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Feasibility Analysis and Potential of Hybrid Wind Solar Energy in Supporting Green Tourism and Green Job Creation in Posong Nature Tourism, Temanggung

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ABSTRACT: Limited electricity supply is a major challenge for tourism development in mountainous areas such as Posong Nature Tourism in Temanggung. This study aims to analyze the feasibility and potential of implementing a Wind-Solar Hybrid Energy system as a renewable energy solution that supports green tourism development and green job creation. The method used is a descriptive qualitative case study approach, based on observations and in-depth interviews with relevant stakeholders. The results of the study indicate that this hybrid system is technically, socially, financially, and environmentally feasible, based on the Gittinger Feasibility Theory framework. The combination of wind and solar energy can provide a more stable electricity supply. In addition to reducing emissions and operational costs, this project creates green energy-based jobs integrated with the tourism ecosystem. This project has been well received by the community and has the potential to empower MSMEs. However, this system is not yet operating optimally, and further strategies are needed to ensure the sustainability of the green energy transition in the rural area of Tlahab Village.

KEYWORDS: Renewable Energy, Hybrid Systems, Green Tourism, Green Finance, Green Jobs.

INTRODUCTION

Indonesia is still highly dependent on fossil energy as the main source of national electricity supply. According to data from the Ministry of Energy, fossil energy consumption in 2020 reached 898.5 billion barrels of oil equivalent (BOE) out of a total energy supply of 1,493.5 billion BOE (Akbar & Yunanda, 2025).The world's reliance on fossil energy is considered to support economic growth, increase productivity and significantly improve people's living standards but has a negative impact on high carbon emissions and major challenges in distributing energy equitably.

One of the main challenges in energy distribution in mountainous areas is limited electricity infrastructure and distance from transmission centers. This result causes many developing tourist villages and agrotourism areas to experience limited access to reliable and sustainable energy supplies. Posong Nature Tourism Area, located in Tlahab Village, Kledung District, Temanggung Regency, is one of the tourist villages with extraordinary natural tourism potential. This area is managed by the village-Owned Enterprise (BUMDes) Bumi Arum Tlahab which boasts a leading ecotourism-based tourism destination.

1.1 Map of Posong Nature Tourism

Along with the increasing number of tourist visits and the development of tourism infrastructure, the need for a stable and environmentally friendly electricity supply in this area continues to increase. Unfortunately, Posong tourism operations currently

rely heavily on diesel-powered generators and battery-powered power storage systems, which are not only expensive in terms of operational costs, but also cause environmental impacts in the form of air pollution, noise, and greenhouse gas emissions. This reliance on non-sustainable energy systems is a major obstacle to realizing green tourism in line with sustainable development principles (UNEP, 2011).

The impact of this limited energy supply is not only felt in the environmental aspect, but also in the economic and social dimensions. The cost of tourism operations becomes high due to the purchase of fuel and maintenance of generators, which ultimately impacts the price of tourism services and visitor comfort. Furthermore, the use of generators also poses the risk of operational disruptions, especially when fuel supply is difficult to obtain. From a social perspective, reliance on old energy systems limits the creation of new jobs based on renewable and educational technologies for local communities.

In response to these challenges, the Tlahab Village Government, along with academic partners, initiated the development of a hybrid wind-solar renewable energy system. This system is designed to combine wind and solar power to provide sustainable and environmentally friendly electricity for tourism areas. In addition to providing a technical solution, this system is also expected to be a starting point for green energy and economic transformation at the village level through the creation of green jobs, such as energy technicians, ecotourism educators, and community energy managers.

However, to ensure the success and sustainability of this project, a comprehensive study is needed regarding the technical, financial, social, and environmental feasibility of implementing the hybrid system. Therefore, this study aims to analyze the feasibility and potential of implementing hybrid wind-solar energy technology in the Posong Nature Tourism area and evaluate its contribution to supporting green tourism and creating green jobs at the local level. This research is expected to provide an academic and practical basis for the development of green energy systems in other mountain tourism areas in Indonesia.

I. LITERATURE REVIEW

2.1 Feasibility Theory

Feasibility theory developed by Gittinger (1982) is one of the most comprehensive frameworks in assessing the feasibility of a project. The goal is to ensure that the project is not only viable but also provides optimal benefits through efficient resource utilization and minimal risk. Gittinger divides feasibility analysis into four main dimensions: technical, financial and economic, social, and environmental. Technical feasibility relates to the operational readiness of the project, including location, technology, and resources. Financial and economic feasibility assesses cost efficiency and potential long-term benefits, both for managers and the community.

