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Implementation of renewable energy using smart light solar cell system for mosque energy efficiency

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ABSTRACT

The outreach activity focuses on improving energy efficiency at Sirothol Mustaqim Mosque in Pasuruan Regency. The primary issue addressed is how to meet the lighting needs of the mosque while minimizing the use of PLN electricity and optimizing the use of lamps and electricity based on the number of congregants. The main objective is to implement renewable energy through solar panels to replace conventional electricity, analyze the efficiency of electricity usage based on lighting requirements, and enhance electricity efficiency based on time and lamp location. Expected outcomes include increased electricity usage efficiency, reduced operational costs for mosque management, and advanced scientific and technological knowledge in the general community. The participatory action research (PAR) method emphasizes active participation and collaboration between academics and the community. The project commences with a field survey to identify energy needs and the potential for solar energy sources on-site. Subsequently, project planning and design are carried out, followed by project implementation with training for mosque administrators. The results of the project's implementation include energy usage efficiency, the integration of renewable energy in a religious context, and contributions to understanding environmental responsibilities. The success of the implementation measure calculations for the usage time of 40-watt lamps using solar energy are provided, along with a comparison of PLN electricity costs and solar energy usage costs. The analyses demonstrate favorable energy efficiency using solar power.

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1. INTRODUCTION

Solar energy as a renewable energy source has been widely used by society as an environmentally friendly energy source (Haryanto, 2021). Energy is obtained from sunlight and converted into thermal or electrical energy. Because Indonesia is located near the equator and receives sunlight throughout the year, the potential for solar energy utilization is enormous (Mayasari et al., 2022). Although solar energy has proven environmentally friendly and cost-effective, its utilization in mosques is still limited (Karina & Thohari, 2018). However, mosques are potential locations for solar energy utilization, especially for cost-saving purposes. Many mosques use electric lights and cooling systems, which consume significant electrical energy daily, including the Sirothol Mustaqim Mosque in Pasuruan Regency.

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The extensive use of electrical energy in mosques results in high electricity bills and contributes to environmental pollution due to carbon emissions from conventional power plants. Utilizing sunlight as an alternative source of electricity generation is a significant innovation. This is not only because sunlight is an abundant energy source but also because solar energy utilization has no negative impact on the environment (Heri, 2012). The electricity generated can illuminate the mosque and power electronic equipment such as speakers and lighting.

The limited use of solar energy in mosques can also be attributed to the lack of Internet of Things (IoT) technology in electricity conservation. IoT enables efficient and real-time energy management and monitoring, which can reduce high electricity costs (Hermanto et al., 2022). Although using solar panels in mosques can help save on electricity costs and reduce environmental impact, the use of solar panels without IoT technology can lead to several issues.

Firstly, solar panels with IoT technology are easier to monitor in real time. With direct measurements from the solar panel system, detecting when solar panels malfunctioning or not operating correctly is more manageable. This can lead to unexpected interruptions in electricity production from solar panels, forcing reliance on conventional electrical sources and resulting in higher electricity costs. Therefore, integrating IoT into the solar panel system allows for more effective monitoring and timely maintenance to maximize energy efficiency (Sutikno et al., 2023).

Secondly, optimizing electricity production from solar panels is easier with IoT technology (Utama, 2017). Solar panels generate electricity that fluctuates depending on weather conditions and the time of day (Ananto & Santoso, 2021). With IoT technology, it is easier to determine when solar panels produce enough electricity and when it can be stored for future use. Consequently, electricity usage from solar panels cannot be efficiently managed, and electricity must be drawn from conventional power sources, resulting in higher electricity costs. Therefore, integrating IoT into the solar panel system optimizes electricity production and storage to meet energy needs more efficiently (Sutikno et al., 2023).

Thirdly, using solar panels without IoT technology also makes optimizing electricity usage in the mosque difficult. Without IoT technology, it is challenging to determine when electrical equipment inside the mosque is in use and when it can be turned off (Primiceri & Visconti, 2017). This can lead to excessive and inefficient electricity usage. Integrating IoT into the solar panel system can help control electricity usage within the mosque more intelligently, thus improving energy efficiency.

