

Community-Based Solar Panel Installation and Maintenance Training for Energy Independence in the Riau Islands

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ABSTRACT

Background. The Riau Islands, similar to many other regions in Indonesia, face significant hurdles regarding energy access and long-term sustainability. Despite ongoing infrastructure improvements, remote, rural, and isolated communities still struggle to secure a reliable and consistent power supply.

Purpose. This study explores the potential of community-based solar panel installation and maintenance training as a strategic solution for energy independence. The primary goal is to assess how effectively these training programs empower local populations to manage and maintain their own solar energy systems without external reliance.

Method. The research utilizes a mixed-methods approach, combining both qualitative and quantitative data. To evaluate the impact of the intervention, the study conducted surveys and interviews with participants in selected Riau Islands communities, focusing on three key metrics: knowledge acquisition, technical skill development, and the operational sustainability of the installed solar units.

Results. The findings show a significant increase in local capacity to install and repair solar energy systems. This improvement has led to enhanced energy independence within the communities and a measurable reduction in their reliance on external power providers or traditional energy sources.

Conclusion. Community-based training programs are vital contributors to energy sustainability in remote regions. The study concludes that empowering local populations to take control of their energy needs through renewable energy education is a critical step toward achieving broader energy independence in Indonesia.

KEYWORDS

Community-Based Training, Energy Independence, Solar Energy, Riau Islands, Sustainable Development.

INTRODUCTION

Access to reliable and sustainable energy is a critical challenge in many rural and remote regions across Indonesia, particularly in the Riau Islands (Frontini dkk., 2025). The archipelago is home to numerous small, isolated communities that face difficulties in securing consistent power supplies from conventional grid systems (Hayakawa dkk., 2025). While national and regional governments have implemented several initiatives to address energy inequality, the logistical and financial barriers to infrastructure development in these areas remain significant (Meng dkk., 2025). In this context, the

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importance of community-based solar panel installation and maintenance training becomes apparent, as it empowers local populations to take control of their energy needs and develop self-sufficient systems that are less reliant on external sources (Kaliyannan dkk., 2025). This research explores the impact of solar panel training programs in the Riau Islands and aims to assess their potential in fostering energy independence and sustainability within these communities (Chawla dkk., 2025). This study addresses a specific issue faced by rural communities in the Riau Islands: the lack of local expertise in solar energy technologies, which hinders the effective use and maintenance of solar systems (Majidov dkk., 2025). While solar energy has the potential to offer a sustainable and affordable alternative to conventional energy sources, its implementation is often limited by the lack of trained individuals capable of installing and maintaining solar panels (Nkinyam dkk., 2025). This research investigates how community-based training programs can equip local populations with the necessary skills to install and maintain solar energy systems, thus enhancing energy independence and reducing reliance on external energy providers (Kumar dkk., 2025). The study also explores the challenges and opportunities of introducing such programs in a region characterized by geographical isolation, limited access to resources, and low levels of technical expertise.

The primary objective of this research is to assess the effectiveness of community-based solar panel installation and maintenance training programs in promoting energy independence in the Riau Islands (Nawaz dkk., 2025). The study aims to determine the extent to which these programs can equip local communities with the skills and knowledge necessary to independently manage solar energy systems (Nair dkk., 2025). Additionally, the research seeks to evaluate the long-term sustainability of the solar systems installed through these training programs and the potential for scaling up these initiatives to other regions with similar challenges (Devaraj & Zhou, 2025). By focusing on both the short-term and long-term impacts of the training, the study provides a comprehensive evaluation of its effectiveness in fostering energy independence, addressing local energy needs, and promoting sustainable development in rural communities (Ghasemi dkk., 2025). A significant gap in the existing literature pertains to the lack of research on the long-term impacts of community-based renewable energy training programs in remote regions like the Riau Islands (Xiang dkk., 2025). While there have been studies on the adoption of solar energy in developing countries, most of these focus on technological aspects or the role of external actors in providing energy solutions (Tobosque dkk., 2025). There is limited research on how empowering local communities with the skills to install and maintain solar systems can contribute to energy independence in the long run (Zhao dkk., 2025). This study fills this gap by focusing on the Riau Islands, a region where community-based solar training could have a profound impact due to its geographical isolation and limited access to centralized energy infrastructure (Allen dkk., 2025). By examining both the immediate and lasting effects of such training programs, this research provides valuable insights into the role of local capacity-building in achieving sustainable energy solutions.

