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Empowering communities through solar energy: A strategic response to power deficits

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ABSTRACT

Mushalla Longga Congkeh in Guguak District, Lima Puluh Kota Regency frequently experiences electricity shortages that disrupt worship and daily community activities. This community service program aims to address the limited electricity supply through the implementation of Appropriate Technology (TTG) in the form of a Solar Power Generation System (PLTS). The implementation methods include socialization, technical training, and mentoring of the local community during the installation and maintenance of the PLTS system. The main objective is to improve access to renewable, environmentally friendly, and sustainable energy sources. The program successfully installed a 100 Wp PLTS system capable of producing approximately 400 WH of electricity per day, sufficient to meet the lighting and sound system needs of the *mushalla*. The impact of this activity is measured quantitatively through increased electricity availability, reduced operational costs, and improved community energy independence. This program demonstrates that solar energy utilization offers a concrete solution to electricity shortages, and its implementation model has the potential to be replicated in other regions facing similar energy access challenges.

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1. INTRODUCTION

Nagari Guguak VIII Koto, located in the Guguak District, Lima Puluh Kota Regency, West Sumatra Province, covers an area of 21.70 km², comprising approximately 20.43 percent of the total area of the district, based on BPS data from 2019. The region consists of eight jorong (village-level administrative units), namely Kuranji, Tiakar, Guguak, Ketinggian, Kubang Tungkek, and Balai Talang. It is situated around 13 kilometers from the district capital in Sarilamak and 125 kilometers from the provincial capital of Padang. With a population of more than 14,000 residents, the area features a diverse topography of hills and plains, providing substantial potential for regional development, particularly in energy and infrastructure. The provincial road that traverses Guguak VIII Koto plays a vital role in connecting it with Payakumbuh City, Suliki, Koto Tinggi (Agam Regency), and Pasaman, thereby facilitating socio-economic mobility and access. The local population is strongly tied to Islamic cultural and spiritual values. This is

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reflected in the active use of *mushalla*s and mosques, which serve not only as places of worship but also as centers for religious education, social gatherings, and community-based financial management such as zakat and donation collection. One of these central religious facilities is *Mushalla* Longga Congkeh, located at the heart of the residential area. It plays a pivotal role in the community, serving as a spiritual center and a space for communal engagement. The *mushalla* is managed by a local committee referred to as the *Mushalla* Management Group, which consists of volunteers from the surrounding community who are responsible for overseeing daily operations and maintaining the facility's infrastructure. Despite its important role, the *mushalla* remains entirely dependent on electricity from the PLN (State Electricity Company), without any form of backup or alternative energy system. This reliance poses challenges given the region's frequent power outages and rising energy demands (Afif & Martin, 2022).

One of the key problems faced by the *Mushalla* Management Group is the inconsistent electricity supply, which often disrupts evening prayers, religious lectures, and special Islamic events. Based on initial field observations and structured interviews conducted by the service team, it was found that the *mushalla* experiences power outages approximately 3 to 5 times per month. These disruptions affect not only lighting but also the sound system that supports communal prayers and announcements. Furthermore, the *mushalla* has no emergency electricity backup such as generators, and the increasing monthly electricity bills add to the operational strain. These issues are compounded by the lack of community awareness and technical knowledge about renewable energy options, which hinders the adoption of sustainable energy alternatives (Sutoyo et al., 2023; Wahyuddin et al., 2023).

To address this issue, the community service team introduced an Appropriate Technology (Teknologi Tepat Guna/TTG) solution through the implementation of a Solar Power Generation System (PLTS) specifically tailored to meet the *mushalla*'s needs. The system includes a 100 Wp monocrystalline solar panel, a battery for energy storage, an inverter, a Solar Charge Controller (SCC), and a Miniature Circuit Breaker (MCB) for safety. The selection of these components was based on cost-effectiveness, ease of installation, minimal maintenance, and compatibility with the *mushalla*'s energy requirements, particularly lighting and sound systems. This technological intervention was accompanied by community training, hands-on technical workshops, and participatory installation, empowering the *Mushalla* Management Group and residents to not only operate but also maintain the system independently (Robertua et al., 2024; Rumbayan et al., 2021). Several recent studies support the relevance and effectiveness of solar-based TTG solutions for community-scale applications. Rusli et al. (2023) demonstrated that a 100 Wp PLTS system is capable of generating an average of 400 Wh of electricity per day, sufficient to power lighting and audio equipment in small religious facilities. Maka & Chaudhary (2024) emphasize that integrating a battery system allows for the storage and availability of power during night hours, addressing one of the major constraints of solar energy systems. Furthermore, Prathibha et al. (2024) highlight the importance of simple, modular system design including safety features like SCCs and MCBs, to ensure long-term usability and user safety in non-technical community settings. These findings justify the selection of PLTS as a technically sound and community-appropriate solution.