Therefore, IoT technology is essential in saving electricity in mosques that utilize solar panels. IoT technology can help monitor and optimize electricity production from solar panels, optimize electricity usage within the mosque, and reduce high electricity costs. Thus, the use of IoT technology on solar panels in mosques can contribute to electricity cost savings and reduce the environmental impact of using electricity from conventional power plants. This aligns with the implementation of environmentally friendly renewable energy. Applying solar panels in Sirothol Mustaqim Mosque provides a theoretical and conceptual framework for using renewable energy in religious and community contexts. Implementing solar panels in mosques can develop theories about how renewable energy can become an integral part of worship in Islam. This can pave the way for a deeper understanding of human responsibility as stewards of the Earth and responsible resource usage (Hidayat et al., 2023).

In this project, the implementation of scientific knowledge is carried out to replace conventional electrical power usage with renewable energy through the use of the Internet of Things (IoT) with the aim of analyzing the efficiency of electricity usage based on the lighting needs inside Masjid Sirothol Mustaqim in Pasuruan Regency. This effort is intended to enhance the efficiency of electricity usage based on factors such as time and the placement of lamps, with a focus on improving energy usage

efficiency within the mosque. Solar energy utilization in mosques can become a center for education on sustainability and environmental protection in Islam. This can generate theories on how religious principles can be integrated with sustainable practices focused on ecological preservation (Budiman & Utomo, 2018).

Figure 1. Problem solving solution

2. METHODS

Method of Activities

The Participatory Action Research (PAR) method is employed to achieve the desired outcomes. Figure 2 is the general steps in the PAR method for community engagement (Rohman & Iqbal, 2016): (1) Collaborative Planning and Action Research. Collaborate with the mosque's *takmir* and the Sirothol Mustaqim mosque foundation to plan the community engagement project, outlining objectives, methods, budget, and necessary resources. In the planning phase, use the action research method to gather relevant data and information related to the issues faced by the community (Parnawi, 2020); (2) Solution Development. Based on findings from the action research, work collaboratively with the mosque's *takmir* and the Shirotol Mustaqim mosque foundation to develop solutions or strategies to address the identified issues; (3) Project Implementation, Evaluation, and Reflection. Implement the project involving the mosque's *takmir* and the Sirothol Mustaqim mosque foundation members impacted by it. This may include training, education, or providing relevant services; (4) Evaluation and Results Dissemination. Evaluate the project's outcomes with the mosque's *takmir* and the Shirotol Mustaqim mosque foundation to assess its impact and determine if any improvements or changes in strategy or actions are needed. Share the project's results with the broader community. This can be done through publications, seminars, workshops, or other means that allow the knowledge and experiences gained to benefit a broader audience; and (5) Sustainability and Continuous Engagement. Ensure that the community engagement project does not remain a one-time activity but can be sustained over the long term to provide ongoing benefits to the served community. Continue involving the community in the planning and decision-making processes so that they actively participate in the changes.

The PAR method for community engagement strongly emphasizes active participation and collaboration between academics and the community, aiming to create tangible positive impacts within the served community (Afandi et al., 2022).

Figure 2. Methods used in community service

3. RESULTS AND DISCUSSION

Results

The implementation of community service regarding the utilization of Smart Light Solar Cell as energy self-reliance in the effort to substitute science and technology in Sirothol Mustaqim Mosque through a series of steps and activities to introduce, implement, and demonstrate the use of Smart Light Solar Cell technology to the community in order to replace conventional technology that is less efficient and has negative environmental impacts. The following are the general steps in the implementation of this community service.

Outreach team to conduct a field survey

The first step is for the outreach team to conduct a field survey to identify energy needs and the potential for solar energy sources at the location. This activity involves the roles of the mosque's committee and the foundation for the education of Sirothol Mustaqim mosque as an initial study of energy consumption patterns, existing infrastructure, and the potential use of solar energy.

