Performance Study and Optimization of Energy Efficiency in a Mosque: Opportunities for Conservation and Cost Reduction

Syahrunizam
Nor Azura
Polytechnic Kota Kinabalu, Sabah Malaysia

Fauzi
Polytechnic Sultan Azlan Shah, Perak Malaysia

Abstract

This study introduces an optimization investigation utilizing Response Surface Methodology (RSM) to enhance the adsorption capacity of methylene blue (MB) from wastewater generated by the coating industry. The adsorbent of interest in this research is sugarcane bagasse biochar, recognized for its potential in wastewater treatment due to its abundant availability and favourable adsorption characteristics. A Box-Behnken was used to design the experimental matrix, considering factors such as initial dilution factor (3.2 - 20 %), temperature (25 – 40 °C), and contact time (1 – 20 hours). Through the execution of the designed experiments, a predictive model was developed to correlate the significant factors and their interactions with MB removal. Furthermore, the physicochemical properties of the produced biochar were investigated through several characterization techniques. The optimization process yielded the following optimum conditions for the adsorption process: a dilution factor of 16.27%, a temperature of 40°C, and a contact time of 1 hour. An in-depth exploration of the physicochemical properties of the produced biochar was conducted, with insights into the functional groups responsible for MB adsorption provided through Fourier Transform Infrared Spectroscopy (FTIR) analysis. Additionally, Scanning Electron Microscopy (SEM) was employed to examine the surface morphology and potential binding sites on the biochar, while particle size analysis assessed the difference in particle size before and after pyrolysis of sugarcane bagasse. The results of this study contribute to the understanding of optimizing sugarcane bagasse biochar for effective removal of methylene blue from coating industry wastewater. The application of RSM allowed the determination of optimal conditions that enhance adsorption efficiency, while the characterization techniques (FTIR, SEM, and particle size analysis) reveal the properties that guide the adsorption process. This research underscores the potential of utilizing agricultural waste-derived biochar as a sustainable and efficient adsorbent for the treatment of industrial wastewater contaminated with dye pollutants.

Keywords: *energy management, energy audit, greenhouse Co2*

INTRODUCTION

Taking inspiration from the United Nations' 2030 Agenda for Sustainable Development, there is a growing initiative to promote the adoption of holistic approaches in greening Houses of Worship. This initiative encourages these sacred spaces to prioritize energy efficiency within their buildings and explore sustainable energy sources such as solar power. By doing so, not only do these Houses of Worship contribute to the well-being of their communities but also extend their positive impact on the surrounding neighborhoods (Anonymous, Guidelines on Green Houses of Worships United Nation Environment Program, 2020). The rise in global CO2 emissions is projected to reach a staggering 50 percent by 2030 without a comprehensive global agreement to limit emissions (Hong, 2007). In alignment with the Malaysian government's commitment to reducing carbon emissions, several implementation strategies have been introduced to realize this vision. By Article 4, paragraph 12 of the Paris Agreement, Malaysia Nationally Determined Contributions (NDC), Malaysia increased its mitigation ambition with an unconditional target to cut carbon intensity against GDP by 45% by 2030 compared to 2005 levels. (Anonymous, Climate Promise United Nation Determined Contributions, 2021). By prioritizing energy efficiency and adopting sustainable practices such as utilizing efficient equipment and incorporating solar energy, green Houses of Worship can actively engage in eco-friendly worship practices. They can go beyond just constructing environmentally conscious buildings and serve as centers for promoting sustainable lifestyles and teachings within their communities. This holistic approach not only aligns with the principles of eco-consciousness but also empowers religious sites to play a significant role in inspiring and fostering sustainable practices among their worshippers and the wider society.

The researcher conducted a meeting with the management of the Pilot Mosque (PM) to discuss the future direction and the necessary steps to transform the mosque into a green place of worship. As part of the process, a site visit and preliminary audit were carried out to assess the mosque's potential for energy efficiency and green practices. The goal of the initial energy audit, conducted by the researcher to provide the mosque management with practical ideas and recommendations for implementing green practices that will ultimately lead to energy reduction at the PM. The researcher will employ engineering considerations and industry best practices to estimate the potential energy savings and associated implementation costs. The findings of the initial energy audit are expected to provide the mosque with valuable recommendations for energy-saving measures. It's important to note that the assessments and recommendations provided by the researcher are based on the information provided by the mosque management and the data collected during the audit period. The calculation of energy savings considers the priority and suitability of the equipment and systems at the Pilot Mosque. This research aims to comprehensively study the performance of energy efficiency in a Mosque. The primary objectives are to investigate energy consumption patterns within the mosque by establishing a baseline year before implementing energy-saving projects, identify potential areas for improving energy efficiency and reducing consumption, and conduct an evaluation of energy efficiency status and green practices with investment requirements while forecasting the achieved savings in energy costs and consumption. By achieving these objectives, the research seeks to contribute to the development of sustainable energy practices in the mosque and provide valuable insights for future energy management strategies.

