Analysis and Improvement of Energy Consumption for Indonesia Mosque

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Abstract

Indonesia as a muslim majority country makes the mosques plays big part of the society. Activities other than prayer are also held in the mosques. Therefore, the electrical energy consumption can be consumptive and inefficient if they are not properly managed. Also with the tropical climate of Indonesia where the humidity is high makes achieving thermal comfort more difficult for the air conditioner, it also makes the energy consumption much higher. In this particular research, we aimed to analyze the energy consumption in some mosques in Indonesia and give a recommendation on how to reduce the electrical energy consumption. By managing the energy and conserving the energy to achieve efficiency in mosques.

Keywords
Energy Management, Energy Conservation, Energy Efficiency, Mosque.

1. Introduction

With the climate change threat getting more and more imminent by day. The human race has been called to strengthen their sustainable solutions. Energy has been one of the most proficient factors in sustainable development. Effective energy management should be conducted in every sector in order to fight against climate change. Energy management itself is considered as a system that helps an organization in controlling, monitoring and managing energy related activities to improve energy efficiency. The need for energy management does not focus solely on the industrial sector but also in the public sector (Antunes et al. 2014; Thollander & Palm 2015). Public facilities such as transportation hubs, market, sporting venues, and also worship places also need energy management due to its variance in energy consumption and since it is public it also needs energy efficiency.

In general, energy use can be minimized by saving energy and efficiency. Some examples of energy saving are reducing the use of some electrical equipment that is not really needed, while examples of energy efficiency are using electrical equipment according to a predetermined time and utilizing other sources such as the sun and so on. According to Ainul (2016), energy management can be said to be successful if there is a reduction in energy costs for operating facilities and equipment and reducing maintenance costs. In addition, energy management will also reduce the impact on the environment and CO2 emissions so that it will make a significant contribution to the activities and financing of a building or various public facilities such as mosques.

Low energy efficiency leads to the high production costs, increasing the production costs and reducing the competitiveness of enterprises, also raising the expenses for public utility payment as for the population and budgetary organizations (Shirrime & Trubaev 2017). So the adoption of green practices into business operations becomes an important issue in many organizations. It is important to develop long-term strategies and to set quantifiable targets for energy saving (Johansson & Thollander 2018). The successful implementation of energy strategy includes a combination of the implementation of energy-efficient technology together with successful energy management practices (Cibinskiene et al. 2020). Mosque, which become the central part of Islam culture that demanded to be supported by high-quality building or architecture artifacts, is one of public building which needs a suitable energy efficiency strategy. Inappropriate way of energy management system will lead to unsuitable thermal environment for the worshipers inside the mosque (Supni et al. (2015).

Because of the importance of research on energy management in mosques, especially in the Indonesian region which in fact has a tropical climate, the research scope in this article is energy management on the mosques that is located in the Soekarno - Hatta International Airport, Tangerang City, Province of Banten, Indonesia. This research will also focus on how to use energy, especially electrical energy in mosques mentioned above by recording the consumption of electrical energy in each equipment in the mosque. Then from the results of the recording, an analysis of the use of electrical energy will be carried out. Furthermore, the results of the analysis will be used as a basis for making proposals for alternative strategies in carrying out energy conservation at the mosque. The proposed alternative strategy is expected to reduce electricity consumption and it is also expected that the decrease in electricity consumption will have an impact on reducing electricity bills that must be borne by mosque managers in the Soekarno - Hatta International Airport area. In addition to the decrease in electricity bills, carbon emissions resulting from mosque operations will indirectly decrease.

