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Adaptive Solar Panel in Wiyata Tech Village, Towards Energy Independence

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ABSTRACT

Nighttime illumination in Wiyata Tech Village, Kutamanah, Sukasari District, Purwakarta, has been limited due to the reliance on low-capacity lamps. To address this issue, solar panels were deployed to provide public street lighting (PSL), aiming to enhance energy autonomy and utilize renewable energy resources. The village, covering an area of 30.1 square kilometers, is part of Sukasari District, which spans 92.01 square kilometers and includes five villages. This community service project involved the installation of solar panels in Desa Kutamanah, with a participatory approach fostering local empowerment and technology adoption. A satisfaction survey conducted one month after installation revealed overwhelmingly positive feedback from residents, who noted significant improvements in lighting and community impact. The program successfully demonstrated the effectiveness of solar panels in improving street lighting, fostering energy independence, and encouraging sustainable use of renewable resources.

***Keywords**: Solar Panel, Wiyata Tech, Public Street Lighting, Community Service*

1. INTRODUCTION

The Sustainable Development Goals (SDGs) are a collection of interconnected global goals set by the United Nations as a universal call to action to end poverty, protect the planet and ensure that by 2030 all people enjoy peace and prosperity **(Abdul Halim Iskandar 2020).** At the local level, these goals are adapted and implemented as Village SDGs, focusing on creating sustainable and resilient rural communities. Village SDGs address a wide range of issues including poverty eradication, food security, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, sustainable cities and communities, climate action, and life below water and on land **(Hák, Janoušková, and Moldan 2016) (Hafni, Rs, and Nanda 2021).**

Figure 1 shows 18 aspects of village SDGs for sustainable village development. Of these aspects, the aspect of clean and renewable energy villages (SDG 7) is a crucial point in realizing sustainable village development **(Lestari et al. 2023).** Efforts to support the aspect of clean and renewable energy village SDGs can be done in various forms: installing solar panels, building wind power plants, building hydroelectric power plants, and utilizing biomass **(Pizzi et al. 2020)**. Installing solar panels is the most effective activity to increase access to clean energy in villages. Solar panels can be used to generate electricity that can be used for various purposes, such as lighting, electronic equipment, and agricultural machinery **(Artetxe et al. 2023)**. Building wind power plants can also be an option to increase access to clean energy in villages. Wind power plants can be used to generate a large amount of electricity to meet the electricity needs of the village. Building hydroelectric power plants can also be a suitable option to increase access to clean energy in villages that have large water potential. Hydroelectric power plants can be used to generate stable and reliable electricity. The utilization of biomass, such as firewood and agricultural waste, also has the potential to be an option to increase access to clean energy in villages. Biomass can be used for cooking, water heating, and even power generation. With these activities, villages can become more self-reliant in energy provision. This will improve the welfare of village communities and reduce dependence on fossil fuels **(Sugandi, Abdoellah, and Gunawan 2022) (Nugroho et al. 2022).**

Figure 1. Village SDGs

However, among all the activities mentioned, the utilization of solar panels holds the greatest potential for energy independence in Wiyata Tech's designated village located in Kutamanah, Sukasari District, Purwakarta. The primary reason is that solar energy is an abundant clean energy source, highly suitable for implementation in Kutamanah village. This suitability is evident from its geographical conditions, which exhibit a notably high specific photovoltaic power of 1463.8 kWh/kWp per annum, surpassing other regions such as Plered District (1408.3 kWh/kWp) and Sukatani District (1402.7 kWh/kWp) in Purwakarta **(Solargis 2024).** Furthermore, solar panels address the village's challenges related to inadequate road access, where journeys to neighboring towns or villages are often poorly lit **(Lorincz, Klarin, and Begusic 2023)**. Additionally, nighttime illumination within the village remains limited, relying on low-capacity lamps. Consequently, the deployment of solar panels is deemed highly appropriate for Wiyata Tech in Kutamanah village, Sukasari District, Purwakarta. In light of the problems identified, the deployment of solar panels for public street lighting (PSL) is necessary. This project aims to cultivate energy autonomy and harness renewable energy resources in Wiyata Tech Village, Kutamanah Village, Sukasari District, Purwakarta.

