to obtain the annual and daily energy profile for Sekolah Kebangsaan Seri Binjai.

2.3.1. Annual & Monthly Energy Profile

The annual energy profile for Sekolah Kebangsaan Seri Binjai was derived from 12 months of energy consumption data obtained from the Tenaga Nasional Berhad (TNB) utility bills. This study focused on analyzing the school's energy consumption data for 2024. The analysis of this annual energy profile provides valuable information for Sekolah Kebangsaan Seri Binjai, enabling the school to monitor and track energy usage patterns within its buildings.

2.3.2. Daily Energy Profile

The daily energy profile in Sekolah Kebangsaan Seri Binjai can be determined using the power logger activity. This power logger activity involves capturing energy data at one-hour intervals over 24 hours, from 12 am until 11 pm on the same days, in order to monitor and establish the daily energy usage pattern within the school buildings.

2.4. Building Energy Index

The energy efficiency performance of the Sekolah Kebangsaan Seri Binjai is evaluated using the Building Energy Index (BEI) equation and compared with the MS1525:2019 BEI standards to indicate the energy efficiency performance of the Sekolah Kebangsaan Seri Binjai [16]. The BEI analysis for the Sekolah Kebangsaan Seri Binjai is computed using kWh/m²/year. This involves the annual energy consumption and the gross floor area of the school building [17-27]. This

calculation was then performed using Microsoft Excel. The equation of the building energy index is represented as follows:

$$BEI = \frac{Annual\ Energy\ Consumption\ (^{kWh}/_{Year})}{Gross\ Floor\ Area\ (m^2)} \quad \textbf{Equation 1}$$

3. RESULTS & DISCUSSION

This section presents the findings obtained from the detailed energy audit conducted at Sekolah Kebangsaan Seri Binjai. The analysis aims to provide a clear understanding of the school's energy consumption patterns, the breakdown of energy usage in the school building, and overall energy performance. This analysis identifies the energy inefficiencies present in the school building and subsequently proposes energy conservation measures (ECMs) for implementation.

3.1. School Energy Profiling

This subsection present the annual, monthly and daily energy usage patterns that occur in the Sekolah Kebangsaan Seri Binjai in analysis the building energy performance. By understanding these patterns, it is importance to identify the major energy usage within the school building and identify the potential areas for energy efficiency improvement in the future.

3.1.1. Annual Energy Profiling

The TNB utility bills were used to evaluate the annual energy consumption of Sekolah Kebangsaan Seri Binjai for the year 2024, as shown in Table 2. The analysis reveals significant fluctuations in energy usage levels, which vary by season and are closely linked to the school calendar and occupancy rates. This volatility highlights the significant dependency of energy demand on school schedules, including teaching hours, vacations, and breaks.

The total energy consumption used was equal to 25,892 kWh in a year, with the highest consumption of electricity in November (2,634 kWh) and then in June (2,585 kWh) and January (2,583 kWh). These months encompass the period of full academic engagement, during which the school operated at maximum capacity, featuring around 22 active school days. Heavy use of lighting systems, ceiling fans, administrative equipment, and other electrical-related devices during these periods raised the need for energy. On the other hand, a significant reduction in energy usage was noted in February (1,564 kWh) and March (546 kWh). The decline in February can be attributed to the conclusion of the Johor school's academic term on 9 February 2024, followed by a school holiday. During this month, the majority of the electricity was allocated to support base load demand, including security lighting and essential equipment. The minimum energy use occurred in March, when the school remained closed until March 9, 2024, with the school still using the energy for base load demand. The level of energy usage in April (1,827 kWh) was lower than average due to the Hari Raya Aidilfitri holiday that also shortened days of operation. In May, June, July, August, and September exhibited very stable consumption between 2,324 kWh and 2,393 kWh, indicating normal academic operations with slight interruptions. However, there was a small decline in September that was associated with the holiday at the mid-term. Energy usage decreased in December (2,153 kWh) as the school break of Term 3 in the KPM academic calendar resulted in a decline of occupancy rates.

