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GREEN ENERGY PROGRAM TO SUPPORT SUSTAINABLE ECOTOURISM: IMPLEMENTATION OF SOLAR POWER PLANT IN MALASIGI TRADITIONAL VILLAGE SORONG REGENCY SOUTHWEST PAPUA INDONESIA

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Abstract:
Green energy initiatives play a vital role in advancing sustainable ecotourism, particularly in remote regions characterized by rich biodiversity yet limited infrastructure. This study investigates the implementation of an 8,700-watt Solar Power Plant (SPP) in the Malasigi Traditional Village, Southwest Papua, and its contribution to supporting ecotourism operations and fulfilling the basic needs of the local community. Employing a qualitative descriptive methodology, the research assesses the SPP's impact on energy efficiency, carbon emission reductions, service quality enhancement in ecotourism, and local economic empowerment. The findings reveal that the integration of the SPP significantly supports ecotourism development by supplying electricity for essential services such as clean water access, lighting, and operational facilities for visitors and residents. Notably, the SPP implementation has led to a reduction in diesel fuel consumption by approximately 3,600 liters annually and a corresponding decrease in carbon emissions of 9.02 tons CO_2eq per year. Furthermore, the community experienced a 53% reduction in energy-related expenditures. These outcomes underscore the strategic value of renewable energy technologies as a foundational component for promoting environmentally sustainable, economically viable, and socially inclusive ecotourism in remote areas.

Keywords: ***Renewable energy, community empowerment, sustainable ecotourism, traditional village.***

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INTRODUCTION

Remote traditional villages in Indonesia are often characterized by their ecological richness and cultural diversity, yet remain marginalized due to infrastructural deficits, limited access to basic services, and economic vulnerability. Malasigi Traditional Village, located in Klayili District, Sorong Regency, Southwest Papua, exemplifies this condition. As the ancestral territory of the *Moi Kelim* sub-tribe—custodians of some of Papua's last remaining lowland forests—Malasigi is not only ecologically significant but also culturally vital. The area harbors unique biodiversity, including 96 bird species (five of which are *birds-of-paradise*), 25 herpetofauna species, and multiple marsupial mammals, as well as rare geological features such as caves and hot springs preserved through *adat* (customary) governance. However, unsustainable land-use practices such as logging and road expansion have caused significant ecological damage and disrupted the community's access to markets and essential services.

One of the most pressing problems facing Malasigi is energy poverty. The community relies on fossil-fuel generators for electricity and clean water access, both of which are constrained by high operational costs and logistical difficulties in obtaining fuel. This situation limits their ability to develop alternative livelihoods, including ecotourism, despite the area's substantial potential. Malasigi's rich biodiversity and cultural landscape offer ideal conditions for sustainable ecotourism, yet a lack of infrastructure—especially energy and water systems—prevents its realization. This condition exemplifies a broader challenge in Indonesia's remote regions, where ecological assets coexist with socio-economic marginalization.

Various studies have emphasized the importance of sustainable energy access in supporting rural development and conservation-based tourism. For instance, Carroll (2004) and Chen et al. (2019) highlight the role of social innovation and community-based renewable energy in achieving environmental and economic justice in remote contexts. However, most existing literature remains centered on large-scale renewable projects, with limited focus on small-scale, community-led solar initiatives integrated within ecotourism frameworks, especially in eastern Indonesia. This research aims to address this gap by examining a locally developed solar power solution as part of a broader environmental and social innovation.

To overcome systemic infrastructural deficiencies, the *Mata Hati Malasigi* program was launched by the indigenous community as a participatory development initiative. A central element of this program is the construction of an 8,700-watt Solar Power Plant (SPP), designed not merely as an energy source, but

as a strategic intervention to enhance environmental resilience, support ecotourism services, and improve public welfare. Unlike conventional approaches, the SPP is managed by the community itself, reflecting a hybrid model of traditional ecological knowledge and green technology.

The present study investigates how this solar energy innovation supports ecotourism and broader community development in Malasigi. Specifically, the research aims to: (1) assess the technical and economic performance of the solar power system; (2) evaluate its impact on reducing carbon emissions and fossil fuel dependency; and (3) explore how it enables ecotourism services and strengthens socio-economic resilience. In doing so, the research offers new empirical insights into the intersection of renewable energy, indigenous empowerment, and sustainable tourism.