2. METHODS

2.1 Road Map

In Figure 2, the 5-Year Roadmap of Wiyata Tech is a blueprint outlining the village's plans and goals for the next five years, from 2024 to 2028. This plan was developed with input from various stakeholders, including the Wiyata Tech government, community members, businesses, and academics. The roadmap is centered around four main pillars: clean and renewable energy, peace and security, quality education, health and well-being, and synergy between MSMEs and partners. In 2024, Wiyata Tech focus on the clean and renewable energy pillar. We plan to implement a solar panel system to meet the village's electricity needs. The year 2025 will prioritize the peace and security pillar by enhancing the community's capacity to manage social conflicts and developing a technology-based security system. In 2026, the focus will shift to the quality education pillar by increasing access and quality of education, as well as developing the SMART Wiyata application. In 2027, the focus will be on the health and well-being pillar by increasing access to and quality of healthcare services and developing a health and disease monitoring system. Finally, in 2028, Wiyata Tech will prioritize the synergy between Micro, Small and Medium Enterprises (MSMEs) and partners in agriculture, tourism, and the creative industry. This step is supported by the development of an innovation center aimed at supporting the growth of MSMEs. This five-year roadmap reflects clear and ambitious goals. It is hoped that with hard work and the support of various stakeholders, Wiyata Tech can become a clean, peaceful, smart, prosperous, and independent village.

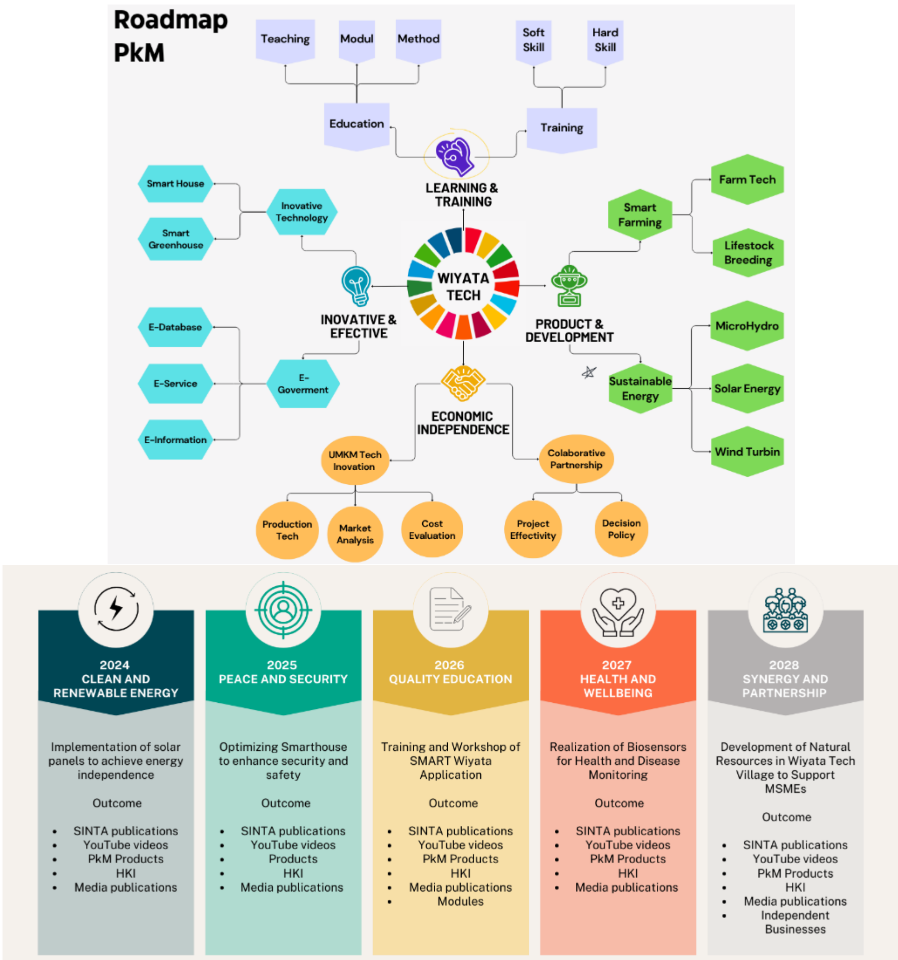

Figure 2. The 5-Year Roadmap of Wiyata Tech

2.2 Location and Target Audience

Community service in the form of the application of solar panel utilization for public street lighting (PJU) was conducted in Desa Kutamanah, located in Sukasari District, Purwakarta Regency. Sukasari District itself has an area of 92.01 square kilometers with a total of 5 villages/urban villages, including Desa Kutamanah. Desa Kutamanah itself has an area of 30.1 square kilometers, As seen in Figure 3 shows the geographic data of Kutamanah Village used to identify strategic locations for solar street light installations. This data shows the population distribution and area that supports the optimization of solar energy.