In line with this context, the purpose of this community service program is to solve the electricity shortage faced by the *Mushalla* Longga Congkeh Management Group through the application of a solar photovoltaic system that provides a sustainable, environmentally friendly, and community-manageable energy solution. This program not only aims to increase the availability and reliability of electricity at the *mushalla* but also promotes energy independence and renewable energy literacy within the local community.

2. METHODS

Activity Design

This community service activity was conducted at *Mushalla* Longga Congkeh, located in Nagari Guguak VIII Koto, Guguak District, Lima Puluh Kota Regency, West Sumatra. The partner involved in this program is the *Mushalla* Management Group, consisting of 15 individuals who are actively responsible for managing worship facilities as well as organizing religious and social activities within the community. The tools and facilities used for program implementation include: (1) 1 unit of monocrystalline solar panel with a capacity of 100 Wp; (2) 1 unit of 12V battery for energy storage; (3) 1 unit of pure sine wave inverter; (4) 1 unit of solar charge controller (SCC); (5) 1 unit of miniature circuit breaker (MCB); (6) A set of cables, connectors, and electrical panel box

Operational Technical Description

The installed solar power system is designed to operate autonomously using a direct current (DC) generation and storage scheme, with the following flow of operation: (1) Solar Energy Harvesting, during daylight, the 100 Wp monocrystalline solar panel captures solar radiation and converts it into direct electrical current; (2) Charge Regulation, the electricity flows into a solar charge controller (SCC), which regulates voltage and current to ensure the 12V battery is charged safely and efficiently, avoiding overcharging or undercharging; (3) Energy Storage, the 12V deep-cycle battery stores the energy generated during the day. This stored energy can then be used during non-sunlight hours, particularly for night-time prayer activities; (4) Power Conversion, the system uses a pure sine wave inverter to convert DC (from the battery) into alternating current (AC), making it compatible with common electrical devices such as lamps and sound systems used in the *mushalla*; (5) System Distribution and Protection, the output from the inverter is connected to the *mushalla*'s internal electrical wiring. A miniature circuit breaker (MCB) is installed as a protective device to prevent electrical overloads or short circuits.

The entire system is housed in a protective box near the main entrance of the *mushalla* for easy monitoring and maintenance. The system is designed to be intuitive, using LED indicators and labeled switches, so that local users without a technical background can operate and maintain it safely.

The design concept of the implemented solar power generation system (PLTS) is an off-grid solar system (standalone, not integrated with PLN), which is intended to meet the basic electricity needs of the *mushalla*, such as lighting and sound system operations. This system is capable of producing approximately ±400 Wh of electricity per day, depending on solar radiation intensity, and stores the energy in a battery for nighttime use. The system's operational technique involves installing the solar panel on the *mushalla* rooftop, wiring it to the battery and inverter, and integrating it into the *mushalla*'s internal electrical circuit. The system is designed to be simple, so that it can be easily operated and maintained by community members.

Program Implementation Methods

The program implementation used an educational and participatory approach, involving three main methods: (1) Socialization and technical training. The first phase involved educating the community about the importance of renewable energy, particularly solar power, as a solution to local electricity shortages. Training materials covered the basic principles of how solar power systems work, the economic and environmental benefits, and an introduction to the system's components (solar panels, battery, inverter, SCC, and MCB). The training was delivered using interactive discussions, live demonstrations, and hands-on practice, tailored to the local community's educational background. The goal was to enhance both awareness and practical knowledge, enabling participants to understand the function and maintenance of the PLTS system; (2) Assisted implementation. In this phase, the community was directly involved in the installation of the PLTS system, guided by the technical team. This included site preparation, mounting of the solar panels, electrical wiring, and configuring the system to power the *mushalla*. This participatory approach ensured that partners not only received technology but also acquired the skills to operate and maintain it. Technical assistance was also provided during the system's first operational test to ensure everything functioned according to design; (3) Program evaluation. Evaluation was conducted using quantitative indicators to measure the program's impact. These included: (a) The amount of electricity generated daily by the PLTS system (±400 Wh/day), measured using a multimeter and battery monitoring tools; (b) The operational duration of electrical loads, such as lighting and sound systems, supported by the system; (c) The increase in participant understanding, assessed through pre-test and post-test scores on renewable energy knowledge and system maintenance.