2. Literature Review

Due to the importance and potential benefits of applying energy management system in mosques, in relation to the worshipers' convenience and contribution to the preservation of the environment, several scientific initiatives and projects have been developed to incorporate elements of environmental sustainability in the management of energy of the mosque. Hussin et al. (2019) conducted research on the energy usage and optimization strategies from a few selected retrofitted air-conditioned mosques in Penang, Malaysia. In Malaysia, most of the old and traditional mosques with excellent air ventilation rarely receive energy assessments because of its low average operational energy intensity as most of the load had only consisted of lightings and small fans. On the contrary, the newer mosques that were retrofitted with mechanical ventilated devices such as the air-conditioning systems are required to undergo energy audits because of its high energy intensity. The result shows that all of the mosque samples had shown a fluctuation of the monthly energy usage, which could be due to the energy wastage associated with less efficient equipment. The air-conditioning systems were found to have performed below the required efficiency level and led to energy wastage as a result of certain factors that had influenced its energy consumption. For this reason, this study had proposed several short and long term strategies by considering the available resources and budget such as the upgrading of the system and system knowledge in the optimization of energy usage. The setting up of a new thermal comfort or temperature adjustment will also provide advantages in terms of intermittent operation hours and load occupancy.

Another study conducted by Supni et al. (2015) to assess and look forward to the energy used by the ordinary mosque with the new high technology and the well-managed design mosque as a step towards a comprehensive study of their effective way of management of the energy system. In building a mosque, efficiency aspects which need to be considered are energy efficiency, water efficiency, the indoor air quality and also the sustainable site planning management. Harsritanto et al. (2021) also conducted a study which aimed to suggest a design strategy for making a sustainable mosque. In building a sustainable mosque, primary design strategies which should be considered are (1) building layouts, (2) lighting strategy, (3) HVAC strategy, (4) water conservation strategy, and (5) IT strategy. Building layouts, lighting, HVAC, and water conservation strategy are closely related to each other, such as the lighting and HVAC installation is depending on the building layouts; or the water recycle in ablution can be functioned as a water cooler for the HVAC. But IT through a monitor and automatic control can emphasize the sustainable Mosque design. Therefore, five of them shall be joined and not be standalone strategies in the application and conceptual design.

According to research conducted by Nurul (2021), mosques as non-residential public buildings can make a significant contribution to energy use due to the large amount and time of use that is carried out every day. According to research conducted, mosques are one of the public facilities that are targeted by the local government for energy management. This is because the changes in the digital age make mosques use more energy than before the digital age. For example, in the past few years not too many mosques have used air conditioners as air conditioners. Meanwhile, after the digital era, all mosques are forced to use air conditioners as air conditioners.

Furthermore, according to Fauzia et al. (2016), energy use in mosques is increasing due to changes in modern mosque designs. Basically, changes to the design of the mosque aim to increase the comfort, tranquility and peace of the congregation in carrying out their worship. However, it is necessary to make adjustments to the design of the mosque so that worshipers still get comfort and on the other hand energy reduction can still be done by saving various electrical equipment.

In a study conducted by Khairul et al. (2022), it was concluded that the design of the construction of a mosque which will reduce energy use must pay attention to lighting and ventilation. Several solutions that can be proposed are to pay attention to the position of windows and glass that face directly to the wind so that it enlarges the ventilation to take place inside the mosque. Furthermore, it is necessary to design water features and landscaping near the mosque so that it can provide cool air and have an impact on the inside of the mosque. Lastly, the air-conditioned main prayer hall is designed as an enclosed space to ensure cool air is trapped to reduce energy and electricity bills.

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Suhono et al. (2020) has conducted research on the energy consumption of mosques in an urban area with a tropical climate. The research is conducted in Yogyakarta, Indonesia involving 15 different mosques to be examined. Indonesia as a Muslim majority country makes the mosques plays an integral part of the society. Therefore, the mosques acts not just only a place for Muslim to pray but there are other activities as well this would make an interesting thing to be examined on the energy consumption of the mosques because there may be inconsistency and variance use of the energy. The results show that the average if the energy consumption of mosques in Yogyakarta is 182.2 kwh/day and the highest consumption came from air conditioning with 29.16% from total energy consumption. Per square meter monthly each mosque varies from the least 0.16 kwh up to 4.54 kwh this shows that the variance from 15 mosques that were used for the research have a large variance. From a total 15 mosques less than 50% of the mosques that met the national standard for lightning. And also only 9 out of 15 mosques that in the context of green building met the energy consumption aspect.

