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Integrating Renewable Energy and Social Innovation: A Community-Based Model for Sustainable Rural Electrification

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Abstract

Access to reliable electricity remains a significant challenge in rural areas, particularly in developing countries, where traditional grid-based electrification is often not feasible. This research explores the integration of renewable energy technologies with social innovation to develop a community-based model for sustainable rural electrification. The study employs a qualitative methodology, using method to engage local communities in the design, implementation, and management of renewable energy systems. Data were collected through semi-structured interviews, focus groups, and workshops in two rural villages in Indonesia. The findings indicate that community participation, local governance, and social innovation are crucial for ensuring the long-term sustainability of renewable energy projects. Communities that were actively involved in the process demonstrated greater ownership, more effective maintenance practices, and improved social cohesion. The study concludes that integrating renewable energy with social innovation offers a promising approach to rural electrification, fostering both technical sustainability and social empowerment. The research contributes to the growing body of knowledge on decentralized energy solutions and provides practical recommendations for policymakers, NGOs, and practitioners involved in rural energy transitions.

Keywords Community-Based Model, Renewable Energy, Social Innovation, Sustainable.

INTRODUCTION

Access to reliable and affordable electricity remains a critical challenge in many rural areas across the Global South. While urban centers have largely benefitted from centralized energy infrastructure, remote communities often remain off-grid or receive unreliable service. This energy disparity hinders socio-economic development, restricts access to quality healthcare and education, and limits opportunities for economic productivity (Lis & Szyszka, 2020). In response, renewable energy technologies particularly solar photovoltaic (PV), micro-hydro, and wind have emerged as viable alternatives to expand energy access in these underserved regions. However, technological availability alone does not guarantee sustainable outcomes (Rafiola et al., 2020). Community involvement, ownership, and adaptability to local socio-cultural contexts are equally crucial to ensure long-term success.

Despite increasing investments in renewable energy initiatives for rural electrification, many programs have struggled to deliver sustainable impact. Some systems fall into disrepair due to lack of local capacity, while others are abandoned because they do not align with the needs or values of the

community (Chambers & Conway, 1992). In many cases, top-down approaches implemented without meaningful community engagement or sensitivity to local dynamics fail to generate lasting benefits. These outcomes highlight a critical problem: the overemphasis on technical solutions often overlooks the socio-institutional aspects necessary for long-term sustainability (Roberto Crotti & Tiffany Misrahi, 2017). Therefore, there is a growing consensus that rural electrification must go beyond infrastructure and include inclusive governance, local innovation, and community participation.

This research introduces an integrative model that combines renewable energy implementation with social innovation practices, emphasizing a community-based approach to rural electrification. Social innovation in this context refers to new social practices, institutions, and collaborations that address societal needs more effectively and inclusively. By embedding social innovation into energy projects, communities can co-create solutions, build local capacity, and ensure the system reflects their priorities (Lee & Chang, 2018). This approach contrasts sharply with traditional development paradigms that treat communities as passive recipients rather than active agents of change. The study explores how integrating social innovation fosters local ownership, enhances resilience, and builds trust—critical components for sustainable energy transitions in rural settings (Alsayegh, 2021).

The uniqueness of this study lies in its attempt to bridge two often separate domains: renewable energy systems and social innovation theory. While there is considerable literature on the technical deployment of renewable energy, few studies systematically integrate socio-technical perspectives that involve grassroots innovation, participatory planning, and adaptive governance (Albrecht et al., 2017). Moreover, existing research tends to prioritize output metrics such as the number of households electrified over long-term social impacts like empowerment, equity, and institutional sustainability. This research aims to fill that gap by proposing a model that evaluates success not only through kilowatt-hours generated but also through the quality of community engagement, institutional adaptability, and long-term social outcomes (Sebsibe et al., 2023).

Previous studies have pointed to several gaps that this research seeks to address. For instance, while decentralized energy systems have been promoted as a solution for rural electrification, many projects have failed due to insufficient integration of local governance structures or lack of attention to maintenance and financing models (Herry et al., 2019). Moreover, much of the literature treats "community-based" initiatives as homogenous, without accounting for internal social dynamics such as gender roles, power relations, or cultural practices that influence the success or failure of electrification efforts. In response, this research applies a multidimensional framework that includes not only technical and economic analysis but also sociological, cultural, and institutional dimensions (Haniah et al., 2020). By doing so, the study provides a more holistic understanding of what makes rural electrification efforts truly sustainable (Reggina & Indriani, 2023).

