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EMPOWERING MADANI COMMUNITIES: SOLAR LIGHTING SOLUTIONS TO INCREASE SAFETY IN RURAL MALAYSIA

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Abstract

This research examines the potential of solar lighting to enhance safety and support sustainable development in rural Malaysia, in alignment with the Madani framework and initiatives by the Ministry of Rural and Regional Development. Focusing on underserved communities, particularly Orang Asli settlements in Perak and Pahang, the research employs a mixed-method approach combining field observations, community feedback, and technical assessments. The findings reveal that solar lighting improves nighttime visibility, reduces safety risks, enhances economic activities, and offers cost-effective and environmentally sustainable solutions. By integrating solar technologies into rural infrastructure, the study highlights their role in promoting self-reliance, community empowerment, and long-term growth. These outcomes contribute to Malaysia's national development goals, as outlined in PLAN Malaysia, and align with Sustainable Development Goal 7 (SDG 7), which advocates for affordable, reliable, and sustainable energy access. Overall, this research highlights the transformative impact of renewable energy in fostering safer, more resilient, and inclusive rural communities in Malaysia.

Keywords: Madani, Rural Development, Solar Lighting, Safety

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INTRODUCTION

In 2023, approximately 21.28% of Malaysia's population lived in rural areas. Rural development is essential to achieving social equity and sustainable progress in Malaysia, aligned with the Madani Framework's emphasis on inclusivity, compassion, and responsibility. This framework envisions a society that prioritizes ethical governance, social responsibility, and community empowerment in areas like economic stability, health, and safety (Malaysia, 2023). However, rural regions face significant challenges such as limited infrastructure and access to resources, which impede community growth and safety. Highlighted by Ngah (2006), a rural region needs to adopt the principles of a sustainable community through the fundamental aspects under this principle, which is the provision of sustainable electricity.

Recently, Malaysia shows a shift from traditional infrastructure-centric approaches to more integrated and participatory frameworks. In the past, rural development planning focused mainly on technical feasibility, such as energy supply and infrastructure performance. Study by Ahamd et al. (2024), revealed that rooftop solar-PV systems improved electricity access and increased illuminance levels by 50–80%, showing the feasibility of decentralized systems in rural Malaysia.

Solar technology presents a sustainable electricity solution that aligns with Madani principles, addressing these challenges by reducing dependence on traditional energy sources and enhancing community well-being (Ahmad et al., 2024). Solar lighting supports Malaysia's sustainability and carbon reduction goals while offering low-maintenance, affordable lighting solutions. In areas with limited or no national grid access, solar lighting enhances visibility and safety, reducing crime-related risks and promoting environmental benefits. This sense of security is essential for rural residents, fostering resilience and empowerment (Renuka Prasad et al., 2017).

According to Sakca et al. (2023), limited access to reliable lighting restricts nighttime activities vital for community growth and safety. Remote locations and challenging terrain often hinder rural areas from connecting to the national grid, and those with access frequently experience outages. This inadequate lighting increases vulnerability to accidents and hampers economic activities, especially for individuals relying on evening work or night markets. Dependence on fossil-fuel-based lighting also burdens households with high energy costs, undermining Malaysia's sustainability goals. Poor lighting infrastructure in rural Malaysia raises safety risks, as insufficient visibility on roads contributes to accidents. Dimly lit public spaces also increase crime risks, as they provide cover for criminal activities (Ahmad et al., 2024). Solar lighting can mitigate these issues by improving visibility, deterring crime, and enhancing overall safety. By extending productive hours, solar lighting supports local

businesses, markets, and community events, boosting economic resilience and quality of life.

Solar lighting aligns with Madani values by offering an eco-friendly, cost-effective alternative that supports renewable energy goals and community self-reliance. These initiatives demonstrate how sustainable technologies can enrich rural life, supporting a harmonious and progressive society in Malaysia. This research aims to determine the potential benefits of solar technologies in advancing sustainable rural development, with a specific focus on the empowerment of underserved communities. Aligned by six core values—sustainability, prosperity, innovation, respect, trust, and compassion—the research supports equitable and balanced development across both urban and rural contexts.

