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Community Empowerment through the Transfer of Portable Solar PV Technology for Energy Resilience in a Disaster-Prone Area

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ABSTRACT

This community service program aimed to strengthen community energy resilience in Batu Busuk, Limau Manis, Pauh District, Padang City, West Sumatra, an area vulnerable to flash floods and electricity disruptions. The program was implemented in partnership with the Palito Nyalo Minangkabau Traditional Arts and Cultural Community and involved 23 participants in total, comprising the Universitas Andalas implementation team and members of the partner community. Conducted in a two-hour session, the program introduced a 2400 VAh portable Solar PV Power Station as an alternative electricity source for essential community activities during grid outages. The technology, adapted from a Universitas Andalas research output, integrates solar charging, lithium battery storage, a pure sine-wave inverter, AC 220 V and DC outputs, and a monitoring system. Activities consisted of socialization, technical presentations, practical guidance, technology demonstration, and technology handover. The demonstration covered system operation, charging, monitoring, and safe utilization of AC/DC outputs. The activity provided participants with practical exposure and an initial understanding of the use and management of solar-based backup energy for social, cultural, communication, and emergency activities. However, the evaluation was primarily qualitative and did not include systematic pre-test and post-test measurements or long-term monitoring of system performance. Continued mentoring, quantitative evaluation, and utilization monitoring are therefore recommended to support sustainable technology adoption. The program demonstrates a practical pathway for translating university research into community-based renewable-energy solutions for post-disaster resilience.

Keywords: community empowerment, disaster resilience, energy resilience, solar PV power station

INTRODUCTION

Natural disasters can significantly disrupt essential infrastructure, including electricity supply, thereby affecting the continuity of social, economic, and community activities. Floods and flash floods are particularly challenging because damage to roads, distribution networks, and other infrastructure can prolong the restoration of essential services (International Energy Agency (IEA), 2024; Miah et al., 2024) . For communities located in disaster-prone areas, access to reliable electricity is therefore not only an issue of energy availability but also an important component of community resilience. Electricity is needed to support basic lighting, communication, information access, emergency activities, and the recovery of local social and economic functions. From the perspective of energy-

system resilience, the ability of an electricity system to maintain or rapidly restore essential services following disruptive events has become an increasingly important consideration in energy planning (Amini et al., 2023). Climate-related hazards and extreme events further emphasize the need to integrate energy resilience into local adaptation and community development strategies (Zhou, 2023).

Renewable energy, particularly solar photovoltaic (PV) technology, offers an opportunity to strengthen energy resilience through decentralized electricity generation. Solar PV systems can utilize locally available solar resources and, when combined with battery energy storage, provide electricity during interruptions of the main grid (Kotani & Nakano, 2023; Tu & Qu, 2024). The integration of rooftop PV and battery energy storage into networked microgrids has been demonstrated as a strategy for improving distribution-system resilience against natural disasters (Galvan et al., 2020). Similarly, standalone solar energy systems have been proposed as an option for improving disaster resilience in rural communities by providing an independent electricity supply when centralized infrastructure is disrupted (Hafeznia & Stojadinović, 2024). Battery energy storage can further support disaster preparedness by maintaining stored energy and reducing the duration of service interruptions during outage conditions (Son et al., 2024). These approaches indicate that decentralized renewable energy can contribute not only to clean energy utilization but also to greater energy security and resilience at the local level.

However, the provision of renewable energy technology alone does not necessarily ensure sustainable benefits for communities. Community energy resilience involves technological, social, organizational, and economic dimensions that need to be addressed simultaneously. (Vallecha & To, 2024) emphasize that community energy and community resilience should be understood from a multidimensional perspective, in which local participation and community capacity are important components of resilient energy systems. Recent case studies further demonstrate that community participation across the planning, installation, and operation stages is important for developing the social and technical capacity required for resilient community energy systems (Vallecha et al., 2025). Similarly, the sustainability of green microgrids is closely related to energy security, resilience, and the ability of decentralized systems to maintain essential services under changing conditions (Kiehbardroudzinezhad et al., 2023). The resilience of community microgrids also depends on integrating technical considerations with social capital, ownership, management, and local socio-economic conditions (Eklund et al., 2024). Recent work on resilient community microgrids also highlights the importance of operational strategies and performance considerations in ensuring that decentralized energy systems can effectively support communities during disruptions (Billanes et al., 2025). Therefore, community-based renewable energy programs should not focus solely on technology deployment but should also strengthen users' knowledge, operational skills, maintenance capacity, and ability to manage shared energy resources (Hadi et al., 2026; Tobin & Lennon, 2025).