Following the initial identification step, the outreach team conducts a more in-depth field survey to identify energy needs and the potential utilization of solar energy sources at the mosque's location. Involving the mosque committee in this initial stage is crucial because they have a profound understanding of energy consumption patterns in the mosque, existing infrastructure, and potential challenges that may arise in using solar energy. Therefore, the active participation of the mosque committee and the foundation for education in this preliminary study enables community service to design more accurate solutions that align with the mosque's needs and its congregation.

Figure 3. The outreach team, accompanied by the mosque committee and the foundation's education administrators surveyed the Sirothol Mustaqim mosque area

Planning and design of the project blueprint

Based on the analysis of local needs and potential, the outreach team, the mosque committee, and the foundation's education administrators plan how the Smart Light Solar Cell technology can be implemented as a self-sufficient energy solution (Firdaus et al., 2021).

After identifying the energy needs and analyzing the potential of solar energy sources at the mosque's location, the next step is detailed project planning and design. The outreach team collaborates with the mosque's committee to begin designing how the Smart Light Solar Cell technology can be implemented as a self-sufficient and sustainable energy solution in the mosque.

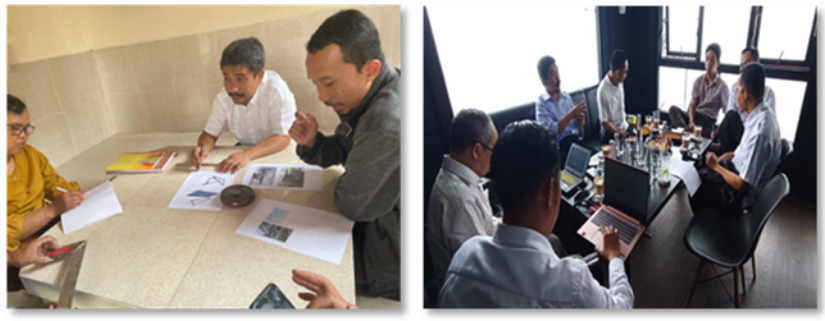

Figure 4. Discussion of solar panel system design and system needs analysis

This planning encompasses various aspects, including selecting the appropriate type of solar panels, determining the optimal location for solar panel installation, calculating energy storage capacity, and designing an IoT-based control system to be used. Collaboration between the community engagement team and the mosque's *takmir* (management) during this stage is crucial because the *takmir* has a deeper understanding of their mosque's specific needs and characteristics. By detailing this project's planning, it is expected that the implementation of the Smart Light Solar Cell technology can proceed more efficiently and align with the mosque's requirements, ultimately contributing positively to energy conservation.

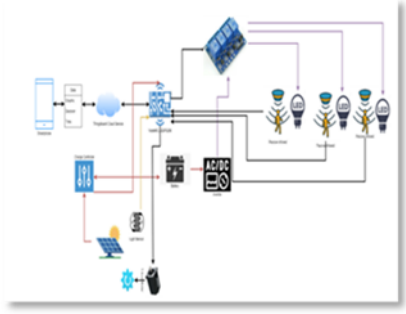

Figure 5. The design of the solar panel system

Implementation of the project

The mosque's *takmir* and congregation members are provided with training on how to care for, operate, and maintain the Smart Light Solar Cell technology. This training involves active interaction and hands-on practice with mosque administrators, enabling them to become self-reliant in using the technology.

Implementing the project is crucial in integrating Smart Light Solar Cell technology into the mosque. One essential aspect of this implementation is training the mosque's *takmir* and congregation members on how to care for, operate, and maintain the technology. This training ensures they can become self-reliant using Smart Light Solar Cell technology. The training is not purely theoretical but also involves active interaction and hands-on practice with mosque administrators. Participants in the training will learn how to operate the Smart Light Solar Cell system, maintain solar panels, and manage energy storage. Additionally, they will gain an understanding of how to keep the technology performing optimally and safely.

By providing this comprehensive training, it is expected that the *takmir* and congregation members can effectively manage and utilize Smart Light Solar Cell technology in the day-to-day operations of the mosque. This will improve energy efficiency in the mosque and empower the local community to maintain and sustain this technology.