LITERATURE REVIEW

Overview of Solar Implementation in Malaysia

Solar power usage in Malaysia is largely limited to the domestic level, with over 10,000 households utilizing photovoltaic (PV) systems. However, large-scale commercial adoption remains minimal due to the high costs associated with PV technology, especially for mass power generation. A significant step in Malaysia's solar journey was the 1995 launch of a 100-kilowatt peak (kWp) demonstration PV project in Marak Parak, Sabah, under the Ministry of Energy, Water, and Communications, which demonstrated the feasibility of PV power technology in the country (Mahesh Vaka et al., 2020). Efforts to integrate renewable energy (RE) into Malaysia's energy mix began in the 8th Malaysia Plan (Oh et al., 2010), yet challenges like limited funding, unappealing tariffs, and lack of industry awareness hindered widespread solar adoption. By 2024, Malaysia had advanced significantly, reaching approximately 2,900 megawatts (MW) of operational solar PV capacity, with ambitious plans to expand further in alignment with the National Energy Transition Roadmap (NETR) (SEDA, 2024).

The Malaysia Renewable Energy Roadmap (MyRER) targets 31% renewable energy (13 gigawatts) by 2025 and 40% (18 gigawatts) by 2035, with a long-term goal of achieving 70% by 2050 to meet the nation's aspiration for net zero emissions (SEDA, 2024). Solar projects, such as utility-scale solar parks and floating PV installations managed by Tenaga Nasional Berhad (TNB) in partnership with local cooperatives, aim to enhance energy access and reliability across Malaysia, especially in rural areas. These projects contribute to sustainability while supporting economic empowerment, reducing dependency on conventional energy sources.

Numerous studies Malik & Ayob (2020), Sarker et al. (2023), and Safari et al. (2020) have explored the application of solar energy in Malaysia.

Several limitations can be identified, particularly concerning its implementation in rural contexts. The existing literature tends to focus on the technical and economic feasibility of solar technologies, often overlooking the socio-cultural and community-based factors that influence adoption and long-term sustainability. As a result, the human dimension, such as community behavior responses, funding mechanism and economic conditions, remains underexplored.

Malaysia Madani Framework and Rural Development Policy 2030.

The Madani Framework, introduced by Prime Minister Anwar Ibrahim, promotes a vision of an inclusive and sustainable Malaysian society (Malaysia, 2023). Centered around six core values—sustainability, prosperity, innovation, respect, trust, and compassion—the framework seeks balanced development across urban and rural areas. It emphasizes improving quality of life, economic growth, and infrastructure for all citizens, with a strong focus on rural development. Key objectives include enhancing access to essential services and economic opportunities, primarily through education, infrastructure upgrades, and job creation initiatives (Malaysia, 2023). While the 12th Malaysia Plan and the National Energy Transition Roadmap (NETR) reinforce efforts to expand renewable energy, including solar, to enhance affordable and reliable power access in rural areas, thereby supporting economic growth and environmental sustainability.

Aligned with this, the Madani Framework complements the Rural Development Policy 2030 (RDP, 2030), which envisions "Prosperous, Inclusive, and Sustainable Rural Living" by 2030. Launched in 2019, RDP 2030 aims to bridge the infrastructure and social amenities gap between rural and urban communities. The Madani Framework and the Rural Development Policy 2030 are synergistic in their pursuit of a sustainable and inclusive Malaysia. Thus, the implementation of solar energy projects serves as a critical intersection point, advancing the shared objectives of economic development, environmental sustainability, and social well-being in rural areas.

Safety Issues in Rural Communities

Rural communities in Malaysia, safety concerns often stem from limited infrastructure, particularly the lack of reliable lighting, which affects visibility and increases risks, especially at night (Ahmad et al., 2024). Generally, traditional energy sources, such as kerosene lamps, with solar-powered lighting mitigate fire hazards, making indoor environments safer and decreasing the risk of household fires. The provision of street lighting in rural regions holds significance for the safety, convenience, and economic advancement of the populace (Kaplan, J., & Chalfin, A., 2022). Nevertheless, numerous villages confront hurdles concerning

street lighting, encompassing issues of uneven distribution and energy efficiency. Considering this, embracing the concept of smart villages becomes imperative for optimizing energy consumption, including the deployment of modern lighting systems tailored to community needs (Ahmad et al., 2024). Solar lighting reduces reliance on the main power grid and mitigates the risks associated with power outages, which can leave communities vulnerable to crime and accidents after dark (Ahmad et al., 2024)