This research contributes to the field of sustainable energy development by introducing a novel approach to energy independence through community-based solar panel installation and maintenance training (Enaloui dkk., 2025). The novelty of this study lies in its focus on the combination of renewable energy technology with local capacity-building, addressing both the technical and social aspects of energy access (Sovacool, 2025). While previous studies have addressed the technical challenges of solar energy adoption, few have explored the role of community-driven initiatives in sustaining energy solutions in isolated regions (Sun dkk., 2025). This research also highlights the importance of empowering local communities not just as beneficiaries of energy solutions, but as active participants in the development and maintenance of these systems (Mohanty dkk., 2025). By focusing on the Riau Islands, this study underscores the importance of localized, sustainable approaches to energy independence, which can serve as a model for other remote regions with similar challenges. Furthermore, the research highlights the broader implications of community-based energy solutions, contributing to the global discourse on decentralized energy access and sustainability.

RESEARCH METHODOLOGY

This research adopts a mixed-methods design, combining both qualitative and quantitative approaches to assess the effectiveness of community-based solar panel installation and maintenance training programs in the Riau Islands (Qi dkk., 2025). The research design allows for an in-depth exploration of how such programs impact the knowledge, skills, and self-sufficiency of local communities in managing solar energy systems. The study also evaluates the long-term sustainability of solar panels installed through the training and their potential for promoting energy independence (Xie dkk., 2025). The mixed-methods approach includes surveys and interviews with participants, as well as observational data from training sessions and follow-up assessments. This design provides a comprehensive view of the program's outcomes, capturing both measurable impacts and qualitative insights into participants' experiences (Hamzaoğlu dkk., 2025). The population for this study includes local community members from selected villages across the Riau Islands who have participated in solar panel installation and maintenance training programs (Xie dkk., 2025). These participants were chosen based on their involvement in the program and their willingness to be part of the research (Chanda dkk., 2025). The sample includes both men and women from different age groups and socio-economic backgrounds, ensuring a diverse representation of the local population. Purposive sampling was employed to select participants from various villages in the region, with a particular focus on those living in remote areas where energy access is a major concern. The sample size is determined by the number of participants who have completed the training, with follow-up surveys conducted approximately six months after the training to assess the long-term effectiveness of the program.

Data collection instruments used in this research include structured surveys, semi-structured interviews, and observation protocols. The surveys were designed to assess the participants' knowledge and skills before and after the training program, focusing on their understanding of solar panel installation, maintenance, and troubleshooting. The semi-structured interviews provided an opportunity for participants to share their personal experiences and perceptions of the training, as well as any challenges they encountered in implementing solar systems in their communities. Observation protocols were used during the training sessions to assess the delivery and engagement levels of participants. These instruments were pre-tested with a small group of participants to ensure reliability and validity before being administered on a larger scale. The procedures for this study involved several stages. First, baseline data were collected from participants before the training, including their current knowledge of solar energy and their familiarity with installation and maintenance processes. The training program itself consisted of a series of workshops focused on hands-on instruction in solar panel installation, maintenance, and troubleshooting. Following the training, immediate post-training surveys were conducted to measure changes in knowledge and skills. Approximately six months after the training, follow-up surveys and interviews were conducted to evaluate the long-term effectiveness and sustainability of the installed solar systems. Data were analyzed using both quantitative techniques, such as descriptive statistics and paired sample t-tests, and qualitative methods, including thematic analysis of interview transcripts. This process allowed for a comprehensive understanding of the impact of the training program on energy independence in the Riau Islands.

