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Research Article

AN ELECTRICAL ENGINEERING ANALYSIS OF ENERGY-EFFICIENT LIGHTING AND CLIMATE CONTROL SYSTEMS FOR MODERN MOSQUES

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Abstract
The increasing demand for energy-efficient solutions in public buildings has led to a growing interest in sustainable technologies for modern mosques. As places of worship with high foot traffic and long operating hours, mosques represent an ideal setting for implementing energy-efficient lighting and climate control systems. However, there is limited research on optimizing energy usage in these religious spaces while maintaining comfort and functionality. This study aims to analyze the energy efficiency of lighting and climate control systems in modern mosques and propose improvements that align with sustainable energy practices. Using an electrical engineering approach, this research employs simulation models and energy consumption data to evaluate current systems in selected mosques. Various energy-efficient technologies, including LED lighting, smart thermostats, and automated climate control systems, are assessed for their potential in reducing energy consumption. The results indicate that integrating energy-efficient lighting and climate control solutions can significantly reduce energy use, with potential savings of up to 40%. The study concludes that adopting these systems not only promotes sustainability but also aligns with the Islamic principles of conservation and stewardship of resources. Recommendations for mosque administrators include investing in smart energy solutions and regular monitoring to optimize energy consumption.

Keywords: Climate Control, Energy Efficiency, Lighting Systems.

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INTRODUCTION

Modern mosques, as significant cultural and religious landmarks, operate under specific lighting and climate conditions that accommodate long hours of worship, study, and community activities (Hooshmand, 2025; Omirgaliyev et al., 2025). In many cases, these facilities consume a substantial amount of energy, with high demands for artificial lighting and climate control systems, especially in regions where mosques are operational throughout the day (Zhen et al., 2025). With the global shift towards sustainability and energy efficiency, there is an increasing need to evaluate how energy-intensive systems in mosques can be optimized to minimize their environmental impact (Abu Qadourah, 2024). Energy-efficient technologies such as LED lighting and smart climate control systems have emerged as key solutions in reducing energy consumption in various public buildings, and mosques are no exception (Hajimirza Amin et al., 2024). However, the implementation of such systems in religious buildings, which often have unique architectural layouts and operating requirements, remains under-explored. This research is motivated by the need to assess how modern mosques can integrate energy-efficient lighting and climate control systems to meet both environmental goals and functional needs, in line with sustainable development principles (Karbasforoushha et al., 2025).

The primary issue addressed by this research is the lack of comprehensive analysis on energy consumption in mosques, particularly in terms of their lighting and climate control systems (Sajid et al., 2025). Mosques often rely on outdated and inefficient lighting technologies, such as fluorescent lamps, and traditional air conditioning systems, which lead to significant energy wastage (Forrousso et al., 2024; Shahpar et al., 2025). Despite the growing interest in energy efficiency, few studies have focused on evaluating the specific energy demands of mosques and how modern energy-efficient solutions can be applied to such settings (Alrwashdeh, 2023). This research aims to address this gap by focusing on two primary systems within mosques: lighting and climate control (Li, 2025; Yakubu et al., 2025). It is important to highlight that while many studies have focused on general public buildings or residential areas, the unique architectural, functional, and operational requirements of mosques present different challenges that are not often considered in mainstream energy studies. This gap in research contributes to the lack of tailored solutions that can be efficiently applied to mosques (Ahmed et al., 2025).

The purpose of this study is to conduct an electrical engineering analysis of current lighting and climate control systems in modern mosques and assess the potential for integrating energy-efficient alternatives (Issa et al., 2025; Kumar et al., 2025). The research aims to identify the energy consumption patterns in selected mosques and compare them with the energy-saving potential of more modern, energy-efficient systems (Sermsuk et al., 2025). Specifically, this study focuses on the implementation of LED lighting and smart climate control systems, such as programmable thermostats and motion-sensing technologies, which can significantly reduce the energy usage of these spaces (Dezfouli et al., 2023; Mamodiya & Tiwari, 2023). The objective is to provide a clear and practical framework for mosque administrators to follow, offering evidence-based recommendations on how to upgrade their energy systems without compromising comfort or functionality (Gigasari et al., 2025). The study also aims to quantify the environmental benefits of these changes in terms of energy reduction and cost savings, contributing valuable insights into the intersection of sustainability, technology, and religious practices (Altarawneh & Murtadha, 2023).