On the other hand, Abdou et al. (2005) conducted research also on the energy consumption of mosques. However, the object of the research is located in the eastern region of Saudi Arabia where the climate is hot-humid. The main point of the research is to analyze the energy consumption of mosques based on their annual billing over the last five years. The purpose of the research is to compare the energy consumption of mosques and analyze the trend of usage over time in addition to further study of their energy system, thermal performance and operation strategies. The results of the research shows that the use of annual billing for energy consumption analysis is feasible but not very accurate. They suggest that direct measuring should be conducted to gather real time data for more accurate calculation.

There is another research focusing on energy consumption of mosques. Yuksel et al. (2022) conducted a research on six mosques in Turkey focusing on the impact of COVID-19 pandemic on the energy consumption, thermal comfort and also indexed air quality. Due to the COVID-19 pandemic restrictions are made also on activities in the mosques. The results show us that the lightning and air conditioner energy consumption decreased during the pandemic compared to before pandemic. The air temperature only varies during prayer time due to less occupancy of the mosques during the pandemic. Turning off fans and air conditioners resulted in higher thermal temperature which causes inconvenience but it proves that it slows down the transmission rate of the virus. Therefore, the pandemic does have an effect towards the energy consumption of a mosque due to the activities restriction that also occurs to mosques.

Sayed Hassan Abdallah (2022) has conducted research that the Smart Control system can monitor and optimize the operations of a building, especially in mosque buildings. In the study entitled "Improved energy consumption and smart eco system for mosques in hot arid climates", the author simulated and calculated several alternative energy saving strategies, especially the application of smart occupancy sensors. The simulation uses several software such as DIAlux and DesignBuilder. The consumption of electrical energy in the mosque can be reduced by as much as 9% by replacing traditional lighting with LED lights. Then the use of a smart control plan can also reduce the Energy Consumption Intensity from 87.5 kWh / m 2 / yr to 69 kWh / m2 / yr. This research takes place in one of the mosques of Assiut University, Egypt. The results of measurements in the field show that the electricity consumption used is 5100 kWh with the largest contributor time being the Maghrib and Isya time which is caused by the inefficient use of air conditioning because during two-prayer times, the mosque is at an open door condition while waiting for worshippers to enter the mosque. The results of simulations in the three applications showed that energy savings of 29% can occur by applying thermal insulation to the outer envelope of the mosque, replacing traditional lamps with LED lights, and installing windows louvres with U-Values 0.263 W/m 2 K and 0.171 W/m2K for the walls and roofs.

Abdou et al. (2005) conducted an assessment of energy use trends in 5 mosques of almost similar type in the eastern state of Saudi Arabia with a hot-humid climate. The assessment was carried out on the data of the electric energy bill for the last 5 years (1999-2003). As we know, mosques are sacral public facilities that Muslims use for worship. In the worship activities referred to, the operation of the mosque takes place by means of an intermittent operation. Mosque operations require considerable electrical energy, especially during mandatory prayer times (5 times per day). To support worship activities, air conditioning is needed to achieve thermal comfort. The analyses of the electric energy bills data presented are useful in showing the general trend and the history of energy use for those mosques. The billing data can provide a reasonable estimate of the overall annual electric energy use for each mosque. However, the billing data is not an accurate reference for comparison of different mosques on a Hijri monthly basis as commonly reported by the Saudi Electric Company.

This is due to the inconsistency in meter readings among the different mosques for the same month and also for the different months of the year for the same mosque. This problem would be aggravated by the use of the lunar (Hijri) calendar, which does not serve in consistently matching energy use with climatic conditions over the years, as the basis for reporting the data without reference to the corresponding solar (Gregorian) calendar. Therefore, to get reasonable data analyses, an effort is required to present the data in a more usable format serving the purpose of the analysis as presented earlier. Yet, electric energy billing data does not provide the necessary segregated energy end uses by the various energy systems for the purposes of detailed mosque energy analysis. Supplementary analysis of detailed energy data as obtained from monitoring will provide more useful information on the energy end use and the potential design and operational strategies for achieving the desired thermal comfort with the lowest energy requirements. This level of analysis is currently the subject of ongoing investigation.

