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Implementation of Solar-Powered Street Lighting and Early Flood Detection Systems: A Community-Based Mitigation and Renewable Energy Initiative

Mualif Nirmala
Universitas Balikpapan, Indonesia
Email: nirmalamualif@gmail.com

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Abstract

Rural communities in Sepinggan Raya, South Balikpapan, face two critical challenges: inadequate public street lighting, which increases nighttime safety risks and limits economic activities, and heightened vulnerability to flash floods due to the absence of an automated early warning system. Previous top-down interventions, including conventional street lighting and manual flood gauges, were ineffective because of high operating costs and limited community engagement, resulting in the rapid deterioration of infrastructure. This community service program aimed to improve public safety, disaster preparedness, and technological literacy through the participatory installation of solar-powered streetlights equipped with passive infrared (PIR) motion sensors and an ultrasonic-based flood early warning system (EWS). The program adopted a Participatory Action Research (PAR) approach, incorporating community outreach, technical assembly workshops involving the local youth organization (*Karang Taruna*), collaborative installation activities, and maintenance training. A total of 30 participants were selected through purposive sampling. Quantitative data collected through pretest and posttest questionnaires were analyzed using paired-sample tests, while qualitative data obtained from field observations were analyzed using an interactive analytical approach. The findings revealed an increase in community comprehension scores from 25% to 60%, the successful installation of five solar-powered streetlights with automated motion detection, and the successful operation of an ultrasonic-based EWS calibrated against manual water-level gauges, which reliably activated sirens when predefined critical water-level thresholds were reached. The participatory process also strengthened the tradition of mutual cooperation (*gotong royong*) and fostered community ownership, equipping residents with technical troubleshooting and maintenance skills to support long-term system sustainability. In conclusion, integrating appropriate renewable energy technologies with participatory community engagement can enhance public safety, disaster preparedness, and local capacity for maintaining resilient and sustainable infrastructure in areas vulnerable to hydrometeorological hazards.

INTRODUCTION

Sustainable rural development depends heavily on the availability of adequate basic infrastructure and community preparedness for potential environmental disasters (Hadi et al., 2025; Rahmani et al., 2022). The target population of this community empowerment program

comprises residents of Sepinggan Raya, located in Kecamatan Balikpapan Selatan (South Balikpapan District), Indonesia. This community resides in a geographically challenging environment characterized by densely populated settlements situated near drainage channels. Residents primarily depend on agriculture and local microenterprises for their livelihoods, making safe, well-lit, and accessible surroundings essential for their daily activities. However, these environmental and socioeconomic conditions increase their vulnerability to infrastructure deficiencies and hydrometeorological hazards, adversely affecting socioeconomic stability, daily mobility, and overall public safety. Balikpapan has recorded recurrent flood events in recent years, and the declining capacity of water catchment areas has been associated with these events (Putra et al., 2026).

The conditions observed within the target community reveal two critical challenges that provide the primary rationale for implementing this community empowerment program. First, the area experiences a severe shortage of adequate public street lighting. Poorly illuminated roads at night restrict residents' economic activities and increase the risks of traffic accidents, crime, and other safety concerns (Kaplan & Chalfin, 2022; Uttley et al., 2025). Second, the community faces a persistent threat of flash flooding caused by sudden increases in surface water levels and drainage channel overflows, particularly during periods of heavy rainfall (Douglas, 2017). The absence of an integrated early warning system (EWS) limits the time available for residents to respond, evacuate, and protect their property, potentially resulting in substantial material losses and threats to public safety (Helmi & Muthohharoh, 2024; Rana et al., 2021; Wimordi et al., 2026).