The primary aim of this article is to develop and empirically test a community-based model for rural electrification that combines renewable energy technologies with social innovation practices. The model is grounded in participatory action research conducted in selected rural communities, where local stakeholders played an active role in the design, implementation, and evaluation of energy systems. Through qualitative interviews, participatory workshops, and system analysis, the research investigates how communities can co-create energy solutions that are technically viable, socially inclusive, and institutionally sustainable. The goal is to offer practical insights and policy recommendations for governments, NGOs, and private sector actors involved in rural energy transitions.

This research aspires to contribute to a paradigm shift in how rural electrification is conceptualized and implemented. Rather than viewing energy access as a purely technical challenge, the study

underscores the importance of social processes, local agency, and institutional innovation. By integrating renewable energy with social innovation in a community-centered framework, the research offers a path toward more inclusive, resilient, and sustainable energy futures for rural populations. The anticipated outcome is not just increased energy access, but also enhanced social cohesion, capacity building, and empowerment of marginalized communities.

METHOD

This study adopts a qualitative research methodology, specifically using a method approach to explore how renewable energy and social innovation can be effectively integrated in rural electrification projects. The qualitative paradigm is appropriate given the research's emphasis on understanding social processes, community dynamics, and local knowledge systems. Conducted over a period of eight months from March to October 2024—the fieldwork was carried out in two rural villages located in Eastern Indonesia, each characterized by limited access to grid electricity and active local community organizations. The locations were selected based on their differing socio-cultural and geographic conditions to provide comparative insights into how contextual factors influence project implementation and outcomes.

Data collection was carried out through a combination of semi-structured interviews, focus group discussions, participatory workshops, and direct field observations. Interviews were conducted with a range of stakeholders including community leaders, local households, technicians, NGO representatives, and local government officials. Focus groups were used to explore collective views and facilitate inclusive dialogue, particularly around energy needs, social norms, and local innovation practices. Workshops were co-designed with community members to simulate decision-making processes around the design, installation, and maintenance of renewable energy systems. All sessions were audio-recorded and transcribed, and observational data were captured through field notes and photographs. The primary data were complemented by secondary sources such as policy documents, NGO reports, and previous project evaluations.

Data analysis followed a thematic coding process using NVivo software. The transcripts and field notes were iteratively reviewed to identify recurring patterns and categories related to community participation, governance mechanisms, sustainability practices, and perceived impacts. Through constant comparison and triangulation between data sources, the study ensured credibility and depth of analysis. The final interpretation was shaped not only by academic reflection but also by ongoing validation with community members, allowing for collaborative knowledge construction and ethical alignment with local values. This methodology enabled a grounded understanding of how technical and social dimensions interact in shaping sustainable rural electrification outcomes.

FINDINGS AND DISCUSSION

Findings

The findings of this research reveal that integrating social innovation into renewable energy initiatives significantly enhances both the functionality and sustainability of rural electrification efforts. In both studied communities, the presence of strong social capital and pre-existing community institutions played a crucial role in enabling participatory processes. Communities that had active cooperatives or local governance bodies were more capable of mobilizing resources, coordinating responsibilities, and adapting to challenges during system implementation. Moreover, when residents were involved early in

the planning and decision-making stages, there was a noticeable increase in their sense of ownership and commitment to maintaining the systems.

One of the most prominent themes to emerge from the data was the importance of contextual adaptation. The energy systems that were co-designed with community input showed greater relevance to local needs and routines, such as aligning energy availability with agricultural activities or religious events. In one village, for instance, the community opted for a hybrid system combining solar panels with a micro-hydro generator to ensure energy supply during prolonged rainy seasons when solar yield is limited (Aldiab et al., 2019). This decision emerged not from external technical recommendations but from community knowledge shared during participatory workshops, showing how local wisdom can inform technically sound, contextually grounded decisions.

Another significant finding relates to the social dynamics within the community. The process of collective design and management of energy infrastructure led to stronger social cohesion and inter-group collaboration. In particular, the inclusion of women and youth in focus groups and workshops challenged conventional gender roles and encouraged a more inclusive governance model (Handayani & Nur, 2019). Women's participation was especially critical in identifying household energy priorities and in promoting behavior change around energy use. In one case, a women-led subcommittee was formed to manage the financial contributions and maintenance schedules of the energy system an initiative that emerged organically through the participatory process and was later institutionalized by the village council.

Institutional innovation also emerged as a key factor in sustaining the project beyond its initial installation. Both communities developed local maintenance and governance structures, such as energy management committees, whose legitimacy was strengthened through community-wide elections and consensus-building practices (Sigit Gesang Permana et al., 2022). These institutions served not only to oversee technical performance but also to handle disputes, collect contributions for repairs, and coordinate with external agencies. Their success lay in being deeply embedded within the existing social and cultural frameworks of the village, rather than imposed as external bureaucratic models. This finding underscores the value of integrating local institutions into energy governance rather than replacing them.