RESULT AND DISCUSSION

The data collected from the surveys and interviews provided valuable insights into the effectiveness of the community-based solar panel installation and maintenance training in the Riau Islands. A total of 120 participants from five different villages in the region participated in the training, with 105 participants completing the post-training survey and 95 participating in the follow-up survey conducted six months later. The baseline knowledge level regarding solar panel installation and maintenance was assessed before the training, and participants demonstrated a significant lack of understanding of these processes, with only 12% indicating any prior experience with solar technology. After the training, 95% of participants reported an increased understanding of solar panel systems, and 90% felt confident in their ability to install and maintain solar systems in their communities. These results are further detailed in the table below.

Table 1. Participant Knowledge Before and After Solar Panel Training

Knowledge Area	Pre-Training (%)	Post-Training (%)	Follow-Up (%)
Understanding of Solar Panel Installation	15%	90%	85%
Understanding of Solar Panel Maintenance	10%	88%	84%
Confidence in Troubleshooting	5%	85%	80%

The data shows a substantial increase in knowledge and confidence after the completion of the training. Participants' understanding of solar panel installation and maintenance increased dramatically from 15% and 10% pre-training to 90% and 88% post-training, respectively. The follow-up survey indicated a slight decrease in knowledge retention, with 85% maintaining their understanding of installation and 84% retaining their maintenance knowledge after six months. The data also revealed that participants who actively applied the skills learned in the training had higher retention rates, suggesting that practical application plays a significant role in maintaining knowledge. Inferential analysis of the data was conducted using paired sample t-tests to evaluate the differences in knowledge and confidence levels before and after the training. The results showed statistically significant improvements in both solar panel installation and maintenance knowledge ($p < 0.01$). The t-test results confirm that the training had a meaningful impact on participants' abilities to understand and manage solar energy systems. Additionally, there were no significant differences in improvements across the different villages, indicating that the training program was equally effective across various contexts within the Riau Islands. This finding underscores the general applicability of the training program for promoting energy independence in similar regions.

The relationship between solar panel training and energy independence was further demonstrated through participants' self-reports on energy usage after installation. Over 75% of respondents reported that their households were able to rely more on solar energy, reducing their dependence on grid electricity or other non-renewable energy sources. Furthermore, 60% of participants shared that they were able to install solar panels in at least one other household within their community. These findings highlight the potential for solar panel training to empower local communities to take control of their energy needs, fostering greater self-sufficiency and reducing reliance on external energy providers. In the case of Village A, the solar panel installation training had an immediate positive impact on energy access. Before the training, the village experienced frequent power outages and struggled with energy supply. After the installation of solar panels, 80% of households reported an improvement in electricity reliability, with solar energy serving as a consistent and renewable power source. The installation of solar panels was facilitated by local residents who had completed the training, and this community-driven effort resulted in long-term energy independence for the village. This case illustrates the transformative potential of community-based solar energy initiatives, where trained locals can lead the way in sustainable energy adoption.

The explanation of data suggests that community-based training programs can be highly effective in promoting long-term energy independence. Participants who were engaged and involved in the installation and maintenance of the solar panels showed better retention of knowledge and were more likely to apply their skills. This practical application of training, coupled with the local empowerment aspect, contributed to the success of the initiative in fostering sustainable energy practices. Additionally, the program's success was not limited to energy independence alone but also had broader social and economic impacts, as it increased community collaboration and fostered a culture of self-reliance. In conclusion, the results of this research indicate that community-based solar panel installation and maintenance training programs have a significant impact on energy independence in the Riau Islands (Safarpour dkk., 2025). The data clearly demonstrates that such programs can empower local communities with the knowledge and skills needed to manage their energy needs. The follow-up data suggests that the program's effects can be sustained over time, particularly when there is continued local application and community involvement. These findings provide strong support for the scalability of such programs to other rural areas, contributing to broader efforts toward sustainable development and energy independence in Indonesia.