These challenges are particularly relevant to Batu Busuk, Limau Manis, Pauh District, Padang City, West Sumatra, where flash-flood events can disrupt infrastructure and community activities. The Palito Nyalo Minangkabau Traditional Arts and Cultural Community serves as an important social and cultural institution in the area, providing a space for traditional arts activities as well as social interaction among community members. When electricity supply is interrupted for an extended period following a disaster, activities at the community center can be affected by limited lighting, difficulties in charging communication devices, disruption of cultural activities, and constraints on other basic community functions. Renewable energy can provide benefits that extend beyond electricity access by strengthening community resilience and supporting local social and economic activities. Evidence from community-based renewable-energy initiatives also

indicates that renewable energy can contribute to resilience beyond conventional energy-access objectives (Prasad et al., 2025).

In response to these challenges, the Universitas Andalas community service team implemented a program that adapted the results of previous research on a portable smart PV Power Station with adaptive AC/DC output and real-time monitoring. The technology was developed as a research output and subsequently adapted for community application in Batu Busuk. The PV Power Station has a capacity of 2400 VAh and is designed to provide alternative electricity for essential community needs during grid interruptions. The system integrates solar charging, battery storage, AC and DC outputs, and monitoring functions, while its portable configuration allows flexible use according to community requirements. This approach is consistent with the emerging concept of solar-plus-storage systems as community resilience infrastructure, where decentralized energy resources can serve as emergency power sources for critical community activities (Murphy et al., 2025). Furthermore, recent research on solar energy adoption for community resilience emphasizes that the successful application of solar-plus-storage technology requires consideration of both technological and community factors (Bosman et al., 2026).

Based on the local context and the identified need for alternative electricity during grid interruptions, the program focused not only on technology provision but also on introducing participants to the practical operation and safe use of the portable PV system. Accordingly, this program aimed to strengthen energy resilience in the Batu Busuk community through the application of solar PV technology and community empowerment. Specifically, the program sought to provide an alternative electricity source during grid outages, support the continuity of social and cultural activities at Palito Nyalo, and improve participants' practical understanding of system operation, charging, monitoring, and safe use of AC/DC outputs. The contribution of the program lies in demonstrating a pathway from university research to community application through technology adaptation, training, demonstration, and technology transfer.

METHOD

The community service activity was conducted at the Huntara of the Palito Nyalo Minangkabau Traditional Arts and Cultural Community, Batu Busuk, Limau Manis, Pauh District, Padang City, West Sumatra, Indonesia. The activity was conducted on 6 August 2026. Palito Nyalo was selected as the community partner because it functions as a center for Minangkabau traditional arts and cultural activities as well as a space for social interaction and community activities. The location is situated in an area vulnerable to flash-flood events, which may cause disruption to electricity supply and consequently affect community activities. The program was therefore designed to provide an alternative energy source while simultaneously strengthening the community's ability to operate and manage the technology.

The activity involved 23 participants in total, consisting of members of the Universitas Andalas implementation team and representatives of the partner community. The community representatives participated in the presentations, technical guidance, demonstration, and technology handover. The participants receiving direct technical guidance were expected to become the initial users responsible for operating the portable PV Power Station at the community facility.

The main technology applied was a portable PV Power Station with a capacity of 2400 Vah as shown in Figure 1. The system was adapted from the Universitas Andalas research output on a portable smart solar power station with adaptive AC/DC output and real-time monitoring.

The main components include:

- solar PV charging system;
- MPPT solar charger;
- lithium battery energy storage;
- pure sine-wave inverter;
- AC 220 V output;
- DC output; and
- monitoring system.

The portable configuration allows the unit to be moved according to community requirements. The system was introduced as a community energy facility rather than merely as a research prototype. The implementation also included explanations and demonstrations of the operating principle, charging procedure, monitoring function, safe AC/DC utilization, energy-use priorities, and basic maintenance.



Figure 1. Portable PV power station

The implementation consisted of five main stages: (1) Socialization and community orientation. The activity began with an opening session and introduction of the objectives and expected benefits of the program. (2) Technical and thematic presentations.

