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ADVANCING GREEN ELECTRICITY THROUGH SOLAR PANEL-BASED STREET LIGHTING WITH LIGHT SENSOR INTEGRATION IN RANGKAPAN JAYA VILLAGE, DEPOK

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ABSTRACT

The growing demand for sustainable energy solutions has highlighted the importance of renewable energy technologies, particularly in urban and semi-urban communities. In Rangkapan Jaya Village, Depok, the lack of adequate street lighting and limited awareness of green energy solutions have created both environmental and safety challenges. This project contributes a replicable model for integrating solar-powered street lighting (PJUTS) into underserved communities using a participatory approach. It also provides a practical framework for community-based training in renewable energy technology, promoting both infrastructure development and environmental education. The activity began with a socialization session explaining the principles and benefits of renewable energy and solar panels. This was followed by hands-on technical training on the installation of PJUTS systems, involving local residents directly in assembling and deploying the equipment in targeted areas. Participants demonstrated increased understanding of solar panel operation and installation. Several solar-powered streetlights were successfully installed, improving lighting in previously unlit areas. Community feedback indicated heightened interest in renewable energy solutions and greater confidence in maintaining the system independently. The project shows that a community-based, educational approach is effective in promoting green technology at the local level. It addressed both practical infrastructure needs and capacity-building, offering a scalable solution for other regions seeking sustainable energy implementation.

ABSTRAK

Peningkatan kebutuhan terhadap solusi energi berkelanjutan mendorong pemanfaatan teknologi energi terbarukan, khususnya pada lingkungan masyarakat perkotaan dan semi-perkotaan. Di Kelurahan Rangkapan Jaya, Depok, keterbatasan fasilitas penerangan jalan serta rendahnya pemahaman masyarakat mengenai konsep energi hijau menjadi tantangan yang berdampak terhadap aspek lingkungan dan keamanan. Kegiatan pengabdian kepada masyarakat ini bertujuan untuk menerapkan sistem penerangan jalan umum tenaga surya (PJUTS) berbasis sensor cahaya sekaligus meningkatkan pengetahuan dan keterampilan masyarakat dalam pemanfaatan teknologi energi terbarukan melalui pendekatan partisipatif. Metode pelaksanaan kegiatan meliputi sosialisasi mengenai prinsip kerja dan manfaat energi terbarukan, pelatihan teknis instalasi sistem PJUTS, praktik perakitan perangkat, serta pemasangan sistem penerangan pada lokasi yang telah ditentukan. Kegiatan ini melibatkan masyarakat secara langsung dalam proses instalasi dan pemeliharaan sistem. Hasil kegiatan menunjukkan bahwa peserta mengalami peningkatan pemahaman terkait prinsip kerja panel surya, sensor cahaya, dan sistem penyimpanan energi. Selain itu, beberapa unit penerangan berbasis energi surya berhasil dipasang dan mampu meningkatkan pencahayaan pada area yang sebelumnya minim penerangan. Kegiatan ini menunjukkan bahwa pendekatan edukatif berbasis partisipasi masyarakat efektif dalam mendukung penerapan teknologi hijau di tingkat lokal. Implementasi PJUTS tidak hanya memberikan solusi terhadap kebutuhan infrastruktur penerangan, tetapi juga meningkatkan kapasitas masyarakat dalam mendukung pemanfaatan energi berkelanjutan.

INTRODUCTION

Urban development in emerging countries has placed increasing pressure on public infrastructure, including the need for adequate street lighting in densely populated neighborhoods. In many urban villages across Indonesia, limited access to reliable street lighting contributes to safety risks, reduced economic activity after dark, and a general decline in community well-being (Abdullah et al., 2024; Pramono et al., 2023; Sutopo et al., 2020; Yasa & Sarief, 2021). Traditional street lighting systems rely heavily on centralized electrical grids powered by fossil fuels, which are not only environmentally unsustainable but also economically burdensome for low-income communities (Abdullah et al., 2024; Yasa & Sarief, 2021). The reliance on non-renewable energy sources for essential public services continues to present a significant barrier to achieving energy equity and environmental targets (Orejon-Sanchez et al., 2021; Pratama et al., 2023). In addition, several reports have highlighted the correlation between poor lighting and increased incidents of crime and accidents in urban areas (Sutopo et al., 2020).