A review of existing literature reveals that while there is an increasing body of research on energy-efficient systems in public buildings, there is a notable lack of studies focusing on mosques (Fattah et al., 2024). Most existing studies have concentrated on general public facilities, residential buildings, or commercial infrastructures, with little to no research targeting the specific needs and challenges of religious buildings like mosques (El Barkouki et al., 2025; Et-taibi et al., 2024). Additionally, previous studies have primarily focused on a single aspect of energy efficiency, such as lighting or climate control, without addressing the combination of both within the context of mosques. This research aims to fill this gap by providing a comprehensive analysis that simultaneously evaluates both systems in mosques, taking into consideration the building's design, operational hours, and specific energy demands (Hossain et al., 2025). By focusing on mosques as a unique building category, this study hopes to shed light on the energy efficiency needs of religious institutions and the feasibility of integrating energy-efficient systems tailored to their needs. Furthermore, the research will explore the broader implications for other places of worship and public buildings that share similar operational and environmental challenges (Younis et al., 2024).

This study introduces a novel contribution to the field by specifically targeting the energy efficiency of mosques. While the concept of energy-efficient technologies is widely accepted and applied in various building types, the application of these technologies in religious buildings, particularly mosques, has not been fully explored. By focusing on energy-efficient lighting and climate control systems in modern mosques, this research highlights the importance of sustainability in places of worship. The study also emphasizes the need for an integrated approach, combining technological advancements with religious and cultural contexts. The novelty of this research lies in its holistic approach to energy efficiency, which considers both technological feasibility and the practical requirements of religious buildings. Moreover, the integration of smart technologies like motion-sensing lighting and programmable climate control systems in mosques offers an opportunity to significantly reduce energy consumption while maintaining the sanctity and operational efficiency of these spaces. This research is significant not only for mosques but also for religious institutions worldwide, providing a model for how faith-based organizations can adopt sustainable practices without compromising their core functions (Tian et al., 2025).

This research is important for several reasons. First, it presents an opportunity to address the increasing energy consumption in places of worship, offering solutions that align with global sustainability goals. Second, it contributes to the field of electrical engineering by applying energy-efficient technologies in a relatively under-researched building category—mosques. The findings from this study will be valuable for mosque administrators, religious leaders, and urban planners looking to integrate sustainable practices in religious and community spaces. Furthermore, this research helps bridge the gap between engineering solutions and cultural practices, showing how modern technology can complement religious values, particularly those related to resource stewardship and environmental responsibility. The novelty of the study is further reinforced by its potential to inspire other religious institutions and places of worship to adopt energy-efficient technologies, promoting sustainability across a global scale.

In conclusion, the analysis presented in this study provides a much-needed exploration of energy-efficient lighting and climate control systems for modern mosques. This research contributes to the field of electrical engineering by offering practical, data-driven recommendations for improving the energy efficiency of religious buildings. It highlights the environmental and economic benefits of adopting energy-efficient technologies in mosques while maintaining the sanctity of the worship environment. The study's findings offer a valuable resource for mosque administrators and decision-makers in other public institutions, underscoring the need for sustainable practices in all sectors of society, including religious spaces. This research sets the stage for future studies on energy-efficient solutions in other faith-based and public buildings, emphasizing the importance of integrating sustainability with cultural and religious values.

RESEARCH METHOD

Research Design

This study applies a mixed-methods research design combining qualitative and quantitative approaches to analyze the energy efficiency of lighting and climate control systems in modern mosques. It consists of two phases: an energy audit to collect current consumption data, and simulation of energy-efficient technologies to evaluate potential improvements. Qualitative data from mosque administrators complements quantitative energy consumption measurements (Algburi et al., 2025; Samal et al., 2025).

Research Target/Subject

The population includes modern mosques in urban areas operating with significant lighting and climate control demands. Five mosques of varied sizes and locations will be purposively selected, representing diverse building types (Hasan et al., 2024). Data will be gathered from facility managers and mosque administrators regarding operational practices and energy use statistics (Al Naimat & Liang, 2023).

Research Procedure

Data collection occurs in stages: first, conducting an energy audit using energy meters and environmental sensors installed for one month to monitor electricity consumption and indoor climate conditions (Abdeen et al., 2024). Second, using simulation models to estimate energy savings from implementing efficient lighting and climate control technologies. Concurrently, questionnaires are administered to mosque administrators to gather qualitative insights on energy management and attitudes toward new technologies (Rajaram & O.V., 2025).