Al-Shaalan et al. (2017) conducted research on the analysis of design approaches to large mosques to be able to conserve electrical energy consumption in the kingdom of Saudi Arabia. The effect of zoning and partitioning of mosque buildings was analyzed in depth in this study. This research is set in the Riyadh City Grand Mosque. 3 case studies were simulated using eQuest software to find out and analyze building energy use. The first 3 case studies are mosques with ineffective materials, then the second is mosques with effective materials but not applied sealing in each room, then the third is mosques with effective materials and the application of sealing in mosque rooms. As it has become an open secret, that Energy consumption is a serious concern in the world in general and in the Kingdom of Saudi Arabia. Mosques are those buildings which operate simultaneously at peak times and not enough focus is given to their designing during construction.

Hence, these buildings have too much potential to attract the attention of concerned authorities. This study is conducted on just one mosque. However, mosques throughout the Riyadh city are quite common as far as the operation and design. Therefore, the results of the mosque can be generalized, but it should be noted the findings may vary per the mosque type, size, operation, and location. Simulation results show that some of the necessary energy conservation techniques should be applied in the construction phase. Electrical energy conservation in Saudi Arabia can be achieved through the combination of three tools. Firstly, the use of efficient electrical equipment; secondly, the application of energy technology in buildings, such as insulation, ventilation and solar energy; and finally, by supportive tools such as public awareness, energy codes, regulations, energy information, and databases.

3. Methods

Below is a flowchart of research on Energy Consumption for Indonesia Mosque:

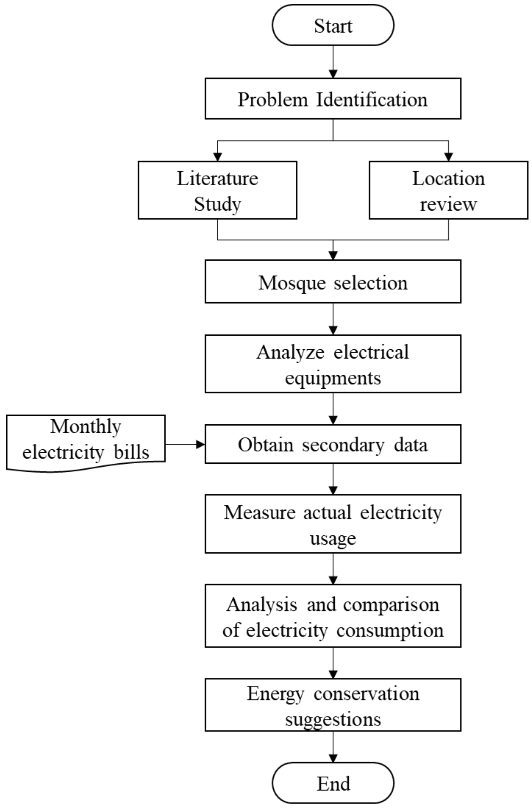


Figure 1. Research Flowchart

The flowchart above is the steps from research conducted on energy conservation in mosques in Indonesia.

There are 4 mosques in several regions in Indonesia which will be used as a place for research. Masjid A is a mosque with an area of 160 square meters. Masjid B is a mosque with an area of 300 square meters. Mosque C is a mosque with an area of 240 square meters. Masjid D is a mosque with an area of 100 square meters. below is the front view of each mosque:

Figure 2. Mosque A

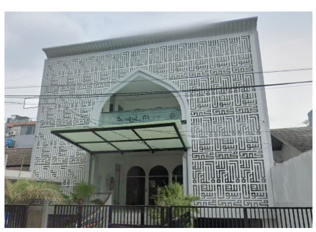


Figure 3. Mosque B

Figure 4. Mosque C

Figure 5. Mosque D

Basically, the electrical equipment found in the four mosques is the same, namely loudspeakers, lamps, air conditioning, fans, vacuum cleaners, water machines, digital banners, and digital wall clocks. Then, from the equipment data it is known that basically the electrical equipment in the mosque consists of 3 main parts that are the biggest contributors to electricity, namely equipment for cooling rooms (air conditioning), equipment related to water (water machine), and equipment related to lighting (lighting). Equipment related to cleanliness and sound systems are not considered because they do not contribute significantly to electricity costs.