LITERATURE REVIEW

Global Shift from Fossil Fuels to Renewable Energy

Conventional fossil fuel-based electricity generation remains a major contributor to global environmental degradation and greenhouse gas emissions. Coal-fired power plants (CFPPs), once the cornerstone of energy systems, are now increasingly viewed as unsustainable due to their harmful emissions and negative public health implications. Global climate summits, particularly COP28, have amplified calls for the early retirement of CFPPs and the acceleration of renewable alternatives (Philip & Kiongson, 2024). This transition aligns with broader decarbonization targets and sustainability goals.

A key milestone in international climate action was the 2015 Paris Agreement (COP21), which mandated carbon emission reductions to limit global warming. Since then, both governments and the private sector have been urged to adopt eco-innovations that reduce fossil fuel dependency, increase energy efficiency, and promote the use of renewable energy sources (1, 5–9). These initiatives include environmental regulations (10), green taxation (11), and financial incentives (12). At the firm level, innovations in green technology are being developed as responses to these environmental demands. Yet, despite these advancements, research on community-level or grassroots-driven renewable energy transitions remains limited.

Eco-Innovation and Drivers of Renewable Energy Adoption

Recent literature has examined the determinants of eco-innovation, especially innovations that substitute fossil fuel-based energy with renewables (13–16). Among the key drivers identified are high operational costs for traditional energy, expectations of stricter environmental regulations, financial incentives for green innovation, and market demand for sustainable practices (19). However, many of these studies focus on industrial or urban contexts, with less attention paid to isolated or marginalized communities that face unique infrastructural and social constraints.

In relation to the Sustainable Development Goals (SDGs), the transition to renewable energy—particularly solar photovoltaic (PV) systems—has been highlighted as an essential innovation. Solar energy technologies are increasingly valued not only for their environmental advantages but also for their potential to foster inclusive development in underserved areas. Yet, more studies are needed to explore how solar PV systems function in rural, biodiverse, and socially complex settings such as Indigenous communities.

Energy Transition and Socioeconomic Dynamics in Indonesia

Indonesia presents a unique case within the global energy transition due to its status as one of the world's largest coal producers and its geographic archipelagic complexity. Nationally, over 60% of electricity is derived from coal, making the country highly dependent on fossil fuel-based energy infrastructure. At the same time, Indonesia's energy transition roadmap seeks to achieve net-zero emissions by 2060, requiring substantial deployment of renewable technologies, such as utility-scale solar PV and energy storage systems (21). Studies suggest that without adopting low-carbon innovations and phasing out coal, Indonesia may fail to meet its climate commitments (20, 22).

The socioeconomic implications of such a transition are significant. Moving away from coal threatens job security and regional economies reliant on extractive industries. Stranded assets and fiscal losses are anticipated unless proactive mitigation strategies, including stakeholder participation and cross-sectoral policies, are adopted (23). There is thus a growing recognition of the need for localized, inclusive, and context-sensitive energy transition models that consider technical feasibility, social justice, and environmental sustainability simultaneously.

Coal Phase-Out and Barriers in Developing Countries

In coal-producing countries like Indonesia, the energy transition involves complex trade-offs. Most global policy frameworks fail to address upstream economic implications for coal-reliant communities (24). Existing research emphasizes two main transition strategies: transitioning to natural gas as an intermediary, or moving directly to renewable sources (25, 26). However, the affordability of clean energy and the lack of investment capacity remain key barriers for developing economies, where energy subsidies often distort market signals.

Indonesia's reliance on coal for state revenue (accounting for up to 80% of mining income) and electricity generation further complicates transition planning (27). Despite efforts to accelerate coal phase-out targets, these must be accompanied by robust compensation schemes, employment transitions, and decentralized renewable solutions to avoid exacerbating inequalities. This calls for integrative models that merge environmental and economic imperatives with local development priorities.

Solar PV as a Strategic Renewable Energy Solution

Solar photovoltaic systems have emerged as a viable solution for clean energy generation in areas with abundant sunlight, particularly in rural and remote locations. Solar PV utilizes solar radiation to generate electricity with minimal environmental impact. Despite higher upfront installation costs, PV systems offer low operational and maintenance costs, short energy payback periods, and high long-term cost-effectiveness (Shaik et al., 2025).

The performance of solar PV systems, however, is subject to environmental variables such as temperature, humidity, and solar irradiance, as well as maintenance practices. Recent advances in stand-alone and hybrid PV technologies make them particularly suitable for decentralized energy systems. As such, they hold significant promise for enhancing energy security, reducing carbon emissions, and enabling sustainable livelihoods in marginalized regions.