The team leader delivered the presentation “Solar Generator for Energy Independence and Community Resilience after Disasters.” The presentation discussed the role of solar-based backup electricity in maintaining essential services when the main grid is unavailable. The second presentation, “Utilization of Solar Energy to Support Social, Cultural, and Community Economic Activities,” was delivered by team member. The session emphasized the relationship between energy availability and social, cultural, communication, and community economic activities. (3) Technical guidance and demonstration. The team provided direct technical guidance and demonstrated the PV Power Station operation, including charging, monitoring, and safe utilization of AC/DC outputs. (4) Technology handover. At 11:30 WIB, the PV Power Station was formally handed over to the Palito Nyalo community. (5) Follow-up utilization and sustainability. The partner was encouraged to operate the system independently, conduct basic maintenance, establish energy-use priorities, and utilize the facility for community needs, particularly during electricity interruptions.

Community Empowerment Approach

The program adopted a participatory community empowerment approach. The partner community was positioned not only as a recipient of technological assistance but also as a participant in the learning, demonstration, and utilization processes. The empowerment process focused on three practical aspects: basic knowledge, operational understanding, and community ownership. The theoretical sessions introduced the concept of energy resilience and the role of solar-based backup electricity, while the technical demonstration allowed participants to observe and practice the basic operation of the portable PV Power Station. The activities covered identification of the main system components, basic operating procedures, charging, monitoring, safe use of AC/DC outputs, energy-use priorities, and basic maintenance. Training and technical assistance are widely used in community-based solar-energy programs to support technology adoption (Rendana et al., 2023). Community participation is also important for sustaining renewable-energy facilities because users need sufficient knowledge and practical understanding to operate and maintain shared equipment (Shiradkar et al., 2023).

Data Collection and Evaluation

Data were collected through direct observation, participant interaction, documentation, and discussions with the partner community during the activity. The qualitative evaluation used several practical indicators: (1) participant attendance and involvement during the sessions; (2) ability to identify the main components and functions of the PV Power Station; (3) understanding of the basic operating and charging procedures; (4) understanding of the appropriate and safe use of AC and DC outputs; (5) ability to recognize basic monitoring information; and (6) participant responses regarding potential use of the system for social, cultural, communication, and emergency activities.

During discussions, participants were invited to describe their understanding of the operating procedures, identify potential applications of the system, and discuss energy-use priorities and basic maintenance. Participant understanding was assessed qualitatively based on their responses, questions, and ability to follow the procedures demonstrated by the implementation team. Technology acceptance was assessed from participants' expressed interest, willingness to use the system, and responses concerning its potential utilization for community activities. Documentation consisted of photographs and activity records used to verify participation, technical demonstrations, and the technology handover. The observation and evaluation were conducted by the Universitas Andalas community service team during the activity.

The collected information was analyzed descriptively by comparing the observed participant responses and involvement with the predetermined qualitative indicators. Because the activity was designed as an initial technology-transfer and community empowerment intervention, no experimental testing of the PV system or systematic pre-test and post-test measurement was conducted. Therefore, the evaluation focuses on participant involvement, practical understanding, technology transfer, and the potential utilization of the PV Power Station rather than quantitative measurement of learning improvement.

RESULTS AND DISCUSSION

The community service program was successfully implemented on 6 August 2026 at the Huntara of the Palito Nyalo Minangkabau Traditional Arts and Cultural Community. The activity commenced at 09:30 WIB with an opening session, followed by remarks from the Universitas Andalas community service team and the partner community. The sequence of activities was designed to connect the community's post-disaster energy needs with a practical renewable-energy solution.

The implementation consisted of socialization, thematic presentations, technical guidance, practical demonstration, and technology handover. This sequence provided participants with both conceptual information and direct experience with the technology. Such a combination is important in community service because renewable-energy technology adoption depends not only on equipment availability but also on the users' understanding of its operation and potential applications.

The first substantive session, introduced the concept of a solar generator as an alternative energy source for post-disaster conditions. The discussion emphasized that electricity interruptions can affect lighting, communication, cultural activities, and other essential community functions. The use of solar energy combined with battery storage provides an alternative to conventional fuel-based generators and can reduce dependence on fuel availability during emergency conditions.

The second session, discussed the use of solar energy for social, cultural, and community economic activities. This topic was particularly relevant to Palito Nyalo because the facility serves as a location for Minangkabau traditional arts and cultural activities. Electricity availability can support lighting, sound-system operation, communication, and other activities associated with the sanggar.

PV Power Station Application

The main technological output was the 2400 VAh portable PV Power Station. The system integrates solar charging, lithium battery storage, a pure sine-wave inverter, AC 220 V and DC outputs, and monitoring functions. The portable configuration provides flexibility for use according to community needs. The system is intended to support essential electrical loads, including lighting, mobile-phone charging, communication equipment, laptops, sound systems, and other basic electronic equipment. During emergency conditions, the available stored energy can be prioritized for critical loads, particularly lighting and communication.