LITERATURE REVIEW

A mosque, being a significant religious edifice for the Islamic community, necessitates a spacious area to accommodate congregants, particularly during prayer times and on Fridays (Alquthami & Alaraishy, 2021). Moreover, the mosque often serves as a venue for religious and communal activities, thereby presenting occupancy patterns that challenge the comfort of the congregation. To address this challenge, measures must be undertaken to ensure congregational comfort, with a focus on the utilization of solar energy as a sustainable alternative (Alquthami & Alaraishy, 2021. Considering Malaysia's geographical location, the nation benefits from substantial sunlight, making it an ideal candidate for the application of green building technology, especially in the context of mosques. Consequently, a green architectural approach, with an emphasis on natural ventilation and lighting, should be prioritized to enhance sustainability and energy efficiency within mosque premises (Hussin, Haw, & Salleh, 2018). Despite their large floor space, most mosques are equipped with air conditioning systems, which leads to increased energy consumption and wastage. To reduce this issue, extensive research has been conducted in Malaysia to analyze the effect of air conditioning on the energy consumption of mosques (Mohamed et al., 2021). This research provides valuable insights into improving energy efficiency while maintaining thermal comfort.

According to the Intergovernmental Panel on Climate Change, IPCC Report 2020, the reduction of carbon dioxide gas emissions can reduce the problem of climate change if electricity savings can be implemented. This relationship between energy efficiency in mosques and environmental impact is in line with global efforts to combat climate change, which emphasizes the importance of sustainable energy solutions in religious structures. When this green solution is implemented an energy audit process will be made by analyzing the data collected. This analysis will help identify specific areas where energy-saving measures, such as LED lighting, energy-efficient air conditioning systems, and reduced base load, can be used effectively. Additionally, the integration of renewable energy sources, such as solar panels, into mosque buildings should be further explored as a sustainable way to reduce energy consumption. The main goal of this research is not only to improve energy efficiency in mosques but also to promote environmental sustainability and reduce operating costs. In line with global efforts to address climate change, this research contributes to a growing body of knowledge highlighting the importance of adopting sustainable energy solutions in religious structures. It is anticipated that the findings of this research will be a valuable resource for mosque authorities and communities wishing to implement energy-saving initiatives, thus ensuring the long-term sustainability of this important place of worship.

METHODOLOGY

PM Mosque has been in operation for 12 years since 2010. The mosque has a building capacity to accommodate approximately 1,300 worshippers, with 600 worshippers in the main prayer hall and 700 worshippers outside. The net floor area (NFA) of the mosque is 2,231.30 square meters, based on measurements. It is located at Pahang. The function of this building is as a place of worship, specifically a mosque that provides comprehensive facilities for the worship activities of Muslim men and women. In addition to the main prayer hall and women's prayer area, the mosque is equipped with a spacious area at the back of the building that can be used for Friday prayers and other special events. There are also administrative facilities such as office space, waiting area, meeting room, lecturer's room, muezzin's room, and imam's room that can be used at any time. The mosque also provides facilities for funeral management with two hearses available. Additionally, the mosque welcomes its congregants to hold wedding ceremonies by providing a venue and a mini wedding dais.

Energy Usage Aspects

In the preliminary energy audit, it is important to analyze the energy usage in PM Mosque. Some aspects to consider in this regard include:

1. Energy usage for lighting: This includes an assessment of the lighting system, types of lamps used, and the use of motion sensors or automation systems to optimize energy usage within the mosque premises.
2. Energy usage for cooling and ventilation: This involves evaluating the air conditioning

system, fans, ventilation, and the potential to improve energy efficiency in temperature control and air circulation within the mosque.

3. Energy usage for electronic equipment: This includes reviewing equipment such as sound systems, projectors, computers, and other electronic devices used in worship activities and events at the mosque.

By analyzing these energy usage aspects, the preliminary energy audit can identify potential opportunities for energy efficiency improvements and energy-saving measures that can be implemented in PM.

Energy Audit Work Scope

The scope of the initial energy audit work is to closely examine the building's operations, observe energy wastage, and perform necessary energy measurements using specialized equipment. The main components of this energy audit include the following aspects:

1. Conducting an energy audit at PM Mosque.
2. Obtaining main profiles at the main electrical source.
3. Gathering electricity bill information.
4. Analyzing data and information related to the building.
5. Proposing potential energy-saving measures (action plans, estimated time for implementing recommended Energy Saving Measures (ESM), energy savings, and implementation costs).
6. Reporting on the initial energy audit.
7. Initial Meeting.