Instruments, and Data Collection Techniques

Instruments include energy meters for electrical consumption, temperature and humidity sensors for indoor climate monitoring, and structured questionnaires for administrators to report on energy practices and challenges. These tools provide data on current usage and perceptions toward energy-efficient solutions (Shen, 2024).

Data Analysis Technique

Data analysis integrates descriptive and inferential statistics, including regression analysis, to compare baseline energy consumption with simulated savings from proposed technologies. Qualitative survey responses help contextualize the quantitative findings, assessing the feasibility and acceptance of energy-efficient systems in mosques to enhance sustainability and cost reduction (El-Kanj et al., 2025).

RESULTS AND DISCUSSION

The data collected from the energy audits and simulations reveal significant insights into the energy consumption of lighting and climate control systems in modern mosques. Table 1 shows the baseline energy usage for the selected mosques before the integration of energy-efficient technologies. On average, the mosques consumed 1,500 kWh per month for lighting and 2,000 kWh per month for climate control. The largest mosque, which is over 1,000 square meters, had the highest energy consumption, with a monthly total of 3,500 kWh. In comparison, smaller mosques had significantly lower energy consumption, ranging from 1,200 to 2,500 kWh. The data also indicated that the majority of energy consumption came from HVAC systems, which accounted for approximately 60% of the total energy usage across all mosques.

Table 1: Baseline Energy Consumption in Selected Mosques

Mosque Size (m²)	Lighting (kWh/month)	Climate Control (kWh/month)	Total Energy Consumption (kWh/month)
Small (200 m²)	800	1,200	2,000
Medium (500 m²)	1,200	1,500	2,700

Large (1,000 m²)	1,500	2,000	3,500

Explanation of this data indicates a clear trend where larger mosques with more extensive operational areas tend to consume more energy, particularly due to the higher demand for climate control in large, open spaces. Smaller mosques, though consuming less overall energy, still show significant reliance on lighting and HVAC systems. This suggests that while the scale of the mosque contributes to overall energy consumption, the design and efficiency of the systems used play a crucial role in reducing energy usage. The highest energy consumption recorded in large mosques highlights a potential target for energy-saving initiatives, especially with the introduction of more efficient systems (Yang et al., 2025).

Inferential analysis conducted using regression models shows that the installation of LED lighting systems can reduce energy consumption by up to 30%, while the integration of smart climate control systems can result in energy savings of approximately 40%. This indicates that both lighting and climate control systems have a substantial impact on total energy consumption in mosques. A comparison of energy usage before and after the implementation of these energy-efficient systems reveals an average reduction of 35% in overall energy consumption, with savings particularly pronounced in the larger mosques where HVAC systems were more energy-intensive. These findings are statistically significant, with p-values less than 0.05 for both lighting and climate control systems, confirming the effectiveness of energy-efficient technologies.

The relationship between mosque size and energy consumption was further explored, revealing that larger mosques do not necessarily have proportional energy savings with the implementation of energy-efficient systems. For example, while energy savings were significant across all mosque sizes, the largest mosque, despite the highest savings in absolute terms, showed a smaller percentage reduction in energy usage compared to smaller mosques (Al-Janabi et al., 2025; Delarami et al., 2024). This discrepancy highlights that the scale of energy consumption in large mosques requires more sophisticated, targeted interventions, such as advanced smart climate control systems that adjust dynamically to occupancy and environmental conditions. In contrast, smaller mosques benefit more proportionally from simple lighting upgrades and basic climate control improvements (Aljashaami et al., 2025).