RESEARCH METHODOLOGY

This study employs three primary methodologies to assess the impact of solar energy projects on the Orang Asli communities in Perak and Pahang: (i) case studies, (ii) numerical analysis and modeling using specific software, and (iii) questionnaire surveys. Each method is tailored to capture different dimensions of the research objectives, providing a comprehensive understanding of the solar installations' effectiveness and community benefits. According to statistics from the Department of Orang Asli Development Malaysia (2023), Pahang and Perak have the highest Orang Asli populations among all states. Therefore, these two states were selected as case study sites for this observation. The combination of these methodologies allows for a multi-level exploration of the project's impact, integrating empirical observations, quantitative analyses, and community feedback.

Data Collection

Two types of solar lights were installed in the Orang Asli settlements: mounted-type lights and pole-street lights. Specifically, a solar charging hub with battery storage and a solar inverter was set up in Case Study 1, an Orang Asli settlement in Perak, and Case Study 2, a settlement in Pahang. Installation of these solar technologies was guided by on-site empirical analysis and tailored to the specific needs identified by each community.

Case Study 1: Orang Asli Settlement in Perak



Figure 1: Case Study 1 at Kampung Sungai Tonggang, Ulu Kinta, Perak

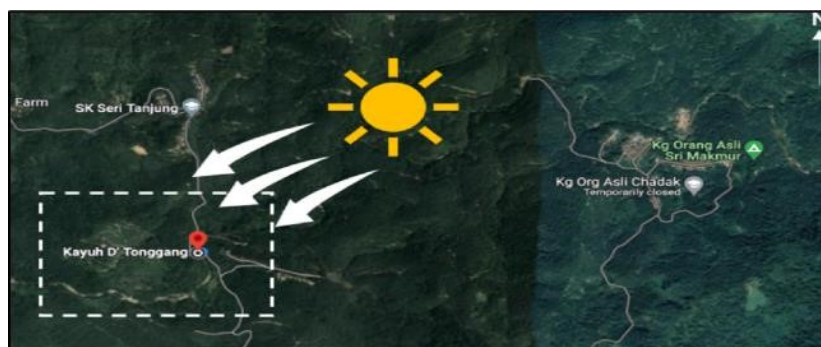


Figure 2: Sun Orientation at Kampung Sungai Tonggang (Source: Google Maps)

The Perak settlement installed solar lighting systems in key outdoor areas like pathways, community centers, and common spaces. Several factors influenced the solar lighting design, including location, shading, and community usage patterns:

1. Pathways: Remote paths required additional lighting for safety, particularly at night. Pole-mounted lights were installed at greater heights to ensure a broad area was illuminated.
2. Community Center: Roof-mounted fixtures were chosen for focused lighting to support evening gatherings and social activities.
3. Shading: Areas with dense tree cover needed additional, higher-wattage lights to counteract the lack of natural sunlight.
5. Toilets and Washing Areas: Moderate lighting with wall-mounted fixtures provided sufficient illumination for safety and hygiene, ensuring these areas were well-lit without excessive energy consumption.
6. External Courtyards: The central courtyard, a space for social events, was equipped with high-wattage lights for bright, uniform illumination to ensure visibility and a safe environment for the community.

Case Study 2: Orang Asli Settlement in Pahang



Figure 3: Case Study 2 at Sungai Kiol, Jerantut, Pahang



Figure 4: Sun Orientation at Sungai Kiol, Jerantut, Pahang (Source: Google Maps)

In the Pahang settlement, similar solar lighting systems were implemented, but adjustments were made based on the community's distinct environment and needs:

1. Pathways: Pathways connecting homes to the community center required heightened lighting due to the remote nature of the settlement. Pole-mounted lights were used to illuminate these critical areas.
2. Open Communal Spaces: Solar-powered roof-mounted lights were installed to provide focused lighting for communal gathering areas, ensuring sufficient brightness during evening gatherings.
3. Shading: Certain areas near forest edges required additional lighting due to heavy shading. High-wattage lights were installed to improve visibility in these darkened areas.
4. Water Collection Points and Toilets: The settlement's washing and water collection points were fitted with moderate lighting, providing a safe, well-lit environment for daily tasks.
5. External Courtyards: Higher-wattage lights were installed in communal spaces and courtyards to create well-lit areas for nighttime activities and social interaction.