Luas Wilayah dan Jumlah Desa/Kelurahan Menurut Kecamatan di Kabupaten Purwakarta

KECAMATAN	LUAS WILAYAH		JUMLAH DESA/ KELURAHAN
	Km²	%	
1. Jatiluhur	60,11	6,19	10
2. Sukasari	92,01	9,47	5

Kode kabupaten	Nama kabupaten	Kode kecamatan kemendagri	Kode kecamatan bps	Nama kecamatan	Kode desa kemendagri	Kode desa bps	Kelurahan desa kelurahan	km total area square square km	Presentase terhadap luas kecamatan
3214	KABUPATEN PURWAKARTA	32.14.15	3214011	SUKASARI	32.14.15.2001	3214011005	KUTAMANAH	30.1	37.62

Figure 3. Geographic Data of Desa Kutamanah, Sukasari District

Furthermore, as reinforced by data from AccuWeather and attached in Figure 4. Desa Kutamanah has significantly higher solar heat and weather characteristics compared to Kampung Cileungsing. This data provides evidence that the wind energy potential in Desa Kutamanah is much higher for generating electricity using solar panels.

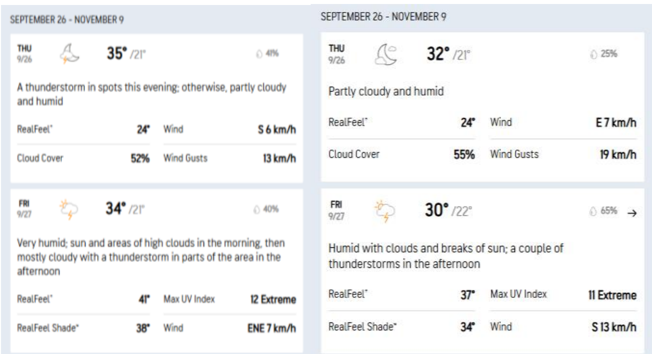

Figure 4. Comparison of Temperature and Weather Data between Desa Kutamanah and Kampung Cileungsing

The target audience of this community service activity is the community of Desa Kutamanah, especially those who have not yet been reached by the PLN electricity network. According to the team's observations during the activities in the village, there are several areas and roads that have not yet gained access to PLN electricity. This has caused difficulties for them in carrying out daily activities, working, communicating, and others, especially at night. Based on the results of the population census released by the Central Statistics Agency of Purwakarta Regency, the population of Desa Kutamanah reaches 3,982 people, with a distribution of 2,068 males and 1,914 females.

2.3 Method

The Figure 5. The implementation method for the solar panel project in Wiyata Tech Village, Kutamanah, follows the **ADDIE instructional design framework (Widyastuti and Susiana 2019)**.The process begins with the **Analysis phase**, where the street lighting needs of Kutamanah Village are determined, identifying the energy shortages faced by the sprawling village that relies on low-capacity lights. Next, the **Design phase** includes planning for the training and installation of solar panel infrastructure to improve street lighting. The **Development phase** encompasses training in the creation of customized solar panel materials and systems, focusing on their use and maintenance by local residents. The **Implementation phase** entails the actual installation of the solar panel systems and training of residents, as well as the use of technologies such as **IoT** to monitor the effectiveness of the system in real-time. The final **Evaluation phase** measures the impact of the solar panel on the quality of lighting and energy independence of the village, complemented by a **community satisfaction survey** that shows very positive feedback on the lighting improvements and community impacts. This project not only enhances lighting conditions in Kutamanah Village but also promotes the adoption of **renewable energy resources** and fosters **community empowerment**. This approach ensures that the solar panel project not only meets the immediate lighting needs but also builds local capacity through training and community involvement in the maintenance and upkeep of their new energy infrastructure. This makes the project sustainable and provides a foundation for similar developments in other areas of the Sukasari District. **PKM Sustainability** focuses on developing maintenance plans, training local stakeholders, and securing ongoing funding or partnerships. The process concludes with a **Finish phase**, documenting outcomes, lessons learned, and recommendations for scalability or replication in other communities. **(Hwang et al. 2020) (Vaughn and Jacquez 2020)** This systematic approach ensures a sustainable and impactful implementation of solar panels in Wiyata Tech Village **(Yadav 2022).**