Methodology of Energy Audit at PM Mosque

The methodology of energy audit encompasses a range of data collection, analysis, and recommendation stages to pinpoint areas for energy conservation and cost reduction. Fig. 1, shows the methodology for the initial energy at PM Mosque.

1. Initial Meeting	2. Desktop Audit	3. Site Audit	4. Data Analysis	5. Report
•Introduction to the energy audit proces •Confirmation of the energy audit team establishment, scope, and implementation schedule	•Analysis of historical bills •Building information (layout, single-line schematic diagram, building cap) •List of equipment and facilities (if available)	•Measurement and logging of power (if necessary •Review and inspection of rooms	•Establishing reference/guideline lines •Allocation/distribution of energy users •Identifying significant energy users (SEU) •Listing energy-saving measures and methods that can be implemented	•Preparation of a draft report •Presentation of the report •Review and revision of the report (if necessary) •Preparation of the final report

Figure 1: Methodology for Energy Audit

METHODOLOGY

Floor Area of the Mosque

PM Mosque is a concrete-structured mosque with a main prayer hall measuring 18m x 18m, consisting of 13 rows (safs). Each row can accommodate up to 40 adult worshippers, allowing for a total capacity of approximately 600 worshippers. Additionally, there is a lower-level prayer room for Muslim women, measuring 15m x 9m, and an upper-level prayer room measuring 18m x 8m. The spacious area at the back measures 18m x 35m and can be utilized to accommodate worshippers, especially for Friday prayers and special events. The description of the total air-conditioned area and non-air-conditioned area is shown in Table 1. Analyzing data and information related to the building by collecting information on the building or facility, including its size, layout, occupancy patterns, and operating hours.

Table 1: Total Air-Conditioned and Non-Air-Conditioned Floor Area

Description	Area (m^2)
Total Air-Conditioned Areas	881.47
Total Non-Air-Conditioned Areas	1,349.83
Total Net Floor Area	**2,231.30**

Building Active Systems

Electricity Supply System

PM Mosque has only one source of low load voltage which is 400V through one TNB meter source. Then, electricity is distributed to each area of the building. Significant energy consumption in this building is the air conditioning system, lights, and "plug" loads. Figure 2 shows the process of power logger installation and measurement process at the electrical distribution box.

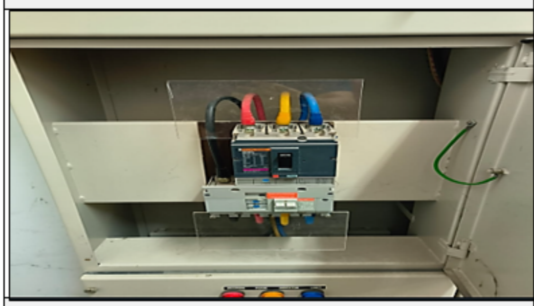
Low Main Incoming Load Voltage	Configuration of the Power Logger Tool
	
Power Logger Installation	Measurement of Power at Incoming Main Supply

Figure 2: Electricity Supply System Electrical Distribution Box

Air Cooling System

In the PM Mosque, there are several types of air conditioning systems available, including air-cooled split units with both ceiling-exposed and wall-mounted options.

Lighting System

There are several types of lamps used in PM Mosque. Approximately 60% have been converted to LED lights. The rest of the lamps still use conventional lamps. Table 2 shows the types of lamps with percentages of usage that are used in the PM Mosque.

Table 2: Types of Lamps in PM Mosque

No	Description	Quantity	Percentage (%)
1	Flourescent Lamp 2ft (LED 9W)	2	0.5%
2	Downlight Lamp (LED 12W)	71	18.8%
3	Downlight Lamp (LED 150W)	11	2.9%
4	Flourescent Lamp Kubah (LED 150W)	282	74.6%
5	Flood Lamp Kubah (LED 150W)	8	2.1%
6	Fasad Metal Hallide Lamp (LED 250W)	4	1.1%
Total Lamp Quantity		378	100%

Air Ventilation System (Plug Load)

The electric fan system is designed to ensure proper airflow in the prayer hall, ensuring the comfort of worshippers and guests inside the building. The mosque's wall design consists of sliding glass doors that can be adjusted to either block or allow the movement of air in and out of the main prayer hall. As a result, the main prayer hall has the option to use either an air conditioning system along with fans or rely solely on fans for air circulation. Table 3 shows the description types of fans used in the Mosque.