The equipment used to measure the energy consumption of electrical equipment in mosques is a clamp meter (picture 6.) and a watt meter (Figure 7.)

Figure 6. Clamp meter

Figure 7. Watt meter

4. Data Collection

Observations were made at the four mosques at different times. Below is the number of air conditioning, water machine, and lighting electrical equipment found in Mosque A, Mosque B, Mosque C, and Mosque D with different types.

Table 1. Number of Electricity Equipment

No.	Equipment Name	Type	Number of Equipment			
			Mosque A	Mosque B	Mosque C	Mosque D
1	Lamp	LED 16 watt	22	36	30	16
2	Air conditioning	3 pk	-	3	2	1
		2 pk	3	3	3	-
		1 pk	2	2	1	2
5	Water machine	500 watt	1	1	1	1

The next step is to calculate the daily power consumption of each electrical equipment. for Air conditioning equipment it is known that the AC is used for 12 hours every day. For water machine equipment, it is known that the water machine is used for 8 hours every day. For lighting equipment, note that the lights are on for 12 hours every day. Below is the result of calculating the power consumption of the four mosques.

Table 2. Power Consumed

No.	Equipment Name	Power Consumed (kWh)/day			
		Mosque A	Mosque B	Mosque C	Mosque D
1	Water Machine	3.2	4.8	4	2.4
2	Air-Conditioning	69.97	156.88	119.54	45.7
3	Lighting	4.18	6.84	5.7	3.04

After obtaining the daily power consumption calculation, then the monthly cost calculation for each electrical equipment is carried out. The cost of electricity set in Indonesia for religious buildings such as mosques every Kwh is IDR 900.00. Below is the result of calculating the cost of electricity per month at each mosque according to the measured electrical equipment.

Table 3. Monthly Cost of Electrical Equipment

No.	Equipment Name	Cost of Electrical Equipment/Month			
		Mosque A	Mosque B	Mosque C	Mosque D
1	Water Machine	IDR 86,400.00	IDR 129,600.00	IDR 108,000.00	IDR 64,800.00
2	Air-Conditioning	IDR 1,916,953.00	IDR 4,297,775.00	IDR 3,275,026.00	IDR 1,251,887.00

3	Lighting	IDR 112,860.00	IDR 184,680.00	IDR 153,900.00	IDR 82,080.00
Total		**IDR 2,116,213.00**	**IDR 4,612,055.00**	**IDR 3,536,926.00**	**IDR 1,398,767.00**

Based on observations made on the four mosques, monthly electricity bills were obtained for 2022 (January-October). below is a report on the cost of monthly electricity bills at each mosque.

Table 4. Monthly Electricity Bills

Month	**Electric Bills**			
	Mosque A	**Mosque B**	**Mosque C**	**Mosque D**
January	IDR 2,500,000.00	IDR 4,800,000.00	IDR 3,750,000.00	IDR 1,600,000.00
February	IDR 2,000,000.00	IDR 4,650,000.00	IDR 3,500,000.00	IDR 1,400,000.00
March	IDR 2,250,000.00	IDR 4,700,000.00	IDR 3,600,000.00	IDR 1,600,000.00
April	IDR 3,000,000.00	IDR 5,000,000.00	IDR 4,000,000.00	IDR 1,750,000.00
May	IDR 2,500,000.00	IDR 4,800,000.00	IDR 3,800,000.00	IDR 1,550,000.00
June	IDR 2,000,000.00	IDR 4,500,000.00	IDR 3,500,000.00	IDR 1,400,000.00
July	IDR 2,800,000.00	IDR 4,800,000.00	IDR 3,800,000.00	IDR 1,750,000.00
August	IDR 2,000,000.00	IDR 4,500,000.00	IDR 3,500,000.00	IDR 1,500,000.00
September	IDR 2,500,000.00	IDR 4,650,000.00	IDR 3,750,000.00	IDR 1,450,000.00
October	IDR 2,250,000.00	IDR 4,750,000.00	IDR 3,750,000.00	IDR 1,500,000.00