Evaluation also involved recording energy usage, system performance during different times of the day, and collecting feedback to identify areas for improvement or future replication. Table 1 showing the program implementation stages.

Table 1. Stages of program implementation

Activity	Description	Goal	Time
Initial situation analysis	Field observations and interviews with the *Mushalla* Longga Congkeh management regarding electricity needs and site readiness for PLTS installation	Identifying electricity shortage problems and assessing location suitability for PLTS	Second week of July 2024
Socialization and renewable energy education	Introducing solar energy concepts, PLTS benefits, and the community's role in using alternative energy technologies	Improving partner awareness about the importance of solar-based alternative energy	Day 1 (August 10, 2024)
Technical training on PLTS system	Introduction to PLTS components, installation simulations, maintenance techniques, and safety procedures	Providing partners with technical skills to manage and maintain the PLTS system	Day 1 (August 10, 2024)
PLTS installation and performance testing	Installation of 100 Wp solar panel, battery, inverter, SCC, and MCB with active partner involvement and output voltage testing	Applying the system based on needs and ensuring optimal function	Day 2 (August 11, 2024)
Advanced training and maintenance guidance	Follow-up training on panel cleaning, battery checks, and energy usage logging	Ensuring sustainability and encouraging maintenance independence among partners	Day 2 (August 11, 2024)
Program evaluation	Measuring energy output (Wh/day), load efficiency, and partner understanding using pre- and post-tests	Quantitatively assessing the program's impact both technically and educationally	Last week of August 2024

The entire program was structured to ensure that community members not only received technical infrastructure, but also the capacity and knowledge to operate and maintain the system sustainably. By combining participatory training, hands-on implementation, and measurable evaluation, this approach aimed to achieve both technical functionality and community empowerment. The step-by-step implementation of the program is summarized in Table 1. The outcomes of these activities are presented and analyzed in the following section.

3. RESULTS AND DISCUSSION

Result

This community service program was implemented through a structured sequence of activities beginning with a needs assessment and culminating in post-installation evaluation. Each stage is described, highlighting both qualitative processes and quantitative outcomes.

Needs assessment and community energy conditions

The program began with a field survey and interviews with the management of *Mushalla* Longga Congkeh in Nagari Guguak VIII Koto. The survey revealed that the *mushalla* experiences frequent power outages, about three to five times per month, especially during evening worship sessions. This issue is exacerbated by the absence of backup systems such as generators or UPS. Furthermore, the local community had limited knowledge about renewable energy, particularly solar photovoltaic systems, despite the area receiving ample sunlight year-round (Afif & Martin, 2022; Alnavis et al., 2024).

Preparation and installation of the solar PV system

The preparation phase began with a comprehensive inspection and pre-assembly of all solar photovoltaic system components at the service team's workshop. This was crucial to ensure that each component functioned properly before field deployment. The system included one 100 Wp monocrystalline solar panel, a 12V 100Ah deep-cycle battery, a 300W pure sine wave inverter, a 10A PWM solar charge controller (SCC), a miniature circuit breaker (MCB), and all required cables, connectors, and a protective panel box. Such a configuration has been recommended in community-scale solar implementations due to its cost-effectiveness, modularity, and ease of maintenance (Rumbayan et al., 2021). During this stage, the team tested the electrical connectivity between the panel, SCC, battery, and inverter. The system was assembled on a trial rig to simulate standard solar charging and to verify the inverter's ability to power basic AC loads such as LED lighting and a small audio system (Bin et al., 2024). Once all components were confirmed to operate as intended, they were repackaged for transportation to the site.

Figure 1. Rooftop panel installation, wiring connections, and inverter setup

The installation was then carried out at *Mushalla* Longga Congkeh. The solar panel was mounted securely on the *mushalla*'s rooftop with an optimal angle and orientation to maximize solar exposure throughout the day. The SCC and battery were placed in a protected area inside the *mushalla*, and the inverter output was integrated into the *mushalla*'s internal AC wiring (Prathibha et al., 2024) . Safety measures, including MCB protection, were installed to prevent overload and ensure secure operation. This setup corresponds with findings by Rusli et al. (2023), who reported that 100 Wp systems are capable of supplying essential daily loads such as lighting and small electronics in religious facilities. Throughout the installation process, local *mushalla* managers participated actively, both to observe and assist with the assembly. This hands-on involvement helped familiarize them with the system layout and operational flow, laying the foundation for their long-term independent management of the system. The participatory model adopted in this project is supported by Robertua et al. (2024), who emphasized that sustainable adoption of appropriate technology (TTG) is strongly linked to direct engagement and community ownership during implementation.