Table 3: Types of Fans in PM Mosque

No	Description	Quantity	Percentage (%)
1	Domestic Wall Fan	40	27%
2	Industrial Wall Fan	45	31%
3	Ceiling Fan	48	33%
4	Air Curtain	10	7%
5	HVLS Fan	1	1%
6	Exhaust Fan	2	1%
Total Fan Quantity		146	100%

Electrical Equipment (Plug Load)

During the audit, several electrical appliances were found to be used in the mosque, including those in the office area and the main mosque building. Examples of these appliances include the sound system, computers, monitors, and others. Appliances such as refrigerators and CCTV operate continuously throughout the day. However, some appliances are used only at specific times and are switched off when not in use, such as fans, televisions (TV), and others.

FINDINGS

Building Intensity

This research focuses on specifically Building Energy Intensity (BEI), which is the annual energy consumption divided by the building area or mosque size. It refers to the building energy intensity benchmark as in Figure 3. BEI is a measure used to assess the energy performance of a building, specifically in the case of houses of worship. It is a benchmarking tool that compares the energy intensity of a particular building category to other buildings in terms of suitability. Typically, it is measured by the annual energy consumption divided by the building area (kWh/m2/annum). However, specific BEI benchmarks for houses of worship at a national level have not been established yet. As a result, comparisons are made with commercial buildings in Malaysia, where the average BEI ranges between 200 and 220 kWh/m2/annum.

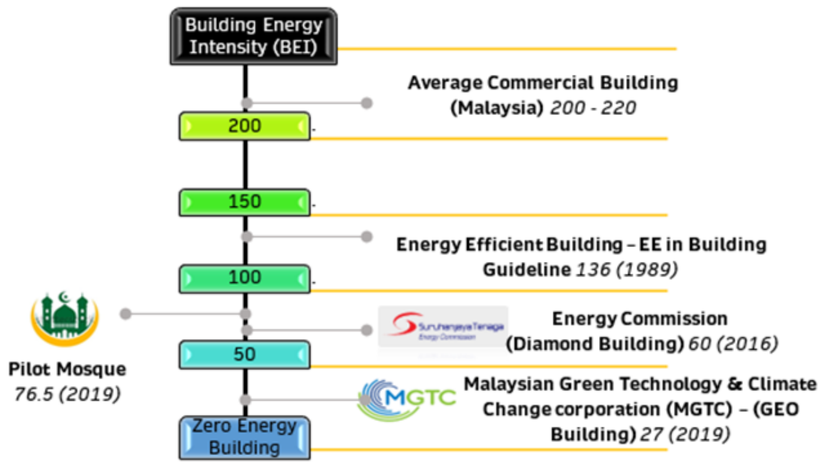


Figure 3: Building Energy Intensity Benchmark

Building Energy Intensity (BEI)

The assessment of building energy intensity in PM Mosque provides an opportunity to explore the effects of energy management practices and efficiency upgrades. Table 4 shows the result of the mosque's energy performance in the years 2019 and 2022.

Table 4: Building Energy Intensity of PM Mosque for the Years 2019 and 2022

No.	Intensity	Result	Unit
1	**Building Energy Intensity (BEI) year 2019** [BEI = Total Energy Consumption in 2019 / Net Floor Area] [BEI = 170,733.00kWh/year/2,231.30m²]	76.50	kWh/m²/year
2	**Building Energy Intensity (BEI) year 2022** [BEI = Total Energy Consumption in 2019 / Net Floor Area] [BEI = 116,370.00kWj/year/2,231.30m²]	52.15	kWh/m²/year
3	**Air Conditioning Energy Intensity (ACEI)** [ACEI = Total Cooling System Energy Consumption / Cooling System Floor Area] [ACEI = 63,817.92 kWh/year/881.47 m²]	72.40	kWh/m²/year
4	**Lighting System Energy Intensity (LSEI)** [LEI = Total Energy Consumption of Lighting System / Net Floor Area] [LSEI = 17,404.44 kWh/year/2,231.30m²]	7.80	kWh/m²/year
5	**Plug Load Energy Intensity (PLEI)** [PLEI = Total Energy Consumption of Plug Load / Net Floor Area] [PLEI = 27,975.72 kWh/year/2,231.30m²]	12.54	kWh/m²/year

Load distribution in the context of using BEI (Building Energy Index) in a building refers to the process of calculating and allocating energy usage to various components and equipment within the building. Its purpose is to understand how energy is utilized within the building and identify sectors that require energy efficiency improvements. Load distribution involves identifying the equipment and systems that consume energy in the building, as well as measuring the amount of energy used by each component. Subsequently, the energy usage can be analyzed, and comparisons can be made based on the established BEI. In the context of a place of worship, load distribution may include calculating the energy usage by lighting systems, heating, cooling, and other equipment used within the building. To achieve a lower BEI, load distribution can help identify sectors that require energy efficiency improvements, such as high-powered lighting or inefficient cooling systems. By conducting load distribution, the owners or management of the place of worship can make informed decisions on how to improve energy efficiency within the building, such as switching to more energy-efficient equipment, reducing unnecessary energy consumption, or optimizing energy usage during strategic times. Load distribution is an important step in the efforts to improve the energy performance of buildings and achieve a better BEI in the category of places of worship or other categories. By understanding the extent to which energy is used within the building, owners or management can take appropriate steps to enhance energy efficiency and contribute to environmental sustainability.