Meanwhile, social feasibility considers the extent to which a project is accepted and supported by the community and its contribution to social welfare. Environmental feasibility assesses the project's impact on the ecosystem and its compliance with the sustainable development principles. Gittinger emphasizes the importance of a multidimensional approach, as projects that are technically superior but socially unacceptable or environmentally damaging remain at risk of failure. In the context of this research, Gittinger's feasibility framework is used to evaluate the potential implementation of a hybrid wind-solar energy system at Posong Nature Tourism, including technical aspects, financial efficiency, social support, and ecological impact as a basis for sustainable decision-making.

2.2 Renewable Energy and Hybrid Systems

Renewable energy is energy that comes from naturally renewable sources, such as sunlight, wind, water, and biomass. According to Twidell (2022), utilizing renewable energy is a key solution to reducing carbon emissions and expanding access to sustainable energy, especially in remote areas where conventional electricity grids are difficult to reach. This energy is seen as an environmentally friendly alternative to fossil energy because it does not produce significant emissions and has long-term potential to support the global energy transition.

Tiwari & Ghosal (2005) added that one of the growing forms of renewable energy utilization that is increasingly developing is the hybrid system, which is the combination of two or more renewable energy sources, such as solar and wind power, in one integrated system. The system is designed so that both sources complement each other in changing weather conditions, thereby increasing the reliability of energy supply. With proper management, hybrid systems can increase efficiency, lower energy storage costs, and reduce dependence on fossil energy generators. In the context of remote areas such as mountainous areas or tourist villages, hybrid systems are an ideal solution because they can generate energy independently, flexibly, and sustainably.

2.3 Green Tourism

Green tourism is a tourism development concept that aims to create jobs involving local communities and emphasizes environmental conservation (Hastuti et al., 2023). UNEP (2011) states that this concept encourages sustainable practices in the aspect of transportation, accommodation, and energy and water management.

Tourism village is one of the implementations of green tourism that utilizes rural areas with unique culture and potential to drive the village economy (Rahmayani et al., 2022). At Posong Nature Tourism, innovations such as hybrid wind solar energy can attract tourists and support green tourism practices.

2.4 Green Finance

Green finance is a financial system focused on environmentally friendly investments with the aim of supporting sustainable economic growth, achieving net-zero emissions, and addressing the challenges of climate change (Fu et al., 2023). According to UNEP (2016) and OECD (2017), green finance includes three instruments, such as green bonds, sustainable CSR funds, and government incentives aimed at supporting renewable energy projects, energy efficiency, and environmentally friendly resource management.

Zhang et al. (2024) stated that the key to successful green finance implementation is the private sector's ability to access sufficient funding. In the context of establishing a tourism village in Tlahab Village, the green finance concept could be a primary source of funding for the installation of a hybrid wind-solar system, given the relatively high initial investment required for a clean energy system.

2.5 Green Jobs

The International Labour Organization ILO (2012) defines green jobs as jobs that significantly contribute to the preservation or restoration of environmental quality. These jobs span sectors such as renewable energy, waste management, natural resource conservation, and sustainable tourism.

In developing a renewable energy-based tourism village in Posong Nature Tourism, the opportunity to create green jobs is wide open. Hybrid energy system technicians, ecotourism educators, waste management operators, and local-based environmentally friendly entrepreneurs are jobs that can be developed. Creating green jobs not only creates new jobs but also harmoniously integrates economic, social, and environmental goals to support the long-term sustainable development agenda (Tănasie et al., 2022).

2.6 Previous Studies

Several studies have shown that the application of hybrid energy systems in remote tourist areas can improve energy efficiency and reduce operational costs. Research by Hidayat et al. (2025) examined the planning and efficiency optimization of a hybrid renewable energy system (HRES) in Bahuluang Tourism Village, South Sulawesi. In the study, an off-grid system combining solar panels, wind turbines, and battery storage successfully generated 209, 851 kWh of energy per year, with a composition of 82.4% solar energy and 17.6% wind energy. This study showed that the hybrid system configuration was not only able to meet the village's electricity needs of 424.1 kWh per day but also reduced carbon emissions and supported the national energy transition towards Net Zero Emissions. The use of HOMER software in the simulation enabled the optimization of system costs and reliability technically and economically.

Meanwhile, Solikah & Bramastia (2024) through a systematic literature study in the New & Renewable Energy Journal emphasized the enormous potential of new and renewable energy resources in Indonesia, especially solar and wind power. This study also emphasized the importance of utilizing renewable energy to support national policy through Presidential Decree Number 5 of 2006 and the energy mix target of 23% by 2025. This study noted that one of the main advantages of renewable energy is its abundant availability, minimal environmental impact, and economic opportunities in the form of developing affordable and environmentally friendly local energy.