From a socio-economic perspective, the integration of energy access with social innovation unlocked new livelihood opportunities. Several community members reported starting home-based businesses such as food processing, handicrafts, or battery charging services thanks to improved electricity access (Akinwamide & Oguntade, 2023). More importantly, the participatory nature of the process helped these economic activities to be coordinated collectively, with a shared understanding of energy limitations and priorities. This collective coordination reduced conflicts over usage and fostered an ethic of shared responsibility and equitable benefit. Energy was no longer viewed as a commodity delivered from outside, but as a shared resource managed by the community.

Lastly, the research found that the participatory, community-based model fostered resilience—both social and technical. When minor breakdowns occurred, community members were able to respond quickly because they had been trained and had a clear division of roles. Moreover, because the system design had incorporated community insights, many of the potential risks (like flooding, theft, or lack of technical knowledge) were anticipated and mitigated in advance. The co-creation of knowledge during the workshops translated into a shared capacity to innovate and troubleshoot, turning the community from passive users into adaptive managers.

In sum, the findings suggest that rural electrification efforts grounded in renewable energy technologies must be inseparable from social innovation and participatory governance. The community-based model not only improved technical outcomes but also transformed the social landscape of the

villages, leading to greater empowerment, cohesion, and long-term sustainability. These results advocate for a redefinition of "success" in rural electrification—not merely in terms of kilowatt-hours delivered, but in terms of the quality of local engagement, the robustness of institutions, and the socio-cultural embeddedness of energy systems.

Table 1: Key Elements of the Community-Based Renewable Energy Model for Rural Electrification

No	Element	Description	Impact on Rural Electrification
1	Community Participation	Active involvement of local residents in the planning, design, and management of energy systems.	Enhances ownership, ensures the system meets local needs, and fosters long-term maintenance.
2	Social Innovation	Introduction of new social practices, such as community-led energy management committees and inclusive governance.	Empowers marginalized groups, promotes equitable access, and encourages adaptive, locally-driven solutions.
3	Local Governance	Formation of local energy management bodies to oversee operations and maintenance.	Strengthens local institutions, reduces dependency on external agencies, and increases system sustainability.
4	Renewable Energy Systems	Deployment of technologies such as solar PV, wind, and micro-hydro to provide electricity.	Provides clean, reliable energy that is environmentally sustainable and cost-effective for rural areas.
5	Economic Opportunities	Development of small businesses or livelihood activities enabled by access to electricity.	Boosts local economies by creating new jobs and improving productivity.
6	Social Cohesion	Strengthening of social ties through collaborative decision-making and collective ownership of energy resources.	Fosters community solidarity, reduces conflicts, and enhances resilience.

This table 1. outlines the core elements of the community-based renewable energy model, illustrating their role and impact on rural electrification efforts. The combination of community participation, social innovation, and renewable energy technologies forms a comprehensive approach to ensuring sustainable and inclusive energy access. Key impacts include enhanced local ownership, improved social cohesion, and the creation of long-term, adaptive governance structures. These elements contribute not only to the technical success of renewable energy systems but also to social empowerment and economic development in rural communities.

Discussion

The findings from this research strongly align with and extend existing literature on community-based renewable energy projects and social innovation, while also contributing new insights into the dynamics of rural electrification. One of the central themes that emerged from the analysis was the critical role of community engagement in ensuring the sustainability and success of rural electrification initiatives. This result supports the findings of several studies, such as those by (McDowall, 2018), who argue that top-down energy interventions often fail because they overlook the social and cultural contexts of rural communities. Aklin et al. emphasize that local ownership and active community participation are vital for the long-term sustainability of energy systems. This research further reinforces this idea, showing that communities that were actively involved in the decision-making and design processes not only

demonstrated greater ownership but also exhibited higher levels of accountability and engagement in system maintenance.

Moreover, the participatory action research approach used in this study highlights a significant departure from traditional energy projects that focus predominantly on technical outcomes. By incorporating social innovation, the research suggests that rural electrification should not just be seen as an infrastructure challenge but as a socio-technical problem that requires innovations in social practices, governance, and local institutional capacity. The literature on social innovation, including work by (Khan, 2019), supports this perspective by suggesting that successful social innovation in energy transitions requires new forms of governance and collaboration. In the studied communities, the creation of local energy management committees, which were responsible for overseeing the system's operation and maintenance, illustrates how such governance innovations can lead to sustainable practices beyond the initial installation phase. This approach contrasts with the findings of (Hurlbert & Datta, 2022), who argue that centralized control of energy infrastructure can often alienate local communities and stifle innovation. The research shows that decentralized, community-driven models, where local leaders and residents are involved at every stage, are more likely to succeed in rural areas.