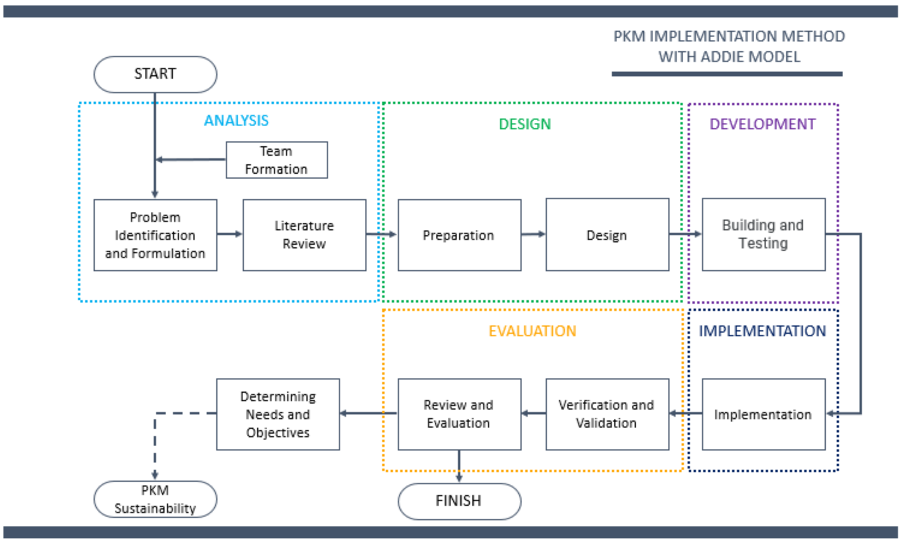

Figure 5. The Method Diagram

3. RESULTS AND DISCUSSION

3.1 Preparation

Preparation began with discussions involving the village government to plan and determine suitable installation sites for the solar-powered streetlights. During these meetings, the author collaborated with local authorities to identify priority areas that would benefit most from enhanced lighting. As a result, specific locations were selected based on the needs of Desa Kutamanah and the potential to maximize the efficiency of the solar-powered equipment. Two strategic spots were chosen—both located on poorly lit roads connecting Desa Kutamanah to the main road. These areas were selected not only due to limited lighting and challenging road conditions but also because they receive ample sunlight, making them ideal for solar panel operation. The precise placement of the streetlights was carefully considered to ensure optimal solar energy absorption and to effectively address the community’s lighting needs.

3.2 Design and Testing

Figure 6 shows the design and testing process involved a series of meticulous activities aimed at ensuring the functionality and efficiency of the system. One of the key components was the integration of a battery pack with a solar panel and a Passive Infrared (PIR) sensor. The solar panel was equipped with an automatic detection feature, enabled by the PIR sensor, which activates the system when motion is detected within the vicinity of the solar panel. This feature enhances the device's operational efficiency by ensuring it operates only when needed. The battery used in this system has a substantial capacity of 90 watts, allowing it to provide illumination from 18:00 to 05:00. To verify its performance, a stress test was conducted where the lamp was operated continuously until the battery was fully discharged.

Figure 6. Solar Panel Testing

This testing process confirmed the battery's ability to handle efficient charging and discharging cycles. Additionally, the lamp was evaluated for uninterrupted functionality, and the PIR sensor was tested for accurate motion detection. Voltage tests were also carried out during the charging process under varying light intensity conditions. Under low light intensity, the battery voltage measured 3.7 volts, while under high light intensity, it increased to 3.83 volts. These results demonstrated that the solar panel effectively recharged the battery under both conditions, ensuring the system's reliability and consistent performance. This comprehensive testing process validated the overall design and operational efficiency of the integrated system.

3.3 Implementation

Figure 7 explains the implementation process of solar-powered streetlight installation through a series of structured steps. The process begins with preliminary preparations, followed by painting the metal components. This step uses anti-rust paint to prevent corrosion and white paint for visual appeal, serving both protective and aesthetic functions. Once painting is complete, the streetlights and solar panels are securely mounted onto the painted metal supports. The next stage involves excavating two designated holes to serve as foundations. Each hole is prepared with compacted soil and a layer of gravel to ensure a stable base. After positioning the metal supports into the holes, concrete is poured in stages using a mixture of cement, sand, and water. The gradual pouring process helps eliminate air pockets and ensures solid structural bonding. The concrete is then compacted and left to cure fully. Finally, after the curing period, alignment and stability checks are performed to verify that each support is correctly positioned and secure.