System testing and measured performance

Pre-installation test

Before deploying the solar photovoltaic system to the field, a preliminary bench test was conducted at the workshop to verify the integrity and functionality of each component. The panel, SCC, battery, and inverter were assembled and connected under simulated sunlight conditions using a trial rig. The panel output reached a peak of 17.2V with a charging current of 4.0A under direct sunlight. The inverter delivered a stable 220V AC output when connected to a combined load of 100W, consisting of five LED bulbs and a small amplifier. This preliminary testing ensured that all components were functioning optimally and safely before being transported and installed at the partner location. It also provided a baseline reference for expected system behavior under ideal conditions.

Post-installation field test

After the installation was completed at *Mushalla* Longga Congkeh, the solar photovoltaic system was tested under real-world operating conditions to evaluate its functionality, safety, and energy output. The test involved powering actual electrical loads used in the *mushalla*, including five 8W LED lamps and a sound amplifier, totaling approximately 100 watts of AC load. During the first week of operation, the system was monitored for three hours each evening, with power supplied entirely from the 12V 100Ah battery that had been charged earlier by a 100 Wp monocrystalline solar panel. System parameters were recorded using a digital multimeter and battery monitor. The panel generated a peak open-circuit voltage of approximately 17.2V and a charging current of around 4.0A under full sunlight. The SCC regulated the charge into the battery efficiently, while the inverter consistently delivered a stable 220V AC output without interruption or signs of voltage drop. Based on an average of four effective sun hours per day, the system produced between 350–400 Wh of energy daily, which was sufficient to support the *mushalla*'s critical lighting and audio functions during evening prayer sessions. These results confirm that the PLTS system can operate independently of the main utility grid and serve as a reliable alternative energy source—particularly during frequent power outages in the area. This performance aligns with expected benchmarks for 100 Wp solar systems operating in tropical environments (Rumbayan et al., 2021; Rusli et al., 2023). This amount of energy was sufficient to meet the *mushalla*'s evening energy needs.

Table 2. Summary of system testing results

Parameter	Pre-Installation Test	Field Test After Installation	Unit
Solar panel voltage (peak)	17.2	16.8–17.0	Volts (V)
Charging current to SCC	4.0	3.8–4.2	Amperes (A)
Inverter output voltage	220	220	Volts (AC)
Connected load	100	100	Watts (W)
Operational runtime	±3	±3	Hours (h)
Estimated daily energy output	350–400	350–400	Watt-hours (Wh)

Figure 2. shows the testing of the inverter and system load simulation during the pre-installation phase
Figure 3. captures the actual field test at the *mushalla*, including panel voltage measurement, SCC and battery setup, and the *mushalla* lighting powered by the system

Educational Activities and Skill Enhancement

Educational activities were carried out using a practical, participatory approach that allowed direct engagement between the community service team and the *mushalla* management group. Instead of holding a formal classroom session, the training was embedded within the installation process, enabling participants to observe and practice in real-time. This method encouraged experiential learning, which is considered effective for technical empowerment at the grassroots level (Robertua et al., 2024). The training materials covered key topics such as the basic principles of solar photovoltaic (PV) systems, the function of each component (solar panel, charge controller, battery, inverter, and MCB), system flow and wiring, as well as simple maintenance techniques. Participants were guided on how to measure battery voltage using a multimeter, recognize operational indicators on the SCC and inverter, and perform essential cleaning and troubleshooting procedures.

Three active *mushalla* managers participated throughout the process. They were able to perform basic operational tasks independently, such as turning the system on and off, monitoring performance, and identifying system issues. This was further supported by the provision of a simplified operational guide in PDF format, which is available as open-access material via the following link: presentation. To evaluate the training outcomes, a structured questionnaire-based assessment was conducted before and after the activity. The assessment measured participant understanding across ten indicators related to solar energy and its applications. As shown in Figure 5.