As a response, solar panel technology has been increasingly adopted as a decentralized and sustainable solution for public lighting (Victoria et al., 2024; Wolff et al., 2021). Solar-powered street lighting systems (PJUTS) have shown great potential in providing consistent illumination while reducing electricity costs and carbon emissions (Anggono et al., 2021; Kurniawan & Kurniawan, 2022). Prior research has demonstrated the effectiveness of solar-powered lighting in various contexts, from remote rural locations to peri-urban zones (Junisbekov et al., 2024). However, many implementations are predominantly top-down, with minimal community involvement, leading to maintenance challenges and limited long-term success (Tsoeu-Ntokoane et al., 2024; Wardhany et al., 2024). Studies suggest that local engagement, particularly through education and hands-on participation, plays a crucial role in ensuring the sustainability of renewable energy projects. Training local residents not only builds technical capacity but also fosters a sense of ownership that supports ongoing operation and maintenance.

This research introduces a community-based approach for implementing solar-powered street lighting in Rangkapan Jaya Village, Depok, integrating socialization, technical training, and installation activities. While previous studies have emphasized technological efficiency and cost analysis, few have examined how participatory models can simultaneously solve energy access issues and enhance community skills. The contribution of this research is the development of a participatory framework that empowers residents through both infrastructure improvement and capacity building, enabling sustainable green energy adoption at the local level.

METHODOLOGY

This community service activity was carried out through a structured training program and hands-on workshop designed to introduce solar panel installation and maintenance to local residents. The event featured five invited speakers from different academic disciplines, including Electrical Engineering, Industrial Engineering, and Informatics, each presenting materials according to their area of expertise. A total of 20 participants from the Casa Arca community in Rangkapan Jaya, Depok, attended the program. These participants were aged between 27 and 38 years old and came from various educational and professional backgrounds. The event consisted of theoretical sessions, interactive discussions, and practical solar panel installation activities. In addition, pre-test and post-test evaluations were conducted to assess knowledge improvement. A maintenance session was also held to ensure that participants could sustain the functionality of the installed system. The multidisciplinary approach and inclusive participant engagement contributed to the overall success of the training.

Design System

The system shown in Figure 1 is a solar-powered automatic street lighting system. It utilizes a solar panel to convert sunlight into electrical energy during the day. This energy is passed through a DC-DC buck converter, which regulates and lowers the voltage to a suitable level before entering the TP4056 module. The TP4056 module is responsible for safely charging two 18650 Li-ion batteries, ensuring protection from overcharging and managing proper current flow.

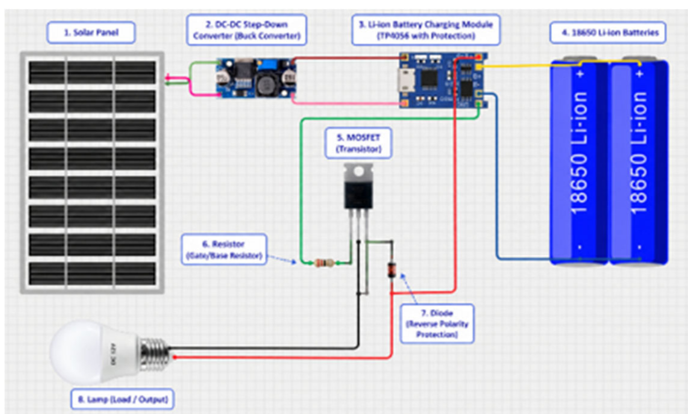

Figure 1. Wiring Diagram

During the daytime, when sunlight is present, the solar panel generates power to charge the batteries. At the same time, a Light Dependent Resistor (LDR) detects the ambient light level. When it senses brightness, the LDR has low resistance, which causes the transistor (used as a switch) to remain off, thereby preventing the lamp from turning on. At night, when it becomes dark, the LDR's resistance increases. This change in voltage at the base/gate of the transistor activates it, allowing current to flow from the battery to the lamp. As a result, the LED street lamp automatically turns on. This system is fully autonomous and uses renewable energy to provide efficient street lighting without manual intervention.

Schedule of Events

The event shows in Table 1 explores sustainable innovation through green technology, community empowerment, and digital transformation. It begins with opening activities and a pre-test, followed by keynote sessions on green energy, solar street lighting, and sustainable industrial systems. Our speaker team consists of experts from Electrical Engineering, Industrial Engineering, and Informatics. In the afternoon, participants will engage in a collaborative workshop focused on practical energy applications. The event concludes with a post-test, a summary of the day's activities, and closing remarks.