Both studies serve as important references for analyzing the feasibility and potential of a hybrid wind-solar system in Posong. Despite having different geographic conditions, the principles of renewable energy integration, local economic benefits, and system efficiency are highly relevant for developing nature tourism in mountainous areas.

II. RESEARCH METHODS

This research was conducted using a qualitative descriptive approach. Hardani et al. (2020) explained that this approach was used to accurately explore phenomena, facts, or events regarding the potential and feasibility of hybrid energy use in the Posong Nature Tourism Area through feasibility theory.

Sinaga (2023) explained that the research data sources were obtained through primary and secondary data. Primary data were obtained through observations and interviews with Posong MSMEs, managers of hybrid wind solar energy innovation, and Tlahab Village officials. Secondary data were collected through literature studies relevant to the research topic. The data obtained were analyzed through data reduction, data presentation, and conclusion drawing (Miles & Huberman, 1994).

III. RESULTS AND DISCUSSION

Posong Nature Tourism in Temanggung has great potential as a green tourism destination but is still constrained by an unstable energy supply. This tourist spot has been established since 2009 and began to be recognized by the public in 2013. Since its

establishment, most MSMEs have relied on generators and car batteries to meet their daily electricity needs. These MSMEs must spend up to IDR 200,000 per day on fuel to operate the generator. This use of generators is not only economically wasteful, but also environmentally unfriendly as it produces carbon emissions.

In addition to generators, other MSMEs use car batteries that are charged once a week only to light one lamp for three hours a day. In fact, some of them choose not to use electricity due to cost constraints and rely solely on emergency lighting at night. This condition represents a significant limitation in supporting tourism operations in a sustainable and efficient manner and becomes an obstacle in achieving the Sustainable Development Goals (SDGs), particularly point 7 on affordable and clean energy and point 8 on decent work and economic growth.

To address the issue of unstable energy supply, the Tlahab Village Government is collaborating with PT Jateng Petro Energi (PT JPEN) and Sarana Patra Hulu Cepu (SPHC) as initiators and providers of financing for the construction of a hybrid system based on wind and solar power. PT Dipa Consultant Utama is also involved as the planner and supervisor of the installation, as well as the implementer of technical assistance to create an energy-independent village. This initiative is a form of environmentally friendly technology intervention that aligns with the principles of green finance and supports the transition to sustainable energy.

The system called Hybrid Wind Solar Energy began construction at the end of 2024. The system is designed to absorb energy from the wind and sun, store it in batteries, and then convert it to AC power through an inverter. However, based on data in the field, the system is still undergoing refinement and testing phase to ensure its performance and stability before full operation.

Figure 4. 1 Posong Windmill System

The interview was conducted with Mr. Satria Pinandita, the expert handling the project. The windmill's operation has undergone three improvements, most of which focused on the design of the blades to adapt to mountainous conditions with unpredictable wind directions. The first design was threaded like an ice cream cone with two blades. Although it spun well, it slowed down under load as the rotation was not strong enough to charge the battery, which requires a minimum of 200 RPM to generate electricity. The second design used three open "n" shaped blades, but the wind often split upward or downward, making it ineffective at moving the mill.

Meanwhile, the third design currently in use is shaped like a tail with three closed blades, and a gearbox is added below the mill. Unlike the previous two designs, which were directly connected to the generator, the use of a gearbox allows one rotation of the mill to produce 20 rotations of the generator. However, this system requires a large starting torque, making the mill feel heavy and requiring manual pushing to start spinning. To overcome this, a bearing is added above the gearbox to maintain a straight position and smoother rotation. Observations on July 20, 2025, showed that in 3.4 seconds, the mill was able to make one rotation. With a gearbox ratio of 1:20, this speed is equivalent to 600 RPM on the generator, producing a voltage of 54 volts and a current of 36 amperes, which converts to about 1,994 watts of electrical power.

The feasibility and potential implementation of this system need to be reviewed from technical, social, financial, and environmental dimensions. From a technical dimension, the hybrid system design shows great potential in providing a more stable power supply throughout the day by utilizing a combination of wind and solar energy. However, there are still technical challenges that need to be overcome, some of which include insufficiently robust windmill dynamo, suboptimal blade design, constraints on the use of the gearbox, and the need for regular maintenance to maintain system stability.