Load Distribution

Load distribution in this research focuses on lighting and cooling systems and plug loads. Table 5 illustrates the estimated monthly average energy consumption distribution in PM during normal months.

Table 5: Estimated Monthly Average Energy Consumption in PM

No.	Description	Estimated Monthly Energy Consumption (kWh)	Percentage (%)
1	Plug Load	2, 331.31	25.62%
2	Lighting System	1,450.37	15.94%
3	Cooling System	5,318.16	58.44%
4	Others (Load)	-	-
Total Energy Consumption		9,099.84	100%

History of Energy Usage

PM Mosque receives its electricity supply through a single meter from Tenaga Nasional Berhad (TNB) under Tariff B (Commercial Low Voltage Tariff). Table 6 shows the tariff rate that is used for the PM mosque.

Table 6: Tariff B (Low Voltage Commercial Tariff)

Description	Unit	Tariff Rate
For the 1st 200 kWh (1 - 200 kWh) per month	cents/kWh	43.50
For the next kWh (201 kWh) per month	cenths/kWh	50.90
Minimum charge per month	RM	7.20

The electricity usage records for the year 2019 were provided by the mosque authorities and were used to analyze the energy consumption profile and establish baseline indicators for this audit. Figure 4 shows the energy consumption performance graph for the year.

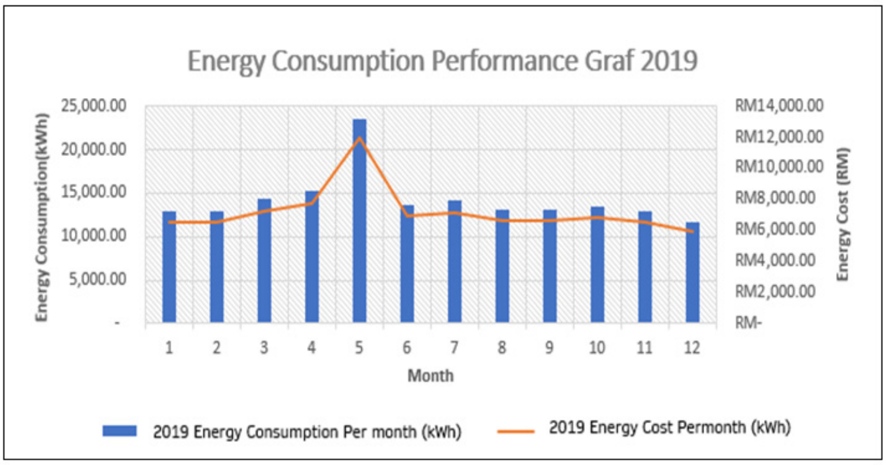


Figure 4: Energy Consumption Performance Graph 2019

Load Profile

Load profiling as in Fig. 5 and Fig. 6 is a method of monitoring energy usage and load patterns in real time. For this initial energy audit, a power logger was installed at the main electrical supply input of the mosque for several days to record the profile of electricity usage.

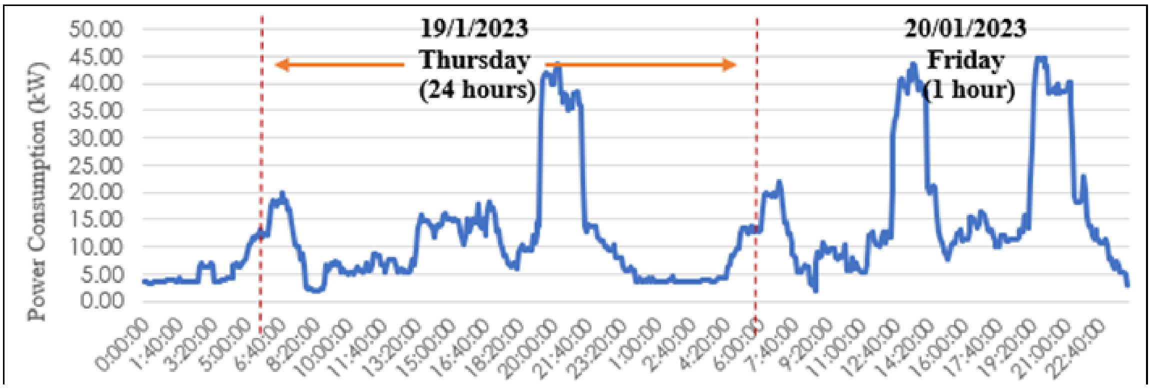


Figure 5: Continuous Load Profile (19/1/2023-20/1/2023)