The application of a portable PV Power Station is therefore relevant to the specific conditions of Batu Busuk. The system does not attempt to replace the existing electricity grid under normal conditions. Instead, it functions as a backup energy resource that can increase the community's capacity to maintain essential activities during grid interruptions. This positioning is consistent with the broader concept of solar-plus-storage systems as decentralized resilience infrastructure. Such systems can provide electricity for critical community functions during disruptions while also delivering everyday benefits under normal conditions.

A key component of the activity was the direct technical demonstration conducted by Fakri Naufal and Imra Nur Izrillah. The demonstration covered the basic operation of the PV Power Station, charging process, monitoring functions, and safe utilization of AC/DC outputs. The demonstration transformed the technology from an unfamiliar technical device into a system that participants could observe and relate to their daily needs. Rather than relying solely on theoretical explanations, participants could directly observe how the system operates and how electrical loads can be connected.

The activity provided participants with initial practical exposure to the operation and safe use of the PV Power Station. Based on observations and discussions during the demonstration, participants showed engagement and understanding of the basic operating procedures. However, the extent of individual skill acquisition could not be quantitatively determined. However, because no standardized pre-test and post-test were conducted, the program cannot yet quantify the magnitude of improvement in participant knowledge or technical skills. The observed outcome should therefore be interpreted as an initial capacity-building achievement rather than a statistically measured learning improvement.

Technology Transfer and Community Empowerment

The program represents a transition from technology provision toward research-based technology transfer and community empowerment. The PV Power Station was not introduced as a stand-alone technological product but as part of an integrated intervention involving explanation, demonstration, handover, and guidance. The partner community was encouraged to understand the importance of responsible energy use, particularly during emergency conditions when the stored energy capacity is limited. Essential loads should be prioritized so that the system can provide the maximum possible benefit during an electricity outage.

The handover of the PV Power Station at 11:30 WIB, represented by Muhammad Ilham on behalf of the partner, marked the transition from demonstration to community utilization. The handover also established a shared responsibility for operation and maintenance. The experience indicates that the success of community energy technology cannot be judged solely from the installation or handover of equipment. Long-term benefits depend on whether the community can operate, maintain, and manage the facility. Consequently, continued mentoring and simple local management arrangements remain important.

One of the significant outcomes of the program was the application of an existing Universitas Andalas research output to a real community problem. The PV Power Station originated from previous research on a portable smart solar power station based on Internet of Things technology with adaptive AC/DC output and real-time monitoring. The technology was subsequently adapted to the Batu Busuk context to make it more appropriate for community use. The adaptation emphasized portability, ease of operation, AC/DC output availability, and monitoring functions. This process demonstrates the role of community service as an important pathway for research hilirisasi. Research outputs can provide greater social value when they are adapted to actual community conditions and accompanied by knowledge transfer and capacity building. The program therefore provides a practical example of the relationship between research, technology adaptation, community empowerment, and disaster resilience.

Table 1 summarizes the main stages, outputs, and empowerment contributions of the community service program. The implementation followed a sequential approach that connected awareness building, knowledge transfer, practical training, technology implementation, and community ownership. The combination of thematic presentations and direct technical demonstrations allowed the partner community to understand both the importance of energy resilience and the practical operation of the PV Power Station. The technology handover subsequently shifted the role of the partner from a participant in the training process to the user and manager of the community energy facility. This sequence indicates that the program was designed not merely as a technology-delivery activity but as an initial community empowerment process aimed at strengthening knowledge, practical capacity, and responsibility for sustainable utilization of the renewable-energy facility. A total of 23 participants attended the activity. Because no standardized pre-test, post-test, or satisfaction questionnaire was administered, the short-

term outcomes were assessed qualitatively through observation, participant responses, discussion, and documentation.