Numerical Analysis and modelling

The numerical analysis and modeling for determining solar energy output in Perak and Pahang were conducted using PVsyst software. This software facilitated the integration of local climate data, including solar irradiance and temperature, to simulate the annual energy yield in these Malaysian regions, which differ in geographical and climatic characteristics. The model provides a comparative perspective on energy production potential between Perak and Pahang. Key parameters for estimating the optimal solar lighting power system

included the average daily energy demand of 50 watt-hours (Wh) for each Orang Asli house, which corresponds to five hours of lighting per day. A 30% safety margin was applied to account for system inefficiencies like battery losses and panel performance, adjusting the energy requirement to 65 Wh per day. Using average monthly solar irradiance data from the model, available daily energy was calculated. The required solar panel wattage was determined by dividing the adjusted energy needs by the available energy. This modelling provides a foundation for selecting suitable solar lighting technologies, with solar-mounted panels ideal for stable, high-exposure locations and pole-type panels adaptable for pathways and residential areas, optimizing energy efficiency for community needs.

Questionnaire Surveys

To assess the impact of solar energy projects on the Orang Asli communities in Perak and Pahang, a structured questionnaire survey was conducted. The study employed a purposive sampling strategy to identify respondents who possessed relevant knowledge and experience with solar energy projects in the Orang Asli communities of Perak and Pahang. This approach allowed for the intentional selection of participants based on specific criteria such as age, location, occupation, and community background to ensure the inclusion of diverse yet contextually appropriate perspectives. A total of 100 questionnaires were distributed across both case study locations to collect quantitative data on various community development outcomes. The responses were meticulously analyzed to gauge community perceptions and evaluate the effectiveness of the solar installations. All survey procedures adhered to ethical research standards established by the institutional research ethics committee and complied with national research guidelines.

RESULT AND ANALYSIS

Empowering Orang Asli and Rural Settlements through Micro-Scale Solar Lighting Technologies

This study's empirical data shows that the implementation of micro-scale solar technologies in Orang Asli and rural settlements in Perak and Pahang as the selected case studies significantly improves energy access and enhances the community's well-being, especially in terms of safety. The solar energy systems were designed to meet the unique needs of these remote communities, providing them with a reliable and sustainable source of electricity, primarily for lighting and small appliances.

General Considerations

For both case studies, energy-efficient LED bulbs were used throughout the settlements to ensure uniform lighting, minimize energy consumption, and avoid dark spots, significantly enhancing the safety and comfort of these communities. The solar installations have improved security, reduced reliance on unsustainable energy sources, and provided long-term benefits for the Orang Asli populations in both Perak and Pahang.

(i) Result 1 - Illuminance Analysis

The illuminance analysis simulation was modeled using Python with the Matplotlib library (Matplotlib, 2024), which allowed for the visualization of data through customizable bar charts. This program effectively demonstrates the relationship between different solar lighting wattages and their impact on illuminance levels in the selected case studies. Figure 1 illustrates the bar chart showing the increase in illuminance after the installation of solar lighting in both case studies, showcasing the effects of different wattages (10, 25, 40, and 100 watts). As the wattage increases, the corresponding illuminance levels also rise, with darker shades representing lower wattages and lighter shades indicating higher wattages.

Table 1: The Empirical Data of Solar Technologies for both Case Studies

Types of Solar Lighting Systems	The Information for Case Studies			
	The System Application	The Purpose	Case Study 1: Perak	Case Study 2: Pahang
Solar Mounted-Lights		Various power systems (watt) have been installed due to location, height and shading factors, for walkway, and external areas.	10 units of 10-watts (min), 25-watts, 40-watts (max)	10 Units of 10-watts (min), 25 watts, and 40 watts (max)

Types of Solar Lighting Systems	The Information for Case Studies			
	The System Application	The Purpose	Case Study 1: Perak	Case Study 2: Pahang
Solar Poled-Lights		For street lighting purposes (surrounding of the village, field, farm areas) due to height and location to disperse the lighting.	5 units of 100-watts	5 Units of 100 watts