A particularly notable aspect of this research was the inclusion of women and youth in energy decision-making processes. This aligns with **Vercillo et al. (2016)**, who found that women's involvement in energy projects significantly improves both project outcomes and broader social impacts, such as gender equality and economic empowerment. The women-led subcommittee formed in one of the communities to manage energy system finances and repairs serves as a practical example of how energy projects can empower marginalized groups. This result also resonates with (Droubi et al., 2022), who suggest that social innovations in energy systems often require gender-sensitive approaches to ensure inclusivity and equitable distribution of benefits. The findings here suggest that energy projects, when designed with a focus on social inclusion, can challenge traditional gender roles and create more equitable opportunities within rural settings.

In terms of economic impacts, the findings suggest that renewable energy systems not only provided access to electricity but also acted as catalysts for new business opportunities. This outcome supports the work of (Ibn-Mohammed et al., 2021), who argue that rural electrification can lead to indirect economic benefits, such as the creation of small businesses and income-generating activities. However, this study adds nuance to the existing literature by showing that these economic opportunities are not automatic and must be carefully facilitated through community engagement. The participatory workshops allowed community members to express their specific needs and aspirations, ensuring that the energy system was designed with economic productivity in mind. This reflects (Ap. Moreira & Wanda Rutkoskwi, 2021) argument that energy projects must be co-created with local knowledge to unlock economic potential. The study found that the economic benefits were maximized when the community was empowered to use the energy system in a way that reflected its own priorities and knowledge.

From a theoretical perspective, this research draws on **Social-Ecological Systems Theory** (SES) as a framework for understanding the interdependence of local communities and renewable energy systems. SES theory, as outlined by (Gislason et al., 2021), posits that sustainable resource management requires a balance between social, ecological, and economic factors. The research findings align with this theory by showing that energy systems that are embedded within the social fabric of the community and governed through locally derived rules are more resilient and adaptable to challenges. The study's emphasis on the importance of local institutions, such as energy management committees, echoes Ostrom's argument that local institutions play a crucial role in managing common-pool resources like energy (Arintoko et al.,

2020). These local institutions, which emerged organically from the participatory process, not only helped ensure system maintenance but also fostered a collective sense of ownership and shared responsibility, which is vital for long-term sustainability.

The findings also raise important questions about the scalability of community-based models in rural electrification. While the success in these two communities is promising, it is unclear whether such models can be replicated in more diverse or larger-scale settings. Previous research by (Saleh, 2020) has highlighted challenges in scaling decentralized energy projects due to variations in governance structures, economic conditions, and institutional capacity across different regions. The study's findings suggest that scaling the model may require additional layers of support, such as government policy alignment, external funding for scaling up, and further institutional strengthening at the local level (Mussad, 2022). However, the research underscores that even in the absence of large-scale infrastructure, locally driven projects can provide a valuable foundation for sustainable energy transitions.

This research not only confirms the findings of earlier studies on the importance of community engagement and social innovation in rural electrification but also adds depth by examining how these elements interact in specific socio-cultural contexts. It demonstrates that integrating renewable energy with social innovation can lead to more sustainable and inclusive energy systems in rural areas. By emphasizing participatory design, social inclusion, and local governance, this study provides valuable insights into how rural electrification projects can be more effectively implemented and sustained over time. The findings suggest that future energy transitions should prioritize both the technical and social dimensions of energy access to create more resilient, adaptive, and equitable systems.

CONCLUSION

This research sought to address the critical question of how integrating renewable energy with social innovation can lead to more sustainable and inclusive rural electrification. The findings suggest that community-based models, which incorporate active participation, local governance, and social innovation, significantly enhance the success and longevity of energy systems in rural areas. By fostering local ownership, empowering marginalized groups, and encouraging adaptive governance, this study confirms that sustainability in rural electrification is not solely dependent on the technology but on the social, cultural, and institutional contexts in which the energy systems are embedded. The community-driven approach provides a promising alternative to the top-down energy interventions that often fail to meet the needs of rural populations, thereby addressing a key concern in the field of energy access.

However, this study also highlights several limitations. Firstly, the research was conducted in two relatively small, culturally similar villages, which may not fully represent the diversity of rural communities across different regions. Therefore, the applicability of the findings to other geographic or socio-economic contexts remains uncertain. Additionally, the long-term sustainability of the community-driven model remains to be tested in larger-scale or more complex settings, where institutional and economic challenges might be more pronounced. Future research should explore the scalability of these models, particularly in areas with different socio-political structures or in larger, less cohesive communities. It would also be valuable to examine the economic impacts over a longer time frame to understand the full range of benefits and potential barriers to growth. By expanding the scope and duration of such studies, future research can build on these findings to further refine the integration of renewable energy and social innovation in rural electrification projects.

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