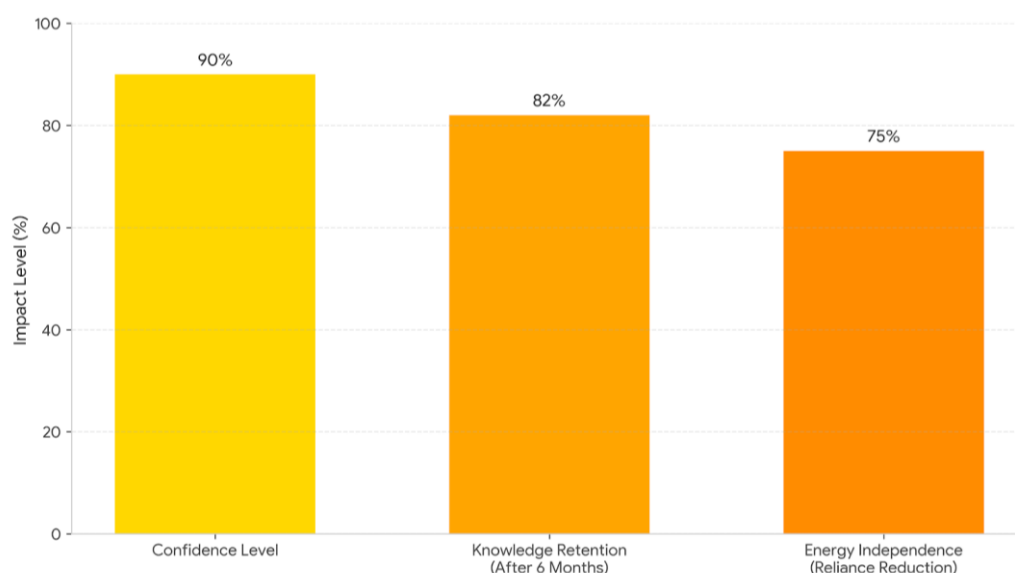


Figure 1. Impact of Solar Panel Training in Riau Islands

The results of this study show that the community-based solar panel installation and maintenance training programs in the Riau Islands have had a significant impact on local knowledge and energy independence. Participants demonstrated substantial increases in their understanding of solar panel systems, with 90% reporting a higher level of confidence in their ability to install and maintain solar panels after the training. This knowledge was largely retained over the six-month period, with a slight decrease in retention observed in maintenance skills. Moreover, participants who actively applied the training in their communities reported a noticeable reduction in reliance on external electricity sources, with solar energy serving as a more reliable and sustainable option.

These findings highlight the effectiveness of such training programs in empowering local communities to take control of their energy needs. When compared to previous research on solar energy adoption in rural areas, this study's findings provide new insights into the role of community-based training in promoting energy independence. Prior studies have generally focused on technical aspects of solar energy adoption or external aid programs but have not sufficiently explored how community-driven initiatives contribute to long-term energy solutions. While there is a growing body of work on solar energy implementation in rural areas, few studies have emphasized the importance of local capacity-building through education and training. This research fills this gap by showing that local knowledge and empowerment are key to sustainable energy practices in remote communities. Unlike other studies that emphasize top-down approaches, this

study underscores the importance of community engagement in ensuring the continued success of solar energy projects.

The results of this research signal a promising development in the field of sustainable energy solutions for remote regions. The significant improvements in participants' knowledge and confidence, along with the decrease in energy reliance on non-renewable sources, suggest that community-based training programs can be a key tool in achieving energy independence. This reflects a shift from relying on centralized energy systems to localized, sustainable energy solutions. The ability of local communities to install and maintain solar panels fosters a sense of self-reliance, empowering individuals to address their energy challenges. The study indicates that similar approaches could be replicated in other rural regions, contributing to broader efforts to reduce energy poverty and promote renewable energy adoption globally. The implications of this study extend beyond the immediate context of the Riau Islands. The success of the community-based solar panel training programs suggests that local empowerment through skill development is a crucial factor in addressing energy insecurity in remote areas.