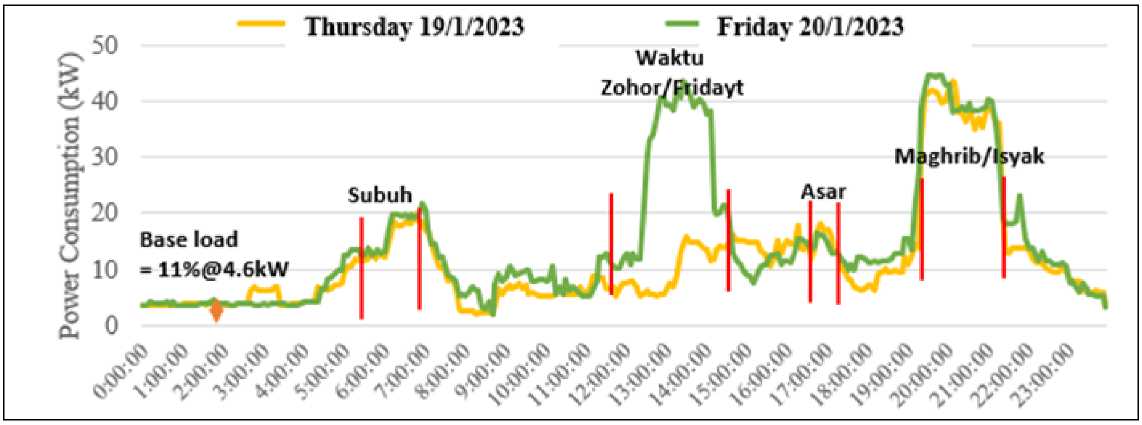


Figure 6: Daily Load Profile

Table 7: Record of Daily Energy Consumption

Date	Day	Operation Hour (Logging)	Energy Consumption (kWh)
19/1/2023	Khamis	24 Hours	273.23
20/1/2023	Jumaat	24 Hours	347.92
Total Energy (2 days)			**621.15**
Estimated Energy (Days other than Friday- 27 Days)			**7,377.08**
Estimated Energy (Friday- 4 Days)			**1,391.69**

Energy Measurement

This section aims to compare the measured energy usage with the energy usage reported in the TNB bill for PM Mosque. The measurements were taken over several days, and the average data from these measurements was extrapolated to represent a month, equivalent to 30 days, in which the measurements were conducted in January 2023. Table 8 shows the annual energy usage for comparison purposes.

Table 8: Percentage Difference between Measured Energy Usage and TNB Bill Energy Usage

Description	**Energy Consumption (kWh/month)**
TNB Bill December 2022	9,077.00
Monthly Projection from “Logging” Reading Record Analysis	8, 768.77
% Difference	**-3.52%**

The result shows the percentage difference in energy usage between the TNB bill for the month of December 2023 and the extrapolated one-month analysis from the "Logging" readings, which amounts to -3.52%. The acceptable range for comparison should be within ± 10% to validate the accuracy of the measurement data taken. Therefore, the measured data falls within the allowed range, and the analysis from the measurements can be considered reliable.

Energy Saving Measures (ESM)

Energy-saving measures (ESM) are identified through on-site data assessment and monitoring data analysis. A brief description of each ESM is provided before calculating energy savings. The explanation of ESM is intended for general understanding. Assumptions are made for certain ESM calculations, and these assumptions are listed in the respective ESM descriptions/ calculations. The proposed ESM will be explained in this section.

ESM 1: Reducing Base Load During Night-time

Base load refers to the energy consumption in the building after working hours or when the building is unoccupied, and electrical appliances are no longer in use. Table 9 and 10 shows the average base load usage for the Mosque as 4.6 kW, accounting for 11% of the recorded maximum demand.