METHOD

This research employed a qualitative descriptive design using a case study approach to analyze the role and impact of solar energy innovation in the development of sustainable ecotourism. The case study was conducted in *Kampung Adat Malasigi*, located in Klayili District, Sorong Regency, Southwest

Papua Province, an isolated area with high ecological value and minimal infrastructure. The qualitative approach was chosen to enable a contextual, in-depth understanding of the social, environmental, and economic transformations influenced by the implementation of the 8,700-watt Solar Power Plant (SPP) in the village.

Data Collection

Primary data were obtained through direct field observations, semi-structured in-depth interviews, and program documentation. Field observations involved systematic visits to observe infrastructure use, energy access patterns, and ecotourism activities. Interviews were conducted with community leaders, local residents, indigenous groups, and program implementers, focusing on experiential narratives and community-based perceptions of change. To ensure the reliability and depth of information, purposive sampling was applied, targeting individuals directly involved in or impacted by the SPP. Secondary data included technical documentation, operational reports, and records from program implementing partners such as NGOs and local government units.

Data Analysis Procedure

Data analysis was carried out thematically through content analysis and pattern matching across five analytical categories:

1. SPP Infrastructure and Technical Specifications – assessing capacity, layout, reliability, and maintenance protocols.
2. Energy Use and Efficiency – evaluating household electricity consumption, lighting, water pumping, and tourism infrastructure.
3. Household Energy Costs and Economic Impact – measuring reductions in fuel consumption, energy expenditures, and savings.
4. Environmental and Conservation Impact – examining changes in deforestation pressure, carbon emissions reduction, and ecosystem preservation.
5. Community Empowerment and Sustainability – investigating local capacity building, knowledge transfer, and governance mechanisms for SPP operation and management.

Coding and interpretation of data were conducted using NVivo to identify recurring themes and interrelationships between categories. Thematic saturation

was achieved through triangulation between interviews, observations, and document analysis to enhance data validity.

The research was conducted in several sequential stages:

1. **Preparation** – formulation of research questions, selection of case study location, and ethics approval.
2. Data Collection – implementation of interviews, observations, and document retrieval.
3. Data Processing and Thematic Analysis – coding, categorization, and pattern identification using qualitative software.
4. Synthesis and Reporting – integration of findings into a narrative that connects SPP intervention with sustainable ecotourism indicators.

RESULTS AND DISCUSSION

Overview of SPP Implementation in Malasigi Village

The introduction of the 8,700-watt Solar Power Plant (SPP) in *Kampung Adat Malasigi* represents a transformative shift in energy infrastructure supporting sustainable ecotourism. The SPP, initiated through a community-based development model, replicates a prior 4,700-kWp solar-powered clean water project in Klasafet District, Sorong Regency, indicating scalability and replicability in similar off-grid regions. The participatory engagement of the Moi indigenous community throughout planning, land allocation, and ceremonial construction (e.g., *siri pinang* ritual) exemplifies cultural sensitivity in sustainable energy deployment. Operational training and capacity building, delivered by Pertamina New & Renewable Energy (PNRE), enhanced the community's ability to manage and maintain the system sustainably.

Green Energy Availability and System Output

The installed SPP provides electricity to 15 households, including homestays and communal buildings. It enables lighting, food preparation, children's learning, and clean water pumping—key for both domestic use and ecotourism.

Fig. 1 Solar Power Plant with Solar Photovoltaic System to produce electricity for building and water pump to support ecotourism in Malasigi Village

Figure 1 illustrates the centralized SPP system supplying power to households and clean water infrastructure.

Category	Pre-SPP (Diesel)	Post-SPP (Solar)
Energy Source	Gasoline generator	Solar Photovoltaic (SPP)
Electricity Reach	<10 households (limited hours)	15 households + homestays
Clean Water Pumping	Manual, diesel-powered, limited	Automated, solar-powered
Operational Hours	Intermittent	10:00 AM – 2:00 PM (optimum)
Seasonal Limitations	Severe in rainy season	Manageable with energy storage

SPP has significantly enhanced the reliability and reach of electricity supply, facilitating essential services and enabling consistent ecotourism operations. The alignment between power availability and peak tourist activity ensures service delivery without reliance on fossil fuel logistics.

Energy Cost Efficiency and Household Economics

Prior to SPP, households relied on diesel generators requiring up to IDR 3,000,000/month for fuel. With SPP, communal contributions have decreased to

IDR 750,000/month, managed by the *Belempe Village Forest Management Institution*.