Table 1. Schedule of Events

No.	Time	Agenda
1	13.00 - 13.30	Participant Registration & Welcome
2	13.30 - 13.45	Opening Ceremony & Opening Remarks
3	13.45 - 14.30	Pre-test for Participations
4	14.30 - 15.15	Session 1: Smart Street Lighting with Solar Technology
5	15.15 - 15.30	Session 2: Control System for Sustainable Infrastructure
6	15.30 - 16.15	Coffee Break
7	16.15 - 17.00	Session 3: Industrial Innovation for Circular Economy
8	17.00 - 17.30	Session 4: Smart Applications for Urban Communities
9	17.30 - 18.00	Break
10	18.00 - 18.45	Session 5: Human-centered Design in Tech-based Solutions
11	18.45 - 19.30	Discussions
12	19.30 - 20.00	Posttest & Feedback Session
13	20.00 - 20.15	Group Photo & Closing Remarks

Evaluation Test

To measure the effectiveness of the knowledge transfer during the event, a pre-test and post-test were conducted. The Question shows in Table 2. The pre-test took place on beginning of the training before the keynote sessions to assess the participants' baseline understanding of green energy, solar street lighting, sustainable systems, and digital transformation for community empowerment.

Table 2. Question of Pre-test & Post-test

No	Question
1	What is the working principle of solar panels in generating electricity?
2	What does the LDR sensor detect?
3	What is an advantage of a solar-powered street lighting system?
4	What does LDR stand for in sensor systems?
5	What is the function of the battery in a solar panel system?
6	One main benefit of solar-powered street lighting is:
7	When sunlight decreases (e.g., at night), the LDR sensor will:

No	Question
8	The energy source from solar panels is:
9	If the LDR is exposed to very bright light, its resistance will:
10	Why is educating the public on solar panel usage important?

After the workshops and keynote presentations concluded, a post-test was administered at the end of the event to evaluate improvements in knowledge and comprehension. The comparison of results between the pre-test and post-test demonstrated a significant increase in participants' understanding of sustainable innovation topics presented by the interdisciplinary speaker team from Electrical Engineering, Industrial Engineering, and Informatics.

RESULTS AND DISCUSSION

Figure 2. Implementation of Solar Panel Training

The installation of solar panel systems shows in Figure 2 for local residents was successfully accomplished, with each unit operating as intended. All systems deliver stable and efficient energy output, meeting the daily electricity needs of the beneficiaries. This outcome demonstrates both the effectiveness of the installation process and the suitability of solar technology to support sustainable energy solutions in the community.

System Installation

The installation shown in the Figure 3 represents a compact solar-powered lighting system designed for energy-efficient outdoor or emergency use. The system consists of a solar panel, a control circuit, a rechargeable battery pack, and an LED lamp.

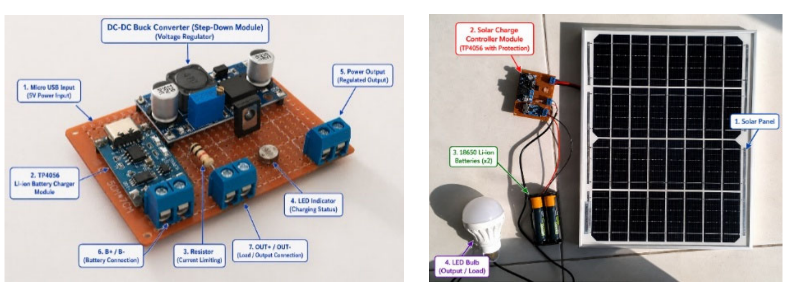

Figure 3. Installation Solar Panel System

In the second image, the solar panel functions as the primary power source, capturing sunlight and converting it into electricity. The electricity generated is sent to a control board, which is visible in the first image. This control board integrates several key components:

1. TP4056 Charging Module: This module manages the charging of lithium-ion batteries (such as the 18650 type). It features a micro USB port for alternative charging and has two output terminals—one connected to the battery and the other supplying power to the circuit.
2. DC-DC Step-Up Converter: This module boosts the voltage from the battery (typically 3.7V) to a suitable level (around 5V or more) for the LED lamp and other components.
3. LDR (Light Dependent Resistor): The LDR sensor detects ambient light levels. When sunlight is present (daytime), the LDR triggers the system to turn off the LED lamp. When it gets dark, the LDR detects the drop in light and activates the lamp automatically.
4. Lithium-ion Batteries: These are connected to the TP4056 module and store the energy collected from the solar panel during the day for use at night.
5. LED Lamp: The LED lamp is connected to the output terminal of the step-up converter. It receives sufficient voltage to operate when triggered by the LDR sensor at night.