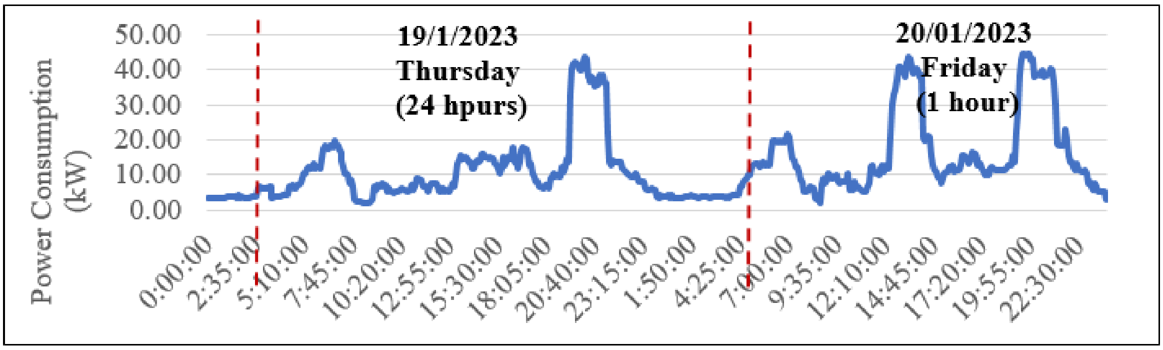


Figure 7: Daily Load Profile

Table 9: Annual Energy Savings Potential

Average Current Base Load (kW)	4.80
Minimum Achievable Power Reading (kW)	2.60
Savings by Turning Off Unused Electrical Equipment (kW)	2.00
Annual Energy Savings Potential (kWh/year)	3,650

Table 10: Annual Energy Usage Base Load

Average Base Load (kW) (11%)	Operating (hours/year)	Annual Energy Consumption (kWh/year)	Annual Energy Cost (RM/year)
4.6	1,825	8,395	4,273.06

There is potential to control the base load by turning off unnecessary loads after the mosque's operating hours during the late evening. One energy-saving measure that can be implemented is improving control over unnecessary loads, such as turning off electrical appliances like water dispenser switches. Table 11 shows the savings resulting from turning off loads during the base load period can lead to a reduction in base load usage by 43% and generate annual savings of up to RM1,857.85.

Table 11: Energy Saving Measures to Reduce Base Load

No	Description	Total
1	Annual Energy Consumption (kWh/year)	8,395
2	Annual Energy Consumption Cost (RM/year)	4,273.06
3	Annual Energy Saving (kWh/year)	3,650.00
4	Annual Energy Cost Saving (RM/year)	1,875.85
5	CO_2 Reduction (tonne CO_2/year)	2.53
	Investment (RM)	**-**
	Pay Back Period (Year)	**-**

ESM 2: Conversion of Metal Halide 250W Façade Lights to LED 100W

PM Mosque currently uses LED technology for lighting inside the building but still uses Metal Halide 250W lights for the external facade lighting. Significant energy savings can be achieved through the initiative of replacing them with energy-efficient lighting, such as LED lights. By replacing the Metal Halide 250W lights with LED 100W lights, substantial energy savings can be realized. LED lights are more energy-efficient and have a longer lifespan compared to traditional lighting technologies. This ESM has the potential to reduce energy consumption for facade lighting and contribute to overall energy savings for the mosque. Table 12 shows the result of energy-saving measures from LED 100W.

Table 12: Energy Saving Measures Resulting from LED 100W Lamp Conversion

No	Description	Total
1	Annual Energy Consumption (kWh/year)	4,380.00
2	Annual Energy Consumption Cost (RM/year)	2,229.42
3	Annual Energy Saving (kWh/year)	2,628.00
4	Annual Energy Cost Saving (RM/year)	1,337.65
5	CO2 Reduction (tonne CO2/year)	1.82
	Investment (RM)	**1,500.00**
	Pay Back Period (Year)	**1.12**

ESM 3: Conversion of 2.5Hp Split Air Conditioner Unit to 5-Star Rated 2.0Hp Split Air Conditioner Unit

As part of energy-saving measures, one out of the 13 air conditioning units with different sizes will be replaced with a 5-star rated and energy-efficient 2.0Hp split air conditioner unit. This conversion has the potential to achieve significant energy savings, amounting to approximately 45%. By upgrading to a higher energy-efficient rating and reducing the capacity of the air conditioner unit, the mosque can optimize its cooling requirements while minimizing energy consumption. Results from Table 13 show the ESM from efficient air conditioner replacement contributes to energy cost savings for the mosque.

Table 13: Energy Saving Measures Resulting from Efficient Air Conditioner Replacement

No	Description	Total
1	Annual Energy Consumption (kWh/year)	2,789.00
2	Annual Energy Consumption Cost (RM/year)	1,419.40
3	Annual Energy Saving (kWh/year)	1,254.87
4	Annual Energy Cost Saving (RM/year)	638.73
5	CO2 Reduction (tonne CO2/year)	0.87
	Investment (RM)	**2,500.00**
	Pay Back Period (Year)	**3.91**

ESM 4: Installation of Photovoltaic Solar System on the Mosque Roof

The installation of a photovoltaic solar system on the mosque roof offers the opportunity to reduce the mosque's dependence on the electricity supply from Tenaga Nasional Berhad (TNB). By harnessing energy from a clean and renewable source, energy savings can be achieved, especially through lower tariff rates over the long term. According to Rahmat et al. 2018, a green roof in a building is an efficient way of reducing building temperature and an effective way to achieve sustainability in architecture and engineering design. The solar photovoltaic system converts sunlight into electricity, which can be used to power various electrical loads within the mosque. This includes lighting, fans, air conditioning, and other electrical equipment. By utilizing solar energy, the mosque can significantly reduce its reliance on grid electricity and, consequently, lower energy costs. Table 14 shows the investment of ESM from the photovoltaic solar system installation of the mosque. The installation of a solar system aligns with the mosque's commitment to sustainability and reduces its carbon footprint by utilizing a clean energy source. It also serves as an educational opportunity to promote renewable energy and inspire the community to embrace sustainable practices. It is important to note that the feasibility and design of the solar system will depend on factors such as the available roof space, orientation, shading, and local regulations. A thorough assessment and consultation with solar energy experts will ensure the optimal design and installation of the photovoltaic system for the mosque.