Figure 6. Installation and training with mosque officials

Monitoring and evaluation

After the implementation, the community service team monitors the performance and effectiveness of the Smart Light Solar Cell. This evaluation can help identify potential issues and ensure the technology operates as expected.

Monitoring and evaluation are crucial steps in this project. The community service team will regularly monitor its performance and effectiveness after implementing the Smart Light Solar Cell technology in the mosque. This monitoring and evaluation aim to identify potential issues that may arise while using this technology and ensure that the system functions as expected. Monitoring will include measuring the electricity production from the solar panels, the status of energy storage, and the energy usage by the mosque. This data will ensure that the system operates efficiently and that the mosque can effectively meet its energy needs.

Evaluation will also involve feedback from the mosque's *takmir* and congregation members who use this technology. By talking to them and listening to their experiences using the Smart Light Solar Cell, the community service team can identify improvements or changes that may be needed in the system or the training provided. Thus, monitoring and evaluation will help ensure that this project successfully achieves its goal of improving energy efficiency in the mosque and empowering the local community to use sustainable technology.

Figure 7. Monitoring and Evaluation Activities

Demonstration and sustainable models

If the initial implementation is successful, the community engagement team can develop a demonstration model that other communities can adopt. This model exemplifies how Smart Light Solar Cell technology can effectively integrate into everyday life.

After the initial implementation proves successful, the next step is to develop a pilot model that can serve as a guide for other communities. This model will be a concrete example of how Smart Light Solar Cell technology can effectively integrate into daily life. The pilot model will encompass all the steps and best practices applied in this project.

The pilot model will be designed so that it can be quickly adopted by other mosques or communities interested in implementing similar technology. It will include system design, operation guidelines, and maintenance and upkeep instructions. By having a robust pilot model, other communities are expected to easily follow the path of this project's success and adopt Smart Light Solar Cell technology for sustainable energy use.

Furthermore, the pilot model will prove that implementing renewable energy-based technology can significantly benefit energy and operational cost savings. Thus, this model will be a step towards sustainability in using more environmentally friendly energy sources in various communities.

Advocacy and dissemination

Information about the successful experience of this community service project needs to be disseminated through various media, such as scientific publications, social media, and local news. This can inspire other communities to adopt similar technologies. The community service activities carried out are documented in videos and uploaded on the social media platform YouTube (Qosim, 2023).

In addition to social media, the community service activities that have been carried out have successfully been featured in online education news located at Siarindo Education Magazine (Yusuf, 2023).

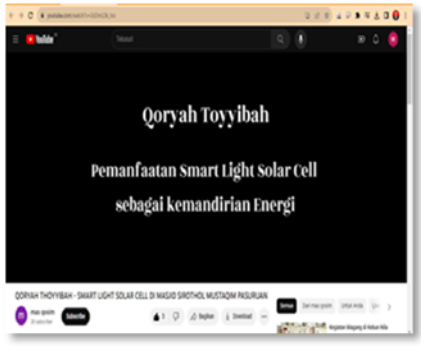

Figure 8. Publication of videos on social media YouTube (Qosim, 2023)
Figure 9. Publication in the online mass media Siarindo Education Magazine.

It's important to remember that the implementation of this community service should be based on a deep understanding of the local context and community needs. The primary goal is to provide tangible and sustainable benefits to the community by replacing conventional technologies with more efficient and environmentally friendly solutions.

Discussion

The installed Smart Solar Charger Controller system has undergone calculations to determine the duration of battery usage and charging by solar panels for an inverter with a load.

The basic formula used is Equation 1 (Eq.1):

$$P = V \times I$$

Where I = Current (Amperes), P = Power (Watts), V = Voltage (Volts)

In the installed system, the load used is 40 Watts, and the battery used is 12V/40Ah. Maka The calculation results are Equation 2 (Eq.2):

$$I = \frac{40W}{12V} = 3.34 \text{ Amperes}$$

Usage time = $\frac{40Ah}{3.34A}$ =11.98 Hours, then subtracted by the battery efficiency of 20%

So, the battery's usage time, starting from a full charge, to power a 40Watt load, is approximately 11 hours and 58 minutes after considering the 20% efficiency loss.