From a social dimension, this innovation has been well-received by the community, marked by the installation of 22 electricity meters at MSME stalls around the Posong tourist area. However, operational challenges arise due to the lack of clear communication regarding the electricity payment scheme, so further coordination between system managers and MSMEs is needed. From an environmental dimension, this system has significant potential to reduce CO_2 emissions that have been caused using fossil fuel generators. Therefore, the implementation of this hybrid system also supports the achievement of SDGs point 13 on concrete climate change action.

As for the financial side, the use of hybrid energy is projected to reduce long-term operational costs compared to generators or batteries, which require regular recharging. The initial investment is relatively large but in line with the findings of the OECD (2017) that global investment in low-carbon infrastructure, such as clean energy, is estimated to reach USD 103 trillion by 2030. However, the fuel savings generated have the potential to cover the high costs incurred up to USD 1.7 trillion per year and thus can support the national energy transition agenda.

Furthermore, the project has the potential to create green jobs not only in the operational and maintenance aspects of technology but also in the development of green energy-based services and education. Currently, the job of an expert technical supervisor from Posong is held by Mr. Hakim. In its operation, the management of windmills in Posong Nature Tourism already has a Standard Operating Procedure (SOP) that covers solar panel maintenance.

Figure 4. 2 Posong Solar Panel System

Beyond the technical aspects, new economic opportunities have also begun to open up. One MSME stated that the availability of electricity will open businesses offering mobile phone charging services for visitors. In the long term, this system can be developed as an educational tourism facility by introducing the concept of green energy to tourists through direct installations and interactive educational programs. The community-based tourism management applied at Posong Nature Tourism aligns with the concepts of green tourism and green jobs as formulated by the ILO (2012) and UNEP (2011), which emphasize the importance of local community involvement in energy management and tourism based on environmental sustainability.

Overall, although the Hybrid Wind Solar Energy project in Posong Nature Tourism is still being refined, the technical and socio-economic analysis demonstrate significant potential to support the green energy transition in rural tourism areas. The success of this project will serve as a replication model for other tourism villages with similar geographic characteristics, while also contributing to the achievement of SDGs targets, particularly points 7, 8, and 13.

IV. CLOSING

5.1 Conclusion

The implementation of the Hybrid Wind Solar Energy system at Posong Nature Tourism demonstrates the feasibility of further development as a sustainable energy supply solution, although it still faces several technical and non-technical challenges. Technically, the system has the potential to provide a more stable electricity supply by combining wind and solar power in accordance with Posong's geographical characteristics. However, refinement of the windmill blade design and regular system maintenance are key priorities for optimal system performance.

From a financial dimension, although it requires considerable initial investment, this system has the prospect of long-term operational cost efficiency in line with the principles of green finance. On the social dimension, the initiative has received a positive response from the community, demonstrated by the installation of electricity meters at MSME stalls. However, further socialization is needed to clarify the tariff scheme and manage usage to avoid confusion.

From an environmental perspective, this project has the potential to reduce carbon emissions generated by generators, as well as support the achievement of the SDGs, specifically point 7 (Affordable and Clean Energy), point 8 (Decent Work and Economic Growth), and point 13 (Climate Change). In addition, this project opens opportunities for the creation of green jobs, both in the fields of technical operations, energy management, and new economic opportunities such as renewable energy-based tourism education and the provision of charging facilities for tourists.

Overall, the hybrid wind-solar system in Posong is not only technically and economically feasible but also has strong social and ecological potential to support sustainable green tourism. With proper management, this renewable energy system is not only a technological solution but also a driver of socio-economic transformation toward a self-sufficient, energy-resilient, and sustainable tourism village.

5.2 Recommendations

The sustainability of the Hybrid Wind Solar Energy system at Posong Nature Tourism requires a comprehensive approach that includes technical optimization and strengthening management aspects. The design of the Vertical Axis Wind Turbine (VAWT) type windmills, the use of high-performance dynamos, and the adjustment of battery and inverter capacity to the actual electricity needs of MSMEs need to be reviewed immediately to ensure a more stable energy supply.

On the management side, the preparation of a fair tariff scheme and payment method, such as a prepaid system (pay-as-you-go) needs to be socialized immediately to create clarity for businesses. The project also has the potential to be developed as a renewable energy-based educational tourism facility, which could strengthen Posong's identity as a green and energy-independent tourism village.

Multi stakeholder collaboration, including village governments, private sector, and educational institutions, is recommended to strengthen funding, human resource training, green finance-based innovations development, as well as support the achievement of SDGs at the local level, especially points 7, 8, and 13.

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