Overall. The finding indicates a strong relationship between the usage of energy and school occupancy. During full academic activity, the energy consumption is always at its peak, whereas when it is on holidays and during festivities, the demand for electricity decreases considerably. This tendency emphasizes the relevance of the occupancy-based analysis in energy audits and identifies the potential to take specific measures related to energy saving during both the operational and non-operational periods.

Table 2. Sekolah Kebangsaan Seri Binjai Energy Consumption Year 2024

Month	Energy Consumption (kWh)	KPM Academic Calender (Johor)

January	2,583	End of 2023/24 Session
February	1,564	Cuti Akhir Persekolahan (Starts Feb 9)
March	546	Holiday (Until Mar 9) & Ramadan Start
April	1,827	Aidilfitri Break
May	2,378	Full Academic Month
June	2,585	Full Academic Month
July	2,393	Full Academic Month
August	2,378	Full Academic Month
September	2,324	Term 2 Holiday (Mid Month)
October	2,527	Full Academic Month
November	2,634	Full Academic Month
December	2,153	Term 3 Break (Starts Dec 21)
Total	**25,892**	-

3.1.2. Monthly Energy profiling

Figure 2 illustrates the monthly energy profile of Sekolah kebangsaan Seri Binjai for the year 2024. The illustrations trend clearly shows how energy use varies by month, with peaks occurring during the whole academic year and declines occurring during school breaks. The decline observed in March is particularly significant, given it aligned with the extended school closures and a reduction in activity levels. Conversely, consistent elevated consumption from May to November indicates stable operating demand. This graphical representation illustrates the correlation between occupancy patterns and usage of electricity, establishing a solid basis for further energy operation evaluation and optimization strategies.

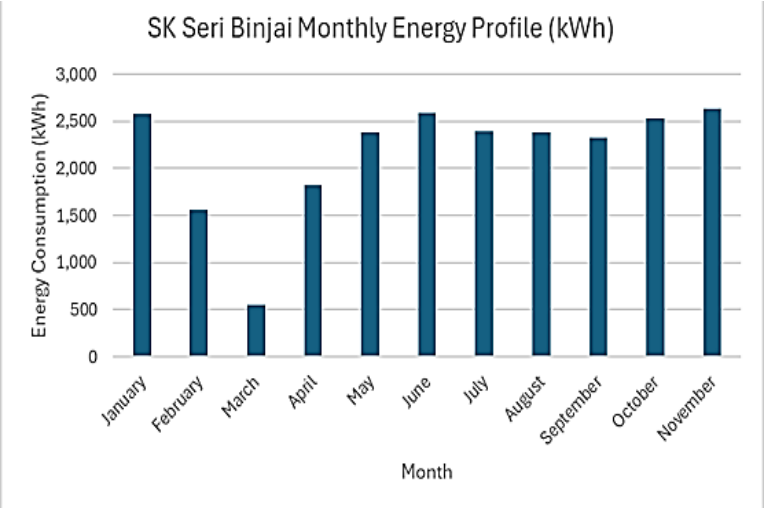

Figure 2. Monthly Energy Profile

3.1.3. Daily Energy Profilling

The load profile analysis shows how Sekolah Kebangsaan Seri Binjai uses energy on a normal day of operation. By analyzing the change of the electrical demand with time, the school's peak load and base load condition, and the school's operational behavior towards the use of energy, the overall school energy performance can be easily identified. This study is important in understanding how energy is consumed during different times of the day and identifying potential inefficiencies in the school operation.

Figure 3 illustrated the daily load profile of Sekolah kebangsaan Seri Binjai, highlighting the variation of energy demand throughout a typical day. The daily peak load during academic activity is recorded between 8:30am and 11:30am, when the classroom, administrative offices, and intensive use of laboratories are fully occupied. During this period, the use of lighting, ceiling fans, and air-conditioning is fully utilized as the temperature outdoors continues to rise and stabilize until evening. In contrast, the base load period primarily occurs at night, indicating less use of energy due to less school activity. The energy needed during this period is usually for security lights, a standby system, and other operations that function beyond school hours. Overall, this daily load profile indicates higher usage of energy consumption during the day due to teaching sessions and slowly decreases after the end of the school activities.