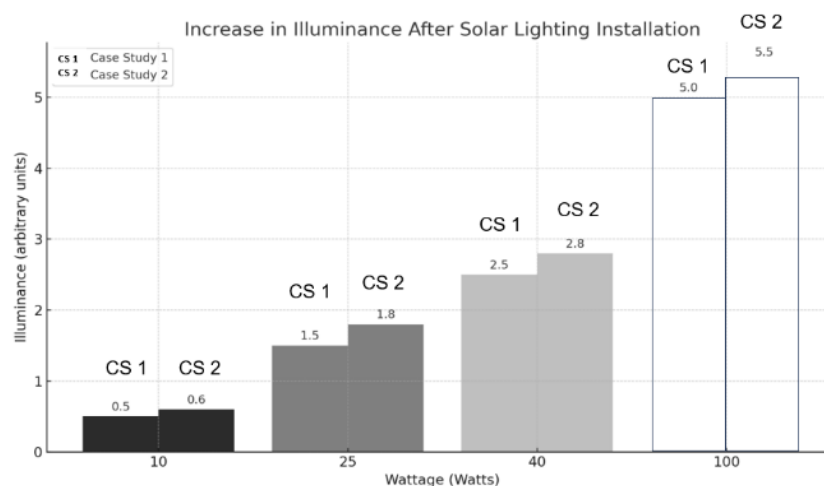


Figure 5: The Illuminance Level After Solar Lighting Installation
 (using Python with the Matplotlib library)

The before-and-after photos in Figure 2 clearly illustrate the improved brightness and visibility in the villages of both case studies, Kampung Sungai Tonggang in Perak (Case Study 1) and Sungai Kiol in Pahang (Case Study 2), following the installation of solar lighting systems, making the results of the project more accessible and visually impactful.



Figure 6: The Before-And-After Photos of the Case Studies

(ii) Results 2 - Determining the Solar Energy Output (for Case Study 1: Perak and Case Study 2: Pahang) for Best Solar Lighting Power System (Watt)

For a model of solar energy output in the Malaysian states of Perak and Pahang (where the case studies are located), PVSyst software (PVSyst, 2023) has been used, and local climate data has been tabulated, considering factors like solar irradiance and temperature, to estimate the potential annual energy yield. This model would allow for a comparative analysis of energy production potential in these regions, which differ in geographical and climatic conditions. To estimate the appropriate wattage for solar lighting for an Orang Asli house, below are the key considerations:

1. **Average daily energy demand for lighting:** Each house needs lighting for 5 hours daily.
2. **Lighting power requirement per day:** The energy in watt-hours (Wh) needed to power sufficient lights for each house.

System efficiency and losses: Factors like battery efficiency, panel performance and potential shading

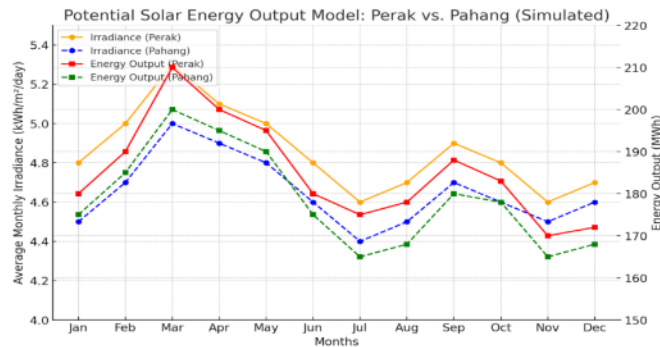


Figure 7: Potential Solar Energy Output Model using PVsyst Software

Figure 3 shows the model that visually represents the potential solar energy output in Perak and Pahang. The graph compares the monthly average solar irradiance (in kWh/m²/day) and the corresponding energy output (in MWh) for both states. The orange and blue lines show irradiance levels for Perak and Pahang, while the red and green lines represent estimated energy output for each month. This model reflects how seasonal variations and geographical differences might influence solar panel performance across these regions, providing insights into energy production trends throughout the year. Using two types of solar lighting technologies, namely Solar-Mounted vs. Pole-Types, the suitable locations for placement of these solar lighting technologies are:

- Solar-Mounted Types: Ideal for fixed locations with stable sunlight exposure, like roofs of the community center or raised platforms - Best Locations: Above the community center and near agricultural plots where they can benefit from direct sunlight.
- Pole-Types: Versatile and can be placed in various locations; easier to relocate if necessary. Best Locations: Along pathways, near homes, and at the edges of common areas.