Table 1. Summary of community service activities. outputs and contribution

No	Activity Stage	Output	Short-term Outcome	Evidence/Assessment
1	Socialization and Orientation	Program objectives and benefits introduced	Participants understood the purpose of the program	Participant interaction and discussion
2	Energy Resilience Presentation	Information on solar backup energy delivered	Participants gained initial understanding of energy resilience	Questions and responses during discussion
3	Social, Cultural, and Economic Utilization	Potential community applications discussed	Participants identified potential uses such as lighting and communication	Discussion with participants
4	Technical Guidance and Demonstration	PV operation, charging, monitoring, and AC/DC use demonstrated	Participants gained initial practical understanding of system operation and safe use	Direct observation, participant responses, and demonstration
5	Technology Implementation	2400 VAh portable PV Power Station made available	Alternative electricity source became available for community use	System demonstration and documentation
6	Technology Handover	PV Power Station transferred to partner	Partner assumed responsibility for utilization	Handover documentation
7	Sustainability and Follow-up	Basic utilization and maintenance guidance provided	Initial basis for continued community utilization	Discussion with partner

Sustainability and Future Development

The formal handover was not considered the end of the program. The partner community is expected to utilize the PV Power Station, conduct basic maintenance, and manage energy use according to priority needs. A community-based management mechanism should be established to ensure that several members understand the operating procedures and can take responsibility for routine use and maintenance. The PV Power Station also has the potential to strengthen the role of Palito Nyalo as a community energy-support point. During normal conditions, the facility can support social and cultural activities, while during electricity interruptions it can prioritize lighting, communication, and other essential services. However, the current program has limitations. Long-term utilization frequency, battery condition, energy production, maintenance performance, and actual operation during a prolonged electricity outage have not yet been systematically monitored. The program also did not conduct quantitative pre-test and post-test assessments.

Group photo of the Universitas Andalas community service team with the Palito Nyalo community members shows in Figure 2. Future activities should therefore include a structured monitoring framework comprising pre-test and post-test assessments, equipment utilization logs, energy-use records, routine technical inspection, and periodic mentoring. These measures would provide stronger empirical evidence of the program's impact and help identify technical or managerial improvements.



Figure. 2 Group photograph of the Universitas Andalas community service team and Palito Nyalo community members.

Outputs, Short-Term Outcomes, and Expected Long-Term Impacts

The results of the program are distinguished into outputs, short-term outcomes, and expected long-term impacts to avoid overstating the evidence obtained from the activity. The direct outputs of the program included the delivery of socialization and technical presentations, technical guidance and demonstration of the 2400 VAh portable PV Power Station, and formal handover of the system to the partner community. A total of 24 participants attended the community service activity.

The short-term outcomes were assessed qualitatively through direct observation, participant interaction, discussion, and documentation. During the technical demonstration, participants were introduced to the main system components, basic operating procedures, charging, monitoring functions, and safe utilization of AC/DC outputs. Participants also discussed potential applications of the system for lighting, communication, cultural activities, and other essential community needs. These observations indicate initial practical understanding and engagement with the technology. However, because no standardized pre-test and post-test or individual skills assessment was conducted, the magnitude of improvement in knowledge or technical skills cannot be quantitatively determined.

The longer-term impacts of the program are expected to include greater availability of backup electricity during grid interruptions, reduced disruption of essential community activities, and strengthened local energy resilience. However, these impacts cannot yet be empirically established from the present activity because long-term system utilization, frequency of use during outages, energy-use records, maintenance performance, and community-level resilience outcomes were not systematically monitored. Therefore, the current results should be interpreted primarily as evidence of technology transfer and initial community engagement, while the longer-term resilience benefits remain expected outcomes requiring further monitoring and evaluation.

Overall, the activity established an initial model for community-based energy resilience through research-derived solar PV technology. The principal achievement was not the development of a new PV technology but the successful adaptation and transfer of an existing research output to address a specific community need in a disaster-prone area.

CONCLUSION

The community service program in Batu Busuk successfully introduced and transferred a 2400 VAh portable PV Power Station to the Palito Nyalo Minangkabau Traditional Arts and Cultural Community as an alternative electricity source for use during grid interruptions and emergency conditions. The program integrated socialization, technical presentations, practical demonstrations, and technology handover. Through direct technical guidance, participants received initial practical understanding of system operation, charging, monitoring, and safe utilization of AC/DC outputs. With 23 participants involved in the activity, the program demonstrated a practical pathway for the downstream application of Universitas Andalas research into a community-based renewable-energy solution supporting social, cultural, communication, and emergency activities.

The evaluation was primarily based on observation, participant interaction, documentation, and qualitative feedback. Therefore, the program provides evidence of technology transfer and initial participant engagement, but does not yet demonstrate measurable improvement in community energy resilience or technical skills. Long-term system utilization, maintenance, and performance also require further monitoring. Future activities should include pre-test and post-test assessments, utilization and maintenance logs, periodic technical monitoring, and continued mentoring. These follow-up measures are expected to provide stronger evidence of the contribution of the PV Power Station to the continuity of essential community activities and local energy resilience during future electricity disruptions.

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