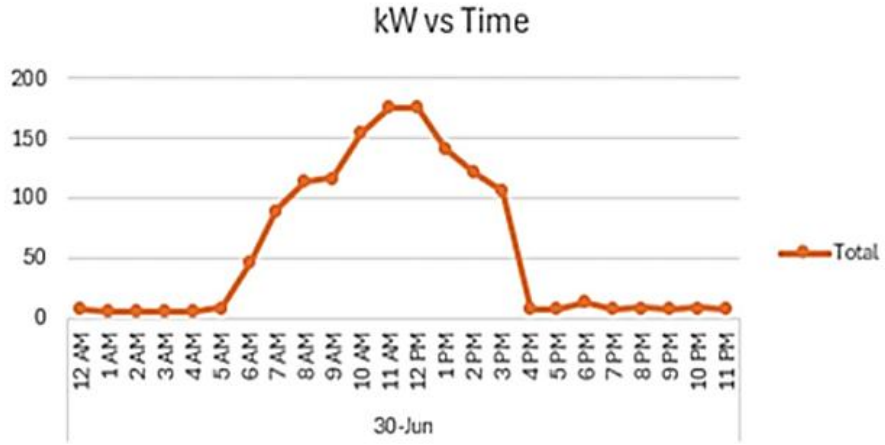

Figure 3. Daily Energy Profile

3.2. Building Energy Index

The Building Energy Index (BEI) is used to evaluate the overall school's energy performance by dividing the annual energy consumption against the total gross floor area based on Equation 1. In this study, the total annual energy consumption of the building is 23,739 kWh, while the total building floor area is 4,074.91 m². Figure 4 indicate the calculation of BEI for Sekolah Kebangsaan Seri Binjai.

$$BEI = \frac{25{,}892\ (\frac{kWh}{year})}{4{,}074.91\ (m^2)}$$

$$BEI = 5.83\ \text{kWh}/m^2/\text{year}$$

Figure 4. BEI Calculation

Based on Figure 4, the Building Energy Index (BEI) for Sekolah Kebangsaan Seri Binjai is approximately 5.83 kWh/m²/year, indicating a very low level of energy consumption compared to the MS5215:2019 standard of 200 kWh/m²/year. This finding is consistent with the characteristics of a typical primary school building, where the primary energy demands are limited to lighting and ceiling fans, with minimal reliance on high-energy systems like air conditioning. Consequently, the total energy demand is relatively low compared to other building types that consume more energy.

However, a lower BEI (Building Energy Index) rating does not necessarily equate to optimal energy efficiency. The energy consumption study reveals that lighting and fan systems account for the majority of electricity usage, suggesting that there is still room for improvement. Implementing energy conservation measures, such as replacing old fluorescent lights with LED lighting, optimizing fan operating schedules, and educating users about energy-efficient practices, can

further enhance energy utilization. Therefore, the BEI can act as a valuable performance metric for assessing the impact of energy-saving initiatives in other areas.

3.3. Load Apportioning

This sub section describes the finding and analysis of building load apportioning for Sekolah kebangsaan Seri Binjai. The load consumptions of major electrical and mechanical system are being measured to understand the load distribution and profile of Sekolah Kebangsaan Seri Binjai operation. The major system measured in the Sekolah Kebangsaan Seri Binjai include lighting system and ACMV system. Figure 5 provided a detailed breakdown of the energy usage by categories that derived from the school equipment inventory.