Table 14: ESM from Photovoltaic Solar System Installation on the Mosque Roof

No	Description	Total
1	Annual Energy Consumption (kWh/year)	170,733.00
2	Annual Energy Consumption Cost (RM/year)	86,903.10
3	Annual Energy Saving (kWh/year)	60,920.64
4	Annual Energy Cost Saving (RM/year)	18,030.82
5	CO2 Reduction (tonne CO2/year)	35.64
	Investment (RM)	**210,000.00**
	Pay Back Period (Year)	**11.65**

Energy Saving Measures (ESM)

In this study, four energy-saving measures were evaluated for their potential impact and cost-effectiveness. The first measure involved reducing the base load at night, resulting in a saving potential of 1846 kWh and a corresponding energy cost reduction of RM940. This approach required no initial investment, and its benefits included a 1.28 tonnes/year reduction in CO2 emissions, along with 2% reductions in both energy usage and costs. The second measure focused on replacing 250W Metal Halide Facade Lamps with 100W LED Lamps. This transition yielded a saving potential of 2628 kWh, reducing energy costs by RM1337. Although an investment of RM1500 was necessary, the payback period was relatively short at 1.1 years. Additionally, it contributed to a 1.82 tonnes/year decrease in CO2 emissions, along with 2% reductions in energy usage and costs. The third measure entailed upgrading a 2.5 Hp Air Conditioning Split Unit to a 2.0 Hp Five Star Rating system. This change led to a saving potential of 1254 kWh and an energy cost reduction of RM638. However, an investment of RM2500 was required, with a payback period of 3.9 years. The CO2 emissions were reduced by 0.87 tonnes/year, accompanied by 1% reductions in both energy usage and costs.

The fourth measure involved installing a Solar Photovoltaic System on the mosque's roof, resulting in a substantial saving potential of 60920 kWh and an energy cost reduction of RM18030. However, a significant initial investment of RM210,000 was needed, and the payback period was 11.6 years. On the positive side, this measure contributed to a significant CO2 reduction of 35.64 tonnes/year and an impressive 35% reduction in both energy usage and costs. In conclusion, these measures varied in terms of their upfront costs, energy savings, and environmental benefits. While measures 1 and 2 offered short payback periods and considerable energy and cost reductions, measure 4 presented a compelling long-term sustainability strategy despite its higher initial investment, with substantial reductions in energy usage, costs, and carbon emissions.

No	**Energy Saving Measures**	**Saving Potential**		**Investment**	**Pay Back Period**	**CO2 Reduction**	**%Energy Reduction**	**%Energy Cost Reduction**
		Energy (kWh)	Cost (RM)	Cost (RM)	Year	Tonne/ year		
1	ESM 1 - Reduce Base Load	1,846	940	-	-	1.28	2%	2%
2	ESM 2 - Convert to 100W LEDLamp	2,628	1,337	1,500	1.1	1.82	2%	2%
3	ESM 3 - Change to 2.0Hp Five Star Rating	1,254	638	2,500	3.9	0.87	1%	1%
4	ESM 4 - Installation of Solar Photovoltaic System	60,920	18,030	210,000	11.6	35.64	35%	35%
	Total	**66,650**	**20,947**	**214,000**	**10.2**	**39.62**	**40%**	**40%**

CONCLUSION AND RECOMMENDATIONS

Green practices are important in preserving the environment and reducing energy consumption at the PM Mosque. Energy efficiency can be improved in mosques by using LED lights as a light source, installing smart power controllers, and optimizing the use of air conditioning and heating systems. The use of green products, reduction of energy and water, and reduction of greenhouse gas emissions are important steps in green practices. Effective waste management also needs to be considered to ensure environmental sustainability. To enhance environmental initiatives at the mosque, it is also recommended to establish a Green Practices Committee, tasked with overseeing and implementing eco-friendly practices. Additionally, conducting educational programs, including lectures and exhibitions, can raise awareness among mosque attendees about the importance of adopting green practices for a sustainable future. By taking these steps, PM Mosque can effectively implement green practices and make a positive contribution to environmental sustainability and energy reduction.

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