5. Results and Discussion

5.1 Numerical Results

Table below is the result of a comparison of electricity costs between the Cost of Electrical Equipment/Month and the Average Monthly Electricity Bills for each mosque.

Table 5. Comparison Cost

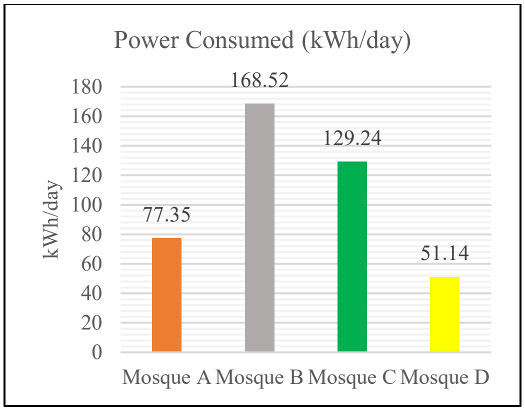
Mosque	**Cost of Electrical Equipment/Month**	**Average Monthly Electricity Bills**
Mosque A	IDR 2,116,213.00	IDR 2,380,000.00
Mosque B	IDR 4,612,055.00	IDR 4,715,000.00
Mosque C	IDR 3,536,926.00	IDR 3,695,000.00
Mosque D	IDR 1,398,767.00	IDR 1,550,000.00

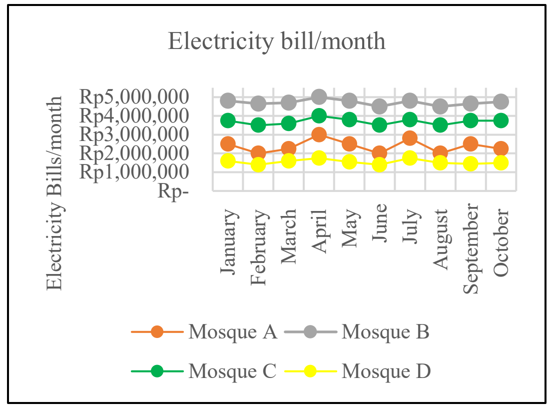
From the data above it can be seen that on average electricity payments made are greater than the cost of calculating energy use. This could be happened because during certain months, such as Ramadan in April and May and Eid al-Adha in July, there are more activities carried out at the mosque so that the time to use the mosque is also longer.

Apart from that, the four mosques are already using pre-paid electricity payments by purchasing electricity tokens. Therefore, with a token purchase system, mosque administrators make purchases at the beginning using estimates from the previous month.

5.2 Graphical Results

The graph below shows the monthly electricity cost incurred by each mosque:





(a) **(b)**

Figure 8.
(a) Power Consumed (kWh/day); (b) Monthly Electricity Costs

Figure 8a describes power consumed (kWh/day) of the 4 mosques that have been surveyed by authpr. As can be seen, Mosque B has the largest power consumed with a value of 168.52 kWh/day, followed by Mosque C, Mosque A, Mosque D with each valued at 129.24 kWh/day; 77.35 kWh/day; and 51.14 kWh/day. This indicates that the larger a mosque, the greater the power consumed/day. Mosque B has the largest area of 300 m2. Then Figure 8b shows the electricity bill/month (Rp/month). In terms of trend, the four mosques have almost the same trend with the highest values found in April 2022 and July 2022. The month of Ramadan in 2022 falls in April 2022 so that there is a significant increase due to the many worship activities during that month so that electricity bills also increase. Furthermore, Eid al-Adha in 2022 falls in July 2022 so there is also a simultaneous increase in the four mosques. Mosque B, which has the largest area among the three other mosques, has the largest electricity bill with an average monthly expenditure within 10 months of Rp. 4,715,000, followed by Mosque C, Mosque A, Mosque D each worth Rp. 3,695,000; Rp. 2,380,000; Rp. 1,550,000. From some of the findings above, it can be concluded that the larger the size of a mosque, the more extra energy conservation efforts are needed to be able to save on electricity usage costs per month. Then, electrical energy conservation can also be done during Ramadan and Eid al-Adha so that the upward trend can also be more stable every month.