Equipment Description	Quantity (Unit)	Rated Power (W)	Energy Consumption (kWh/day)
Lighting System			
Fluorescent Bare Channel 1XT8 2 feet	131	36	4.716
Fluorescent Bare Channel	33	18	0.594
ACMV System			
Panasonic 60" 3 Blade Ceiling Fan	92	72	6.624
Panasonic F MU408 Wall Fan 16"	9	54	0.486
Total Consumption Perday		12.42 kWh/day	

Figure 5. Distribution of Daily Electrical Energy Consumption by Equipment

Figure 6 illustrates that the total daily energy use amounts to 12.24 kWh/day, encompassing the energy consumption of two primary systems in Sekolah Kebangsaan Seri Binjai. The ACMV system, primarily responsible for fan consumption, accounts for approximately 57% of the total daily energy usage, while the lighting system contributes around 43%. The large number of continuously running fans during school hours and the significant demand for lighting across classrooms account for this disparity. Consequently, the findings indicate that energy-saving measures should focus on both systems to enhance the school's energy efficiency and optimize energy use within the building.

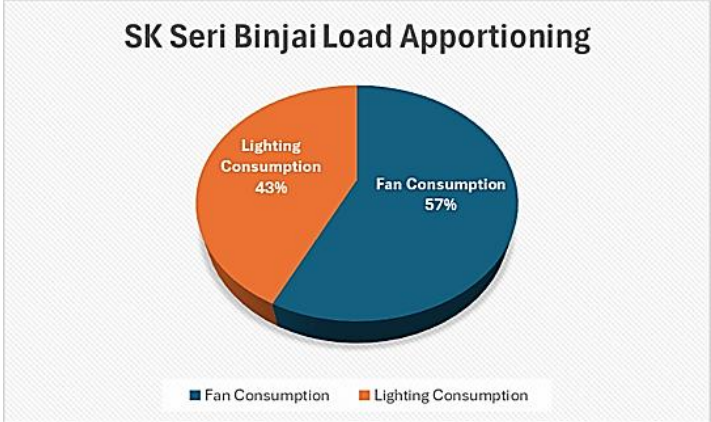

Figure 6. Daily Sekolah Kebangsaan Seri Binjai Load Apportioning

3.4. Energy Conservation Measures Implementation

This detailed energy audit studies has identified and purpose several energy conservation measured (ECM) to be implemented in the Sekolah Kebangsaan Sri Binjai. There are 3 energy conservation measures recommendation that can be implement in the school building. Under this sub-section, the recommendation of energy conservation measures (ECM) implementation into the occupancy behaviour and replacement to energy efficiency appliances and operations.

3.4.1. ECM 1 – Adopting Energy Efficient Behaviour

Under ECM 1, the recommendation that can be applied in the school buildings is to encourage students and staff to adopt energy-efficient behaviors in daily activity. This recommendation encourages the occupants to switch off electrical appliances such as lighting, fans, air conditioning, or other appliances when leaving a room. Advise occupants to always unplug chargers and electronics when not in use due to these electrical appliances still consuming energy even when turned off. Moreover, encourage teachers and school staff to shut down the laptops and monitors when not in use.

Besides that, electrical equipment such as fans that are not regularly cleaned and maintained can cause energy consumption to be higher due to the dust and dirt sticking to the surface of the equipment. An unclean fan can reduce the efficiency of the fan motor and degrade indoor air quality in the building. Therefore, regular cleaning and maintenance are needed for optimal performance of the electrical equipment. Rooms that are using the air-conditioning need to keep the temperature range in between 24 and 26°C to help reduce the need for the air conditioner to work harder to maintain the desired temperature. Such practices can lead to lower energy consumption and optimized energy use in the school building. Moreover, the temperature range of 24–26°C is suitable for general comfort in the room, as it is neither too cold nor too hot for the human body. By implementing this recommendation in the school building, energy usage can be optimized, which will contribute to improving the school's energy efficiency.