Metric	Before SPP	After SPP
Monthly Fuel Expenditure/HH	IDR 3,000,000	IDR 750,000
Annual Savings per Household	–	~IDR 27,000,000
Community Management Model	None	Belempe (CSR-based)

Households save approximately 75% in energy costs, enabling financial reallocation toward health, education, or small business development. The shift toward decentralized communal management reflects empowerment and institutional sustainability.

Carbon Emission Reduction and Environmental Value

The replacement of 3,600 liters of diesel annually equates to an estimated reduction of 9.02 tons CO_2eq/year. This aligns with the village's commitment to *Hutan Desa* (Village Forest) conservation and bolsters its image as an ecotourism hub.

Indicator	Value
Diesel Replaced	3,600 liters/year
CO_2eq Emissions Reduced	9.02 tons/year
Environmental Designation	*Hutan Desa* (Village Forest)

The emissions offset directly contributes to Indonesia's low-carbon transition and global decarbonization goals. Integrating renewable energy into forest governance reinforces the ecological integrity of Malasigi.

Support for Ecotourism and Local Economic Activities

SPP facilitates reliable service delivery for ecotourism operations, particularly birdwatching—a signature attraction due to the region's endemic bird species. Previously, tourists were required to bring fuel; this constraint has been eliminated.

Ecotourism Enhancements Enabled by SPP:

1. Homestays now offer consistent lighting and clean water.
2. Tourist stay duration has increased due to improved amenities.
3. Forest product processing (e.g., banana chips) has grown, with electricity enabling refrigeration and small machinery operation.

The integration of SPP has moved the village from a subsistence model to an eco-entrepreneurial framework. Renewable energy access transforms biodiversity into an economic asset while maintaining conservation priorities.

Community Empowerment and Capacity Building

Training provided by the Electrical Team RAM (Pertamina EP Papua Field) included modules on:

1. Solar panel operation and cleaning
2. Battery and inverter maintenance
3. Load management and system diagnostics

This technical education has empowered women and youth, creating an inclusive knowledge system that ensures operational longevity and equitable participation.

The program's capacity-building component illustrates that infrastructure alone is insufficient—socio-technical integration is essential. Empowering marginalized groups ensures resilience and adaptability in managing off-grid energy solutions.

Synthesis and Broader Implications

The SPP deployment in Malasigi Village illustrates how renewable energy serves as a foundational infrastructure for achieving interlinked sustainability goals—clean energy, poverty alleviation, ecosystem protection, and inclusive development. The participatory model adopted—integrating *adat* (customary) values, corporate social responsibility (CSR), and technical assistance—offers a replicable prototype for other remote Indigenous communities in Southeast Asia.

Unexpectedly, the project also led to the revival of traditional practices such as communal forest zoning and seasonal resource governance, indicating that renewable energy can act as a catalyst for broader social innovation when deployed with cultural competence.

Renewable energy initiatives, when embedded within local traditions and participatory governance, yield multidimensional benefits. Malasigi demonstrates that clean energy transitions are not solely technical shifts but socio-ecological transformations, especially when community ownership and knowledge transfer are central.

CONCLUSION

This study has demonstrated that the implementation of a Solar Power Plant (SPP) in the Malasigi Traditional Village serves not only as a technical response to energy scarcity but also as a strategic enabler for sustainable ecotourism, community empowerment, and environmental stewardship. As outlined in the introduction, the research sought to explore how renewable energy, when integrated with local participation and ecological values, can foster a transformative development model in remote Indigenous communities.

The findings confirm that the deployment of SPP technology contributes significantly to reducing household energy expenditures, lowering carbon emissions, improving the quality of tourism services, and enhancing community cohesion and technical capacity. Beyond its functional role in energy provision, the SPP has become an infrastructural catalyst that bridges economic revitalization and conservation goals.

Importantly, this research affirms that energy interventions rooted in cultural contexts and community-based governance—such as in the case of the Moi people—can result in more inclusive, resilient, and scalable outcomes. The participatory approach and integration with *adat* (customary) systems underscore the potential for replicating such models across other traditional and ecologically sensitive areas in Indonesia and beyond.

Future research should further examine the long-term socio-economic and ecological impacts of decentralized renewable energy systems, especially in relation to governance structures, market linkages, and youth participation in technology stewardship. Additionally, expanding comparative studies across different geographies could enrich understanding of how cultural adaptation shapes the success of sustainable energy transitions in diverse socio-environmental settings.

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