To determine the solar panel wattage for lighting needs in Perak and Pahang, the calculations are as follows:

- Lighting requirement per day: 5 hours
- Estimated daily energy needs: 50 watt-hours (Wh) per day for each house

To account for system inefficiencies (like battery and inverter losses), a 30% safety margin will apply:

- **Adjusted daily energy needs=50 Wh×1.3=65 Wh**

Using the average monthly irradiance data from the model (see Figure 2):

- **Perak average irradiance: 4.85 kWh/m²/day**
- **Pahang average irradiance: 4.67 kWh/m²/day**

To Convert Irradiance to Daily Available Energy (in Wh/m²/day)

Since 1 kWh = 1000 Wh:

- **Available energy in Perak = 4.85 kWh/m²/day × 1000 = 4850 Wh/m²/day**
- **Available energy in Pahang = 4.67 kWh/m²/day × 1000 = 4670 Wh/m²/day**

The required panel area (in m²) is calculated by dividing the daily energy needs by the available solar energy:

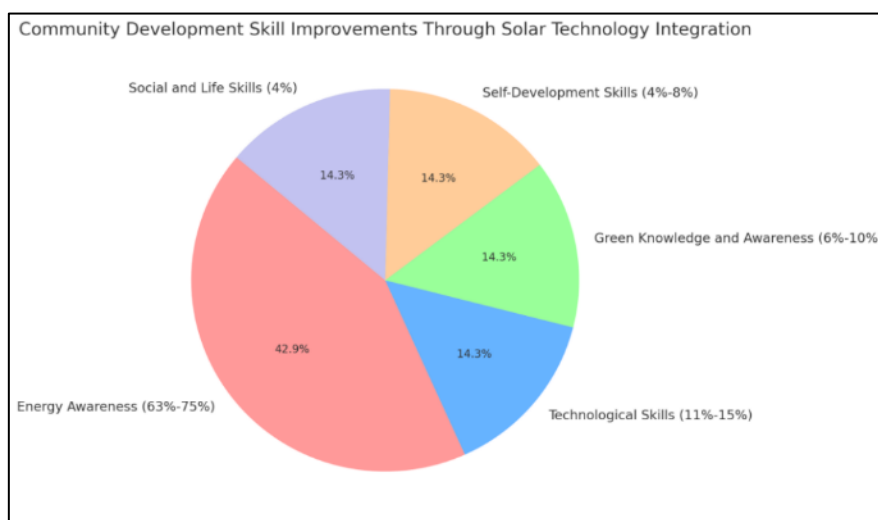
- **For Perak = 65 Wh / 4850 Wh/m² ≈ 0.0134 m² × 100 = 1.34 W**
- **For Pahang = 65 Wh / 4670 Wh/m² ≈ 0.0140 m² × 100 = 1.40 W**

Thus, the estimated solar panel wattage required for basic lighting in an Orang Asli house is 1.34 W for Perak and 1.40 W for Pahang. This wattage can support essential lighting needs based on available sunlight in each location.

(iii) Result 3 - Positive Community Impacts

In Case Studies 1 and 2 of Orang Asli settlements in Perak and Pahang, the solar projects have contributed significantly to community development by increasing green awareness and promoting environmental education among the people. A total of 100 questionnaires were distributed to both case studies. Results indicate a positive response from community members following the installation of solar technology (see Figure 4). These questionnaires analyzed five core areas of community development as shown in the pie chart.

Integrating solar technologies within the community has provided valuable hands-on experience in renewable energy, significantly boosting community development skills. Energy Awareness saw the highest increase, rising from 63% to 75%, as community members became more informed about energy savings.



Technological skills also improved, from 11% to 15%, equipping participants with the knowledge needed for sustainable energy implementation. Green knowledge and awareness increased by 6% to 10%, raising understanding of solar energy benefits. Additionally, self-development skills grew by 4% to 8% as individuals gained confidence in sustainable practices, while social and life skills improved by 4% due to collaborative activities in these programs.