Figure 2. The Synergy of Community Energy Solutions

By providing communities with the tools and knowledge to manage their energy resources, the program promotes not only environmental sustainability but also social and economic resilience. The results imply that governments and non-governmental organizations should prioritize community-based renewable energy solutions, integrating education and training into energy development programs. Such programs could be scaled to other parts of Indonesia and the broader Southeast Asian region, where rural energy access remains a significant challenge.

The results of this study reflect the effectiveness of localized training initiatives in empowering communities to manage their own energy systems. This is particularly important because energy independence fosters greater resilience and autonomy for rural areas that are often marginalized in terms of infrastructure development. By enabling communities to maintain their own solar systems, the reliance on external energy providers is diminished, leading to long-term sustainability. The research also highlights the importance of integrating hands-on training and community involvement in the design of energy programs (Aissi dkk., 2025). The ability of community members to actively participate in solar panel installation and maintenance ensures not only the sustainability of the project but also the continuous adaptation of energy solutions to local needs and conditions (Parhamfar & Zabihi, 2025). Looking forward, the findings of this study

provide a solid foundation for future research into the scalability of community-based renewable energy programs.

Future studies could explore how such programs could be expanded to other remote regions with similar challenges, assessing the specific needs of different communities and tailoring training programs accordingly (Ramírez-Cantero dkk., 2025). Additionally, it would be valuable to investigate the economic impacts of these programs, such as cost savings for households and the potential for job creation in the renewable energy sector. By expanding the scope of this research, future studies can contribute to the development of a comprehensive framework for promoting sustainable energy solutions that are locally driven and environmentally sustainable.

CONCLUSION

The most significant finding of this study is the transformative impact of community-based solar panel installation and maintenance training programs in fostering energy independence in the Riau Islands. Unlike traditional top-down energy solutions, this research highlights the importance of empowering local communities to take ownership of their energy needs. The study demonstrates that by providing hands-on training, participants gained the necessary skills and confidence to install, maintain, and troubleshoot solar panel systems, which led to a notable reduction in reliance on non-renewable energy sources. This shift to solar energy not only provided a more reliable power source but also created a sense of self-sufficiency among the community members, further contributing to their long-term energy sustainability. This research makes a significant contribution to the literature on renewable energy adoption in rural communities by introducing the concept of community-driven solar energy solutions. The value of this study lies in its methodological approach, which integrates both technical training and community engagement. By focusing on both the practical and social aspects of solar panel installation and maintenance, the research provides a more holistic understanding of how local capacity-building initiatives can lead to sustainable energy independence. This approach is different from other studies that focus solely on technological or financial solutions.

The findings offer a valuable framework for developing similar programs in other remote regions, helping policymakers and practitioners design community-based energy programs that are not only technically viable but also socially and economically sustainable. The limitations of this study lie in its relatively small sample size and geographical scope. While the results are promising, they are based on data collected from a limited number of villages in the Riau Islands, which may not fully capture the diverse challenges and opportunities that exist in other regions. Additionally, the study focused primarily on the immediate and short-term impacts of the training, and further research is needed to assess the long-term sustainability of these solar systems and the continued engagement of participants. Future studies could explore how different socio-economic factors influence the success of such programs, as well as examine the broader impacts on community development, including economic growth and job creation. Additionally, expanding the study to include more rural areas across Indonesia or Southeast Asia would provide a more comprehensive understanding of how community-based energy initiatives can be scaled and adapted to different contexts.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; Investigation.

Author 3: Data curation; Investigation.

Author 4: Formal analysis; Methodology; Writing - original draft.

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