The wiring setup ensures an automatic lighting system that is self-sufficient and operates without the need for grid electricity. Red and black wires are used for positive and negative terminals, while other color-coded wires connect the sensor and modules properly. The entire system is mounted on a prototyping board for testing or small-scale deployment.

Maintenance System

Based on the visual observation of Figure 4, which shows a solar-powered electronic system, the following insights regarding the maintenance and functionality can be noted.

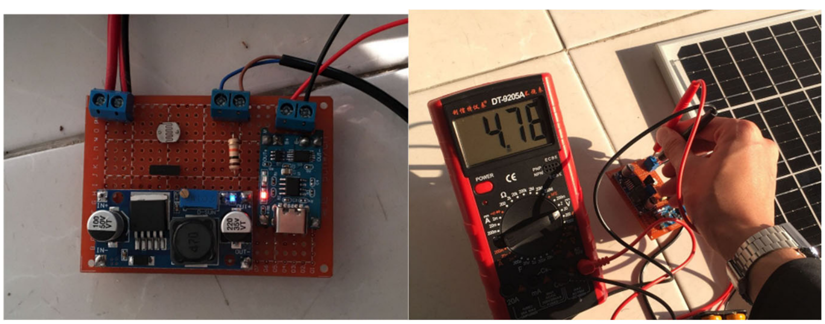

Figure 4. Maintenance Solar Panel System

The image on the left displays a prototyping board connected with a step-down (buck) converter and several other electronic modules. The blue LED indicator on the step-down converter is clearly lit, confirming that the module is active and receiving input power. This is a positive indication that the system is functioning properly at this point.

Meanwhile, the image on the right shows a multimeter reading of 4.78V, taken from the output of the converter, which is connected to a solar panel. Given that typical solar panels of this type usually provide an effective voltage of around 18–20V, and that the minimum charging voltage for a battery system is 5V, the reading of 4.78V suggests that the charging voltage may be slightly insufficient, especially if under load.

Figure 5. The implementation of Solar Panel System

Outcome of Solar Panel Installation

The solar panel installation program shows in Figure 5, resulted in the successful deployment of five solar panel systems to selected households in the community. Each system was installed according to proper technical standards and tailored to meet the household's specific energy needs. Following installation, all five systems were tested and demonstrated to operate smoothly under normal conditions. The beneficiaries reported that the systems functioned reliably, providing a consistent source of renewable energy and reducing their dependence on conventional electricity. This outcome reflects the program's effectiveness in achieving its objectives and delivering tangible benefits to the community.

Test Evaluation

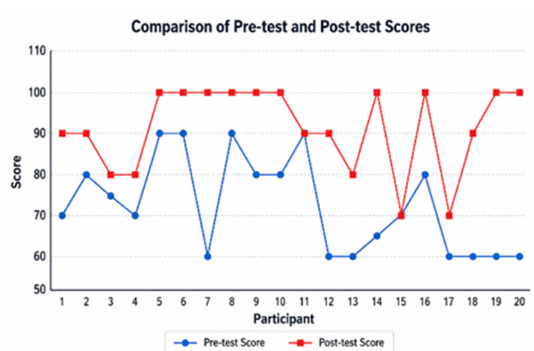

Figure 6. Evaluation Test Result

The Figure 6 presents the evaluation test results, illustrating the comparison between participants' pretest and posttest scores in the solar panel installation training program. It is evident that there was a significant improvement in participants' understanding and knowledge after the training. Most participants showed increased scores in the posttest, with many achieving perfect scores (100), especially participants 5 through 11. This indicates that the training was effective in delivering the necessary skills and concepts. The consistent rise in posttest scores across nearly all participants demonstrates a successful learning outcome, reflecting the community's improved capability in solar panel installation and maintenance following the educational activity.

CONCLUSION

The community empowerment program in Casa Arca, Rangkapan Jaya, Depok, successfully enhanced the participants' knowledge and practical skills in solar panel installation and maintenance. The training involved five expert speakers from diverse disciplines—Electrical

Engineering, Industrial Engineering, and Informatics—who delivered material aligned with their areas of expertise. A total of 20 community members, aged between 27 and 38 years and coming from varied backgrounds, actively participated in the program. The comparison between evaluation test results showed a significant improvement in understanding, confirming the effectiveness of the educational approach. Furthermore, all five solar panel systems distributed during the activity were successfully installed and functioned properly, indicating that participants were able to apply the knowledge gained. This success demonstrates the importance of interdisciplinary collaboration and inclusive community involvement in supporting sustainable energy initiatives at the grassroots level.

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