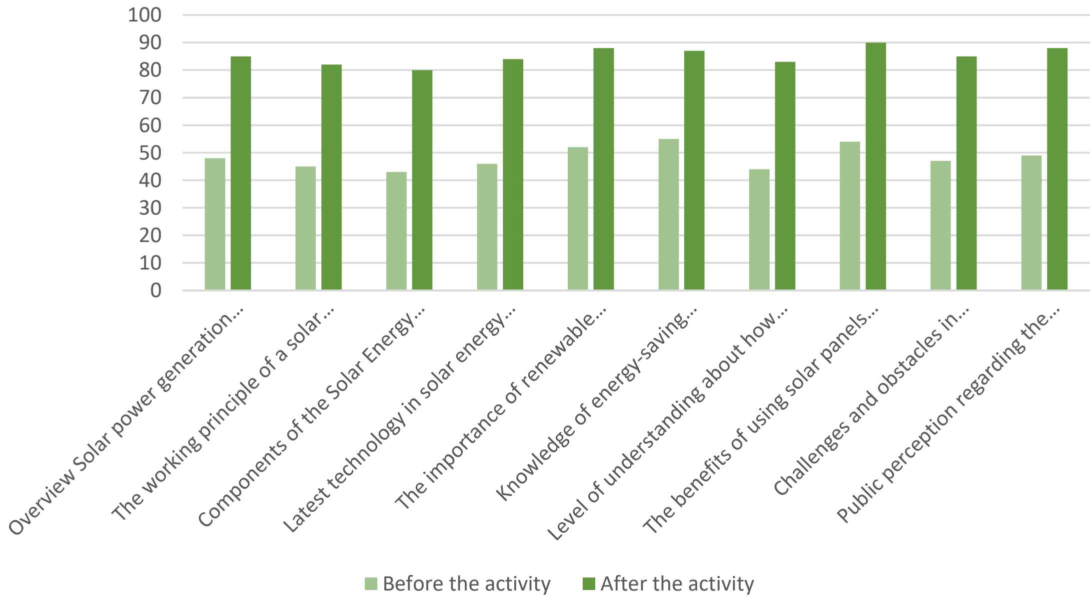

Figure 5. A significant improvement was observed across all categories, particularly in areas such as the benefits of using solar technology, understanding system components, and energy-saving awareness

While the focus of documentation was on hands-on activity and technical engagement, a group photo was also taken with the participants at the end of the session. Although not included as a core implementation documentation, this photo serves as supporting evidence of participation and community involvement.

Figure 6. Photos of participants using multimeters, engaging in inverter testing, interacting during hands-on explanation, and group photo after completion of the training

Maintenance and Community Monitoring

Following the installation and initial operation of the PLTS system, the service team conducted a monitoring and mentoring phase to ensure the system's sustainability and the community's ability to operate it independently. Over the course of one week, members of the *mushalla* management team were accompanied in performing daily maintenance and basic system supervision. The maintenance tasks focused on simple but essential routines such as inspecting battery voltage using a multimeter, cleaning the solar panel surface from dust or debris to ensure optimal light absorption, and monitoring indicator lights on the charge controller and inverter. The team also demonstrated how to safely isolate the system using the miniature circuit breaker (MCB) in the event of troubleshooting or maintenance needs.

During this phase, three key caretakers of the *mushalla* were observed to have gained confidence and technical competence in operating and maintaining the system. They were able to document battery status, identify system conditions, and ensure that the system operated within safe parameters without assistance. A simple daily log sheet was provided to support long-term tracking of system performance and battery condition. This community-based monitoring strategy aligns with the participatory and empowering nature of the program. By integrating local actors into system management, the initiative ensures long-term operability, reduces dependency on external technicians, and increases community ownership over the technology (Robertua et al., 2024; Rusli et al., 2023).

System Schematic

The schematic diagram of the implemented off-grid solar photovoltaic system is shown in Figure 7. It illustrates the flow of electrical energy from the solar panel, through the solar charge controller (SCC), to the battery, and finally through the inverter and miniature circuit breaker (MCB) to supply AC electrical loads in the *mushalla*.