Figure 7. Implementation

3.4 Verification and Validation

After the solar-powered lights are installed, the lights are turned on in standby mode. This standby mode allows the lighting system to operate at minimal power, thus increasing the battery's lifetime. In this mode, the lights will turn on with minimal lighting, but when an object (road user) passes by the light, the light will turn on to its maximum brightness. This is because the lamp is equipped with a PIR motion sensor that allows the lamp to detect objects in its surroundings, whether it is a human or a vehicle. Thus, its use will be optimal for road users and also the lifetime of the lamp's use. Figure 8 shows the condition of the lights during day and night, and illustrates their operational status.

Figure 8. Results (Night and Day) with Standby Mode

3.5 Review and Evaluation

One month after the installation of the solar panels, a satisfaction survey was conducted with 10 randomly selected residents who pass the roads. The survey aimed to evaluate the effectiveness and benefits of the solar panel system. Overall, the residents expressed highly positive feedback, emphasizing the significant impact of the installation on the local community. Figure 9 using a pie chart to display public knowledge about solar panels. The chart shows that 60% of respondents have knowledge about solar panels. The pie chart visually outlines these proportions, with clear sections showing the percentage of respondents who have knowledge about solar panel technology and those who do not.

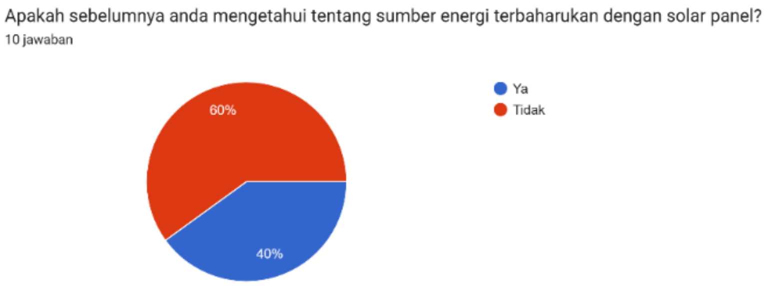

Figure 9 Public knowledge about solar panels

Figure 10 presents data on the satisfaction of the Kutamanah Village community towards street lights equipped with solar panels. Based on the diagram, 90% give a 'very good' rating, they expressed satisfaction with the performance and reliability of the solar-powered street lights, highlighting their effectiveness in providing adequate lighting and contributing to energy savings.

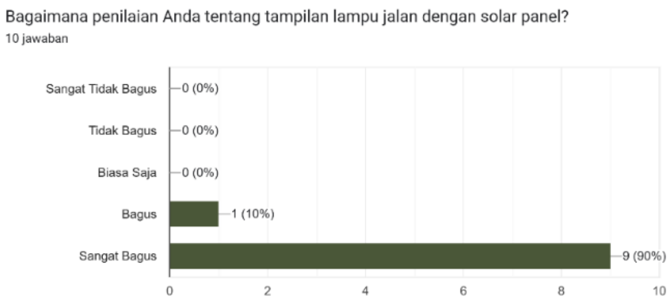

Figure 10 Public satisfaction with street lights with solar panels

Figure 11 presents data on the public's desire to increase the number of street lights using solar panels. According to the chart, 90% of respondents expressed support for expanding the installation of solar-powered streetlights. The chart effectively illustrates the widespread enthusiasm for increasing the adoption of solar energy in public infrastructure.

Figure 11. Public's desire to increase the number of street lights using solar panels

3.6 Determining Needs and Objectives

The follow-up program for solar panel implementation in Kutamanah aims to broaden the impact of the initiative and ensure the sustainability of the energy management system already in place. Key activities include developing partnerships with stakeholders such as local governments, schools, and community organizations to replicate the technology in other areas requiring improved lighting, such as residential neighborhoods and schools in nearby villages. Additionally, further socialization and training sessions will be conducted to educate the community and village officials on the use and maintenance of solar panels, fostering greater understanding and energy independence.

4. CONCLUSIONS

The implementation of solar panels in Kutamanah has proven effective in improving street lighting and fostering energy independence for the community. This technology provides a practical solution for illuminating rural areas, particularly village roads, while promoting community self-reliance in utilizing available natural resources. Through participatory and empowering approaches, the program not only enhances street lighting but also encourages sustainable adoption of renewable energy technologies. To further optimize these benefits, it is recommended to expand the coverage of solar panels to other public areas and frequently used facilities.

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