5.3 Proposed Improvements

Air Conditioner System Operational Management
Since AC has been the most significant electricity consumer, therefore by properly managing the usage of the air conditioner can be effective in reducing the electricity consumption in mosques. There are four ways in managing the air conditioner to obtain energy efficiency according to Budaiwi & Abdou (2013).

The first one is to control the hours of the AC operation, since most of the usage of the AC is to comfort the air when people are praying therefore the AC does not need to be fully operated most of the time. Approximately one hour during the prayer time is considered enough to comfort the air temperature for praying (Budaiwi & Abdou, 2013).

The second one is to provide an enhanced AC system that is modular instead of centralized. Therefore, we can turn on and turn off a certain AC according to the praying room section to achieve thermal comfort for the worshippers (Budaiwi & Abdou, 2013).

The third one is to set the timer automatically for the AC operation. The time of the prayers are known therefore it can be an input on scheduling the timer set for the AC hours of operation (Budaiwi & Abdou 2013).

The fourth and last one is to set the air supply system not too high from the occupied zone in order for the cooled air to circulate more efficiently in the occupied zone.By installing the AC at the lowest height can be effective to more efficiently cool the occupied zone. Therefore, the energy required to achieve thermal comfort may be reduced (Budaiwi & Abdou 2013).

It is proven that these strategies can reduce the cooling energy consumption in mosques from 23% up to 36% of the total energy consumption. Therefore, these steps can be trialed in other mosques as well (Budaiwi & Abdou, 2013).

Energy Saving for Lighting

As mosque is a building to provide place for worshippers to pray and active for 24 hour, and lightings become second biggest energy consumption, it is necessary to conduct further study to increase efficiency for lighting system for mosque. The smart LED lighting systems have received attention in both research communities and industry as an efficient means of energy conservation. In order to provide minimal energy consumption and satisfy users' requirements for illumination level, the smart LED system can control and manage the overall illumination in the indoor space by considering that the LED lamps have the possibility to be dimmed (Petkovic et al. 2022). Automation also can be applied by using LED lamps with motion sensors on the prayer area. The motion sensor has been a priority rather than a light sensor because the usage of the prayer area depends on the activities and not on the light conditions (Harsritanto et al. 2021). Energy saving in lighting can also be done by reducing illuminance with slow and limited dimming, providing smaller ranges of available illuminances, having a low anchor point for manually dimmable fixtures, providing energy conservative default settings, like lighting automatically switched off and shading pulled up, providing available and tangible lighting and shading control interfaces (Gentile 2022).

Water System Operational Management

In order to reduce the energy consumption by the water system there is an option to install motion sensor in the tap water to reduce the water waste from the ablution activity. By installing a motion sensor in the water tap, it can reduce the flow of the water during the ablution (Harsritanto et al., 2021). This could prevent the water from being wasted during the ablution and may imply towards the energy consumption.

6. Conclusion

This paper presents an energy consumption analysis among mosques in Indonesia. Data on energy usage, active hours, and monthly electricity bills have been obtained from four mosque sample in certain places in Indonesia. The findings were evaluated to find equipment with highest electricity usage. From four mosques, equipment with highest energy usage is air conditioner, followed by lighting. To reduce electricity consumption, improvement can be done by controlling the usage hour of air conditioner according to visitor behavior and conduct automation for turning the air conditioner on and off. Lighting system as second highest energy usage can also be operated efficiently by applying automated LED lighting system and utilize direct sunlight during the day.

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