DISCUSSION

Active engagement with the Orang Asli and rural villagers ensured that solar lighting technologies were culturally appropriate and met local needs. Community members were trained to manage and maintain the systems, promoting self-reliance and sustainability. Integration of solar technologies aligns with the MADANI framework by fostering sustainability, inclusivity, and empowerment. Energy awareness increased from 63% to 75%, supporting the Amanah (A) and Nurturing a Sustainable Economy (N) pillars, while technological skills improved by 11–15%, reflecting the Innovation (I) pillar. Gains in green knowledge, self-development, and social skills further demonstrate ethical stewardship under the Morality (M) pillar.

The Community-Based Approach (CBA) enhanced lighting conditions, supporting nighttime economic activities, increasing safety, and reducing risks. Villagers reported greater foot traffic, sales, and safer environments, illustrating how solar technologies improve both economic and social outcomes. These interventions demonstrate practical renewable energy solutions that reinforce the MADANI values: sustainability, prosperity, innovation, respect, trust, and compassion. Overall, the project advances SDG 7 by providing reliable, clean

energy, promoting long-term self-reliance, and supporting inclusive development in rural and indigenous communities.

1. Sustainability (“Kelestarian”)

The use of solar lighting, a renewable energy source, reduces dependence on fossil fuels and minimizes environmental impact, promoting long-term ecological balance within the Orang Asli communities. By using solar-powered lights instead of diesel generators or kerosene lamps, both villages now enjoy clean energy that aligns with green development and sustainable living goals.

2. Prosperity (“Kesejahteraan”)

Improved lighting enhances night-time visibility, promoting safer environments and enabling more evening social, cultural, and economic activities, contributing to overall community well-being. Villagers can now carry out evening gatherings, small businesses, and educational activities for children under well-lit and safer conditions, fostering economic and social growth.

3. Innovation (“Daya Cipta”)

The project demonstrates the application of innovative green technology—solar lighting—to address rural electrification challenges in a cost-effective and adaptive manner. Tailoring solar lighting to suit the specific needs of Orang Asli settlements, including low maintenance and off-grid functionality, reflects practical innovation aligned with community context.

4. Respect (“Hormat”)

By engaging the Orang Asli through a Community-Based Approach (CBA), the project respects their cultural values and prioritizes inclusive participation in decision-making. The community was consulted and involved in selecting the locations for solar light installation, acknowledging their needs and respecting indigenous knowledge and preferences.

5. Trust (“Kepercayaan”)

Transparent implementation and community involvement foster mutual trust between stakeholders, including researchers, local authorities, and the Orang Asli communities. Regular meetings and updates created an open dialogue, enhancing trust in the project's intention and outcomes, and ensuring the community feels ownership over the improvements.

6. Compassion (“Ihsan”)

The initiative is driven by a genuine commitment to improving the safety and quality of life of marginalized groups, demonstrating care for underserved

communities. Prioritizing solar lighting in key communal areas like walkways, homes, and gathering spots addresses safety concerns and shows empathy for the Orang Asli's everyday challenges.

CONCLUSION

This study demonstrates that micro-scale solar technology provides significant benefits for Orang Asli and rural communities in Perak and Pahang. Energy-efficient solar lighting improved safety, access, and availability of illumination while reducing reliance on unsustainable energy sources. Illuminance analysis showed that light intensity increased linearly with wattage (10–100 W), with optimal daily requirements calculated at 1.34–1.40 W. Community engagement enhanced energy awareness (63% to 75%) and technical skills (11% to 15%), enabling residents to operate and maintain the systems sustainably, fostering self-reliance and resilience.

Solar installations included fixed lights at community centers and expandable pole-mounted lights for pathways and shared spaces, improving night-time mobility and supporting small businesses. The initiative aligns with Malaysia's MADANI framework by promoting sustainability, inclusivity, and people-centered development, while contributing to SDG 7 on affordable and clean energy. Overall, this model illustrates a practical, scalable approach for rural electrification, economic development, and renewable energy education, offering a blueprint for future community-based solar initiatives.

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