3.4.2. ECM 2 – Replacement to LED Lamps

Currently, the lighting system used in the Sekolah Kebangsaan Seri Binjai is T8 fluorescent lamps, which are relatively inefficient compared to modern LED lighting. Although most of the school spaces are equipped with up to six fluorescent lamps, measured illuminance levels remain below the standard requirement of 300–500 lux. This condition indicates lumen depreciation, poor fixture efficiency, and high power consumption for the school occupant, leading to an uncomfortable condition.

Under ECM 2, the recommendation that can be applied in the school building is to replace the fluorescent lamps with LED lamps. This can help in improving the school's energy efficiency due to the LED-type lamps consuming less power compared to the fluorescent lamps. Besides that, the LED-type lamps had a longer lifespan compared to the fluorescent lamps, which helps in reducing the replacement and maintenance costs. LEDs also provide higher luminosity that is suitable for school occupants to read, study, and do work. Figure 6 presents a comparison of the existing fluorescent-type lighting with the proposed LED-type lighting.

Fluorescent Types

Lighting Type	Units	Rated Power / Units (W)	Total Existing Power (W)
4ft T8 Fluorescent	131	58	7598
2ft T8 Fluorescent	33	18	594
Total		8192 W	

LED Types

Lighting Type	Units	Rated Power / Units (W)	Total New Power (W)
4ft T8 LED	131	22	2882
2ft T8 LED	33	8	264
Total	3146 W		

Figure 6. Comparison Between Fluorescent and LED Types

3.4.3. ECM 3- Energy Efficient Ceiling on Fan Operation

Ceiling fans are another major electricity-consuming component in the school. The audit identified 92 units of Panasonic 60-inch 3-blade ceiling fans installed across classrooms and offices. These fans consume significantly different power levels depending on their operating speed as shown in figure 7.

Figure 7. Ceiling fan Power Consumption

The results indicate that operating fans at high speed significantly increases power consumption—more than four times that of low-speed operation. To achieve energy savings, it is advisable to promote the use of fans at low to medium speeds during regular classroom activities. Additionally, awareness programs for teachers and students can help educate them on optimal fan usage, such as the benefits of using low to medium speeds to reduce energy consumption during regular classroom activities. Implementing this ECM 3 can enhance the school's energy efficiency and align with sustainable goals by ensuring more effective energy use.

4. CONCLUSIONS

In summary, this research effectively carried out a thorough energy audit of Sekolah Kebangsaan Seri Binjai, Tongkang Pechah, Johor, to assess the building's electrical energy performance and pinpoint significant inefficiencies. The audit was carried out in compliance with Malaysian Standard MS 1525:2019, encompassing a twelve-month analysis of electrical billing, walkthrough inspections, on-site measurements, and a comprehensive review of energy performance. The findings reveal that the academic calendar significantly influences energy consumption at the school, with increased demand during entire operational periods. Moreover, this audit determined that the Building Energy Index (BEI) for Sekolah Kebangsaan Seri Binjai is 5.83 kWh/m²/year for the year 2024, indicating a very low level of energy consumption compared to the MS5215:2019 standard.

The analysis further indicated that mechanical ventilation systems, especially fans, are the primary contributors of energy usage in the school building, followed by the lighting system, representing around 57% and 43% of the overall energy consumption in the school. These findings highlight the significant impact of the operational equipment on overall energy demand within the school environment. Therefore, several Energy Conservation Measures (ECMs) were proposed that include the replacement of conventional fluorescent lamps with energy-efficient LED lighting, optimization of ceiling fan operation, and the promotion of energy awareness among school occupants. Overall, this study demonstrates that a systematic energy audit effectively identifies inefficiencies, reduces operating costs, and enhances sustainable energy management in primary school buildings. Additionally, the findings serve as a practical reference and baseline for future energy efficiency improvements in similar educational facilities. For future work, it is recommended that comprehensive energy monitoring be conducted over extended periods using advanced monitoring systems, such as real-time energy management systems (EMS). This approach would facilitate a more detailed analysis of energy consumption patterns and enable a more effective identification of inefficiencies, especially during varying seasonal and occupancy conditions.

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