11.98 hours - 2.395 hours = 9.585 hours (9 hours 35 minutes)

So, in the smart light solar charger system, the battery's endurance from a full position to power a 40 W lamp can last for 9 hours and 35 minutes.

The implementation of solar panels at the Sirothol Mustaqim mosque has generated theories and concepts related to using renewable energy in a religious and community context. The deployment of solar panels at the mosque can further develop ideas about how renewable energy can become an integral part of worship in Islam. This can pave the way for a deeper understanding of human responsibility as stewards of the Earth and the responsible use of natural resources.

Mosques that utilize solar energy can serve as centers for education on sustainability and environmental protection within Islam. This can generate theories on how religious principles can be integrated with sustainable practices that focus on environmental conservation.

Scientific Discussion

Energy

The installation of solar panels in Sirothol Mustaqim Mosque results in efficiency, encompassing optimal energy usage, wise utilization of natural resources, and maximum returns on investment in renewable energy technology. The energy generated by solar panels with a 100 Watts-peak (WP) capacity in a day heavily depends on factors such as geographical location, solar panel orientation, panel tilt, weather conditions, and seasons. However, we can provide a general estimate to give an idea of how much energy can be generated by 100 WP solar panels in a day.

Solar panels with a capacity of 100 WP in a sunlit location can produce approximately 3-5 hours of full sunlight each day, depending on the factors as mentioned above. Solar panels can generate energy ranging from 300 Wh (watt-hours) to 500 Wh daily. In one day, the energy generated in Wh (watt-hours)

can be converted to kWh (kilowatt-hours) by dividing it by 1000. Therefore, the power generated by 100 WP solar panels in one day ranges from 0.3 kWh to 0.5 kWh.

However, it's important to note that this is a general estimate, and actual figures can vary significantly based on geographical location and changing weather conditions. Additionally, solar panels typically produce little power throughout the day due to fluctuations in sunlight intensity. Therefore, a monitoring system will help measure the actual energy production from the solar panels.

Financial efficiency

To calculate the cost of a 40Watt light bulb running for 5 hours at an electricity rate of 1600 Indonesian Rupiah (Rp) per kWh, you can use the following calculations in Equation 3 (Eq.3):

Calculate the energy consumption in kWh:

Energy (kWh) = Power (kW) × Time (hours)

Energy = 0.04 kW × 5 hours = 0.2 kWh

Calculate the cost in Rupiah:

Cost (in Rupiah) = Energy (kWh) × Cost per kWh

Cost = 0.2 kWh × Rp 1600 = Rp 320

So, the cost of running a 40Watt light bulb for 5 hours is Rp 320. If you want to calculate the monthly cost for running the light bulb for 30 days you can use the following calculations in Equation 4 (Eq.4):

Monthly Cost = Daily Cost x Number of Days

Monthly Cost = Rp 320 x 30 = Rp 9,600

Therefore, the cost of running the 40Watt light bulb for 5 hours a day for 30 days would be Rp 9,600.

4. CONCLUSION AND RECOMMENDATIONS

The Community Service Program aims to enhance the community's understanding of renewable energy technology and how to integrate it into their daily activities in the mosque. With the successful installation of the solar power generator and a well-functioning system, this program is expected to be an inspirational example for other mosques to adopt similar technology for energy savings and environmental conservation. In addition to providing direct benefits to Shirotol Mustaqim Mosque, this program is also anticipated to have a broader positive impact by promoting awareness of sustainability and the use of renewable energy within the local community. Therefore, this program benefits Shirotol Mustaqim Mosque and can create a broader positive impact by inspiring other mosques to follow suit in implementing renewable energy technology, running more efficient operations, and actively participating in environmental preservation through carbon reduction efforts.

There is a need to increase the energy storage capacity to supply more lighting and other electrical equipment. Regular and consistent monitoring of the built system is crucial to track its performance and ensure it operates smoothly. This activity also aims to identify potential issues or improvements that may be needed in the future. Additionally, further development in monitoring can be done online as the internet network in the service area advances, allowing for real-time monitoring and prompt action if necessary.

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