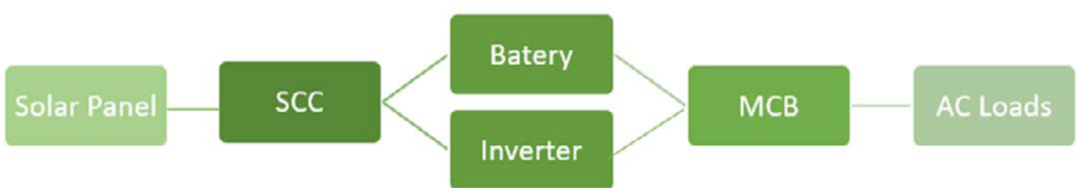

Figure 7. Off-grid solar PV system schematic for *Mushalla* Longga Congkeh

Discussion

The implementation of a 100 Wp off-grid solar photovoltaic (PLTS) system at *Mushalla* Longga Congkeh has proven to be a technically feasible, contextually appropriate, and socially impactful solution for addressing the local electricity shortage. With an average daily output of 350–400 Wh, the system effectively meets the *mushalla*'s evening electricity needs, such as lighting and sound amplification, particularly during power outages. This is consistent with findings by Rumbayan et al., 2021 and Rusli et al., 2023, who noted that a 100 Wp panel in tropical climates typically produces 300–450 Wh/day. System testing confirmed the stability of the inverter output at 220V AC under a 100W load, demonstrating reliable energy delivery. The inclusion of safety features such as a miniature circuit breaker (MCB) and LED indicators enhanced system accessibility and operability for non-technical users. As reported in other TTG-based community interventions, such simplicity is key to user adoption and long-term sustainability (Maka & Chaudhary, 2024; Robertua et al., 2024).

Educational components played a central role in the program's success. A structured pre-test showed limited community understanding of renewable energy, with the highest initial scores not exceeding 55. After the participatory educational session, which covered the principles of solar power, system components, benefits, and maintenance practices, post-test results showed significant improvement, with scores rising to as high as 90 in key areas such as energy cost reduction (Sutoyo & Shomad, 2023; Utama et al., 2024). This indicates that practical, context-based training is more effective than theoretical instruction alone (Hamdani et al., 2024). Furthermore, community involvement in the installation process, covering the mounting of solar panels, battery setup, inverter configuration, and wiring, strengthened the sense of ownership and engagement. The participatory model applied here aligns with the principles of community-based energy resilience (Alnavis et al., 2024).

From a sustainability perspective, the project emphasized the transfer of skills through post-installation mentoring. *Mushalla* caretakers were trained to perform routine maintenance tasks such as panel cleaning, battery voltage checks, and system monitoring, ensuring system reliability over time (Abdulla et al, 2024). The availability of open-access educational materials further supports ongoing learning and replication. Importantly, the impact of this initiative extended beyond mere electrification. The increased awareness and literacy around renewable energy among community members opens up the possibility of household-level adoption and grassroots innovation. This also sets a replicable example for other places of worship facing similar energy constraints. The experience at *Mushalla* Longga Congkeh illustrates how integrating education, community participation, and appropriate technology can yield not only technical results but also social empowerment and environmental awareness (Bashiru et al, 2024; Joleha et al., 2024; Kurniawan et al., 2024; Yasin et al., 2024).

4. CONCLUSION AND RECOMMENDATIONS

This community service program successfully achieved its primary objective of increasing access to electricity at *Mushalla* Longga Congkeh through the implementation of an appropriate technology (TTG) solution in the form of a 100 Wp off-grid solar photovoltaic (PLTS) system. The system produced an average of 350–400 Wh/day, which was sufficient to power essential electrical loads such as lighting and sound systems for approximately 3 hours per night, meeting the energy demands during worship and social activities. In addition, the program significantly enhanced the technical knowledge and skills of the local community. Based on the results of the pre-test and post-test assessments, participant understanding of solar energy principles and system maintenance increased from a baseline score of 55 to 90 in key knowledge indicators. This demonstrates a measurable improvement in community energy literacy and the capacity for system management. The outcomes of this program highlight the strong correlation between the intended goals, enhancing local energy access and knowledge, and the actual, quantifiable results achieved through structured implementation and education.

Despite its success, the program had several limitations. First, the system was designed to meet only the basic evening energy needs and did not account for broader daytime usage or future load increases. Second, long-term monitoring data was limited to an initial observation period, which may not reflect seasonal variations in solar radiation. Third, the absence of formal certification or follow-up sessions for participants could affect the long-term consistency of system maintenance. Based on these limitations, the following recommendations are proposed for future community service initiatives: (1) Expand system capacity in future implementations to accommodate larger loads or longer usage durations, including daytime activities; (2) Incorporate long-term monitoring and evaluation, preferably over several months, to capture real performance variability and guide technical improvements; (3) Replicate the model in other rural or semi-urban places of worship where electricity reliability is still a challenge, using this *mushalla* as a reference point for scalability.

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