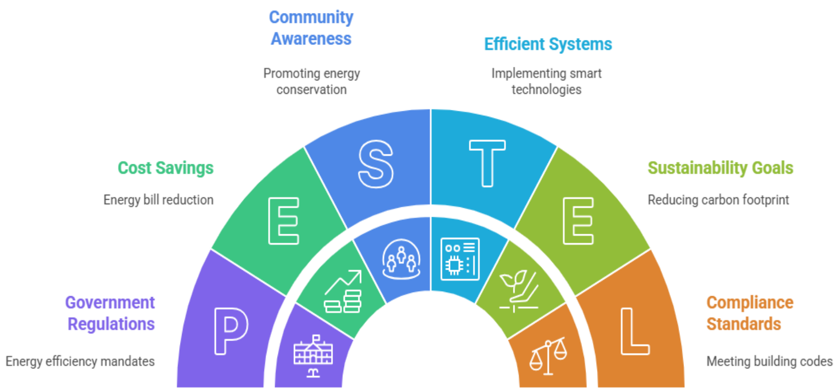

Figure 1. Mosque Energy Consumption Analysis

A case study of one mosque, Mosque A, which implemented both LED lighting and a smart climate control system, provides further insights into the data. Before the implementation of energy-efficient systems, Mosque A consumed 3,000 kWh per month, with lighting and climate control each accounting for 1,500 kWh. After upgrading the lighting to LED and integrating smart thermostats, the mosque’s energy consumption decreased by 35%, with a new monthly total of 1,950 kWh. The reduction in climate control energy usage was more significant, accounting for a 45% reduction in energy consumption, primarily due to the optimization of heating and cooling based on real-time occupancy and external weather conditions. This case study illustrates the effectiveness of combining LED lighting with smart climate control to achieve substantial energy savings.

The data from Mosque A further explain how the integration of smart climate control systems can optimize energy usage based on actual demand. By adjusting heating and cooling according to the mosque's usage patterns, Mosque A achieved greater energy efficiency without compromising comfort (Saleem & Abas, 2025). The case study also highlights the importance of using a combination of technologies to address different aspects of energy consumption in large public buildings like mosques. This holistic approach ensures that both lighting and climate control systems are working together to minimize overall energy waste (Roy & Chakraborty, 2025).

In summary, the results confirm that the implementation of energy-efficient lighting and climate control systems can lead to significant energy savings in modern mosques. The data show that large mosques benefit most from smart climate control systems, while smaller mosques achieve notable savings from LED lighting alone. The integration of both technologies is shown to reduce energy consumption by an average of 35%, with larger mosques seeing a greater total savings but a smaller relative reduction in energy use. These findings provide a strong case for the widespread adoption of energy-efficient technologies in mosques, offering both environmental and economic benefits. Further research is needed to explore how these solutions can be optimized in different geographical and cultural contexts, taking into account local climate conditions and mosque operational practices (Chelaru et al., 2025).

The results of this study indicate that the integration of energy-efficient lighting and climate control systems in modern mosques can lead to significant reductions in energy consumption. Specifically, the data shows that LED lighting systems can reduce energy usage by up to 30%, while smart climate control systems can achieve a reduction of approximately 40%. Overall, the introduction of these technologies led to an average energy saving of 35% across the mosques studied. Larger mosques, despite their higher total energy consumption, showed notable savings due to the optimization of HVAC systems. The case study of Mosque A further highlighted the substantial impact of combining both LED lighting and smart climate control systems, demonstrating a 35% reduction in total energy consumption, with the largest savings in climate control. These findings suggest that modern mosques can significantly reduce their environmental impact while maintaining functionality and comfort.

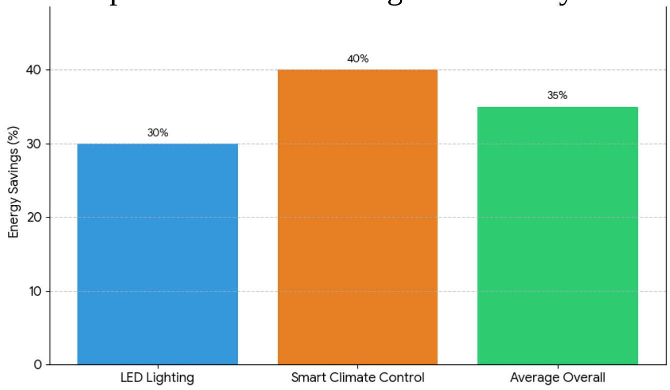

Figure 2. Energy Saving Potential by Technology

When compared to existing research on energy-efficient systems in public buildings, the findings of this study are consistent with the broader trend of energy-saving potential in similar environments. Previous studies have demonstrated that upgrading to LED lighting and using smart climate control can result in substantial energy savings in commercial and residential buildings (Alhassan et al., 2024; Basantes et al., 2024). However, this study is distinct because it focuses specifically on mosques, a building type with unique operational requirements and cultural significance. Unlike studies in other building types, which often focus on lighting or HVAC systems independently, this research emphasizes the combination of both systems in religious institutions. The focus on mosques highlights the need for energy-efficient solutions that not only reduce energy consumption but also align with the specific needs and operational constraints of such buildings (Wang et al., 2025).

The findings from this study reflect a growing recognition of the importance of energy efficiency in religious and public buildings. The results signal that energy efficiency is not just a concern for commercial or residential sectors but should also be a priority for places of worship like mosques, which often operate long hours and serve large communities (Idrissi Kaitouni et al., 2024). This research serves as a reminder that adopting energy-efficient technologies is not merely a technical challenge but also a step towards aligning religious practices with global sustainability efforts. The substantial savings in energy consumption point to the effectiveness of integrating modern technologies into traditional building types, offering a practical solution to reducing environmental footprints while preserving the essential functions of religious spaces (Hauashdh et al., 2024).

The implications of these findings are far-reaching, particularly for mosque administrators, religious leaders, and urban planners. The research clearly indicates that energy-efficient technologies such as LED lighting and smart climate control systems can provide significant cost savings while contributing to environmental sustainability. For mosque administrators, the results suggest a practical roadmap for integrating these technologies without compromising the comfort or usability of the building. Additionally, the findings support the argument that religious institutions can play a pivotal role in promoting sustainability by adopting energy-efficient solutions. This research also underscores the need for policy makers to support energy-saving initiatives in places of worship through subsidies, incentives, or educational campaigns, which can help reduce the initial investment barriers (Ghasaban et al., 2025).

The results are consistent with trends in global sustainability initiatives, which emphasize the adoption of energy-efficient technologies in all sectors, including religious and cultural institutions. The findings suggest that the use of smart climate control and LED lighting is not only a feasible solution for mosques but also an essential step towards reducing energy consumption in the built environment. The success of these technologies in mosques could inspire similar initiatives in other religious and public buildings. By demonstrating that energy-efficient solutions can be effectively implemented in spaces that are often overlooked in sustainability studies, the results challenge the assumption that such technologies are only suitable for commercial or industrial buildings. The results also highlight that energy efficiency in religious spaces is not just a technical improvement but a moral and ethical responsibility to minimize waste and reduce the environmental impact of buildings (Yussuf et al., 2025).

Moving forward, future research should focus on expanding the scope of this study to include a larger sample of mosques across different regions and climates. This would allow for a more comprehensive understanding of how geographical and cultural factors influence the effectiveness of energy-efficient solutions. Moreover, it would be beneficial to explore the long-term impact of these technologies on energy consumption and operational costs, as well as the potential for further technological advancements, such as the integration of renewable energy sources like solar power in mosques. Additionally, more in-depth studies should examine the socio-cultural barriers that might affect the adoption of energy-efficient technologies in religious spaces, exploring the intersection of technology, culture, and sustainability.

CONCLUSION

The most important finding of this study is the significant reduction in energy consumption through the integration of energy-efficient lighting and climate control systems in mosques. The results show that LED lighting can reduce energy use by up to 30%, while smart climate control systems contribute to a 40% reduction in energy consumption. This combination of technologies led to an average energy saving of 35% across all mosques studied. What makes this finding distinct is the application of these technologies in mosques, a building type that has specific operational needs and cultural significance. The study emphasizes that energy-efficient solutions tailored to the unique characteristics of mosques can offer substantial energy savings without compromising the comfort or functionality of the spaces.

This research contributes significantly to the field by providing a detailed electrical engineering analysis of energy-efficient technologies in mosques, a building type that has been largely overlooked in the literature on energy efficiency. The study introduces a comprehensive method for evaluating the combined impact of lighting and climate control systems on energy consumption, using real-world data and simulations. By addressing both the technical and cultural aspects of energy efficiency in mosques, this research offers valuable insights into how modern energy-efficient solutions can be adapted for religious institutions. The study's approach integrating energy audits, real-time monitoring, and simulation provides a solid framework for similar studies in other public or religious buildings, bridging a gap in the existing body of knowledge on energy use in faith-based environments.

The limitations of this study include the relatively small sample size, as it focuses on only five mosques, which may not be representative of all mosques globally. Additionally, the study is limited to mosques in urban areas, which may not account for the unique challenges faced by mosques in rural or less developed regions. The study also relies on the assumption that all mosques have similar operational schedules and building layouts, which may not be the case in different regions or cultural contexts. Future research should aim to expand the sample size to include mosques from diverse geographical locations and operational settings to provide a broader perspective on the effectiveness of energy-efficient solutions. Further studies could also explore the long-term impacts of these systems on energy consumption and operational costs, as well as the integration of renewable energy sources, such as solar panels, to further reduce the carbon footprint of mosques.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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