To address these challenges, this program draws on empirical evidence and conceptual frameworks emphasizing the importance of strengthening community resilience through appropriate technologies. Recent literature highlights the potential of affordable renewable energy technologies to support sustainable community-based disaster risk reduction. For instance, Indonesia possesses vast solar energy potential (Silalahi et al., 2021), and solar-powered public street lighting has been installed in several villages as an energy-efficient alternative that reduces dependence on grid-supplied electricity and recurring electricity expenses (Hadi et al., 2025; Nugraha et al., 2023). Furthermore, EWS prototypes incorporating ultrasonic water-level sensors and microcontrollers have been shown to monitor water levels in real time and deliver automatic warnings to residents of flood-prone areas, offering a more effective alternative to manual monitoring (Hasibuan et al., 2025; Wahid et al., 2024; Wijaya & Siagian, 2024). Advances in Internet of Things technologies have further expanded the capabilities of such systems (Esposito et al., 2022). These findings suggest that integrating appropriate technologies into community infrastructure can enhance environmental safety and disaster preparedness, particularly when accompanied by structured capacity-building initiatives (Ks et al., 2026; Lestari et al., 2026; Pramudita et al., 2024).

Despite the documented benefits of these technologies, previous interventions by external stakeholders have demonstrated limited long-term effectiveness in addressing similar challenges. Local governments and nongovernmental organizations have previously attempted to support comparable communities through the installation of conventional public streetlights and manual water-level gauges. However, conventional grid-connected lighting systems imposed substantial recurring electricity costs on village budgets, occasionally resulting in

service interruptions. Similarly, manual water-level gauges were less effective during nighttime conditions or extreme weather events because they required direct visual observation. More importantly, these interventions involved limited community participation, as equipment procurement and installation were predominantly conducted through top-down approaches without sufficient technical training or maintenance education (Buchori et al., 2022). Consequently, inadequate maintenance capacity and limited community ownership contributed to the deterioration of infrastructure and reduced the long-term sustainability of these interventions (Fathoni et al., 2021; Prilandita et al., 2022).

Therefore, the primary objective of this community empowerment program is to improve public safety, disaster preparedness, and technological literacy by addressing the community's specific infrastructure needs through participatory technological interventions. Achieving this objective requires the active involvement of residents throughout the planning, implementation, and maintenance stages (Fatmah et al., 2024; Ks et al., 2026). Accordingly, the program adopts a community-based participatory approach involving structured community outreach and awareness-raising activities, technical assembly workshops conducted in collaboration with the local youth organization (Karang Taruna), and the joint installation of solar-powered streetlights and an ultrasonic-based flood EWS. By engaging residents throughout the process, from identifying local challenges and determining technological requirements to installing equipment and providing maintenance training, the program seeks to ensure not only the successful deployment of appropriate technologies but also their sustainable operation and management. Ultimately, this integrated approach is expected to strengthen community ownership, enhance local technical capacity, and contribute to the development of safer, more resilient, and self-reliant communities vulnerable to hydrometeorological hazards.

METHOD

This community empowerment program was conducted in Sepinggan Raya, Kecamatan Balikpapan Selatan, Indonesia, from November 6, 2025, to February 15, 2026. Before the intervention, the community faced inadequate street lighting, which increased nighttime accident risks and restricted economic activities. Residents living near drainage channels also lacked an automated flood detection system and relied on visual monitoring, which often delayed evacuation during heavy rainfall. The program aimed to improve community resilience through the installation of solar-powered streetlights, an ultrasonic-based flood early warning system (EWS), and technical training to strengthen residents' capacity for independent infrastructure maintenance.

This study employed a Participatory Action Research (PAR) approach that emphasized active collaboration between researchers and community members. The approach was adapted to incorporate hands-on technical training, enabling residents to participate directly in assembling, installing, and maintaining solar-powered streetlights and ultrasonic water-level sensors. Activities included community outreach, technical workshops, collaborative equipment installation, and maintenance training involving village officials and members of the local youth organization (*Karang Taruna*).

Data were collected through field observations, technical measurements, and community assessments. Purposive sampling was used to select 30 participants, including village officials, Karang Taruna members, and household representatives from flood-prone areas. Pretest and posttest questionnaires were administered to assess changes in technological literacy and disaster preparedness. Questionnaire content validity was evaluated through expert review, while internal consistency was assessed using Cronbach's alpha. Technical performance was evaluated through direct observation and equipment testing. Passive infrared (PIR) motion sensors were tested to assess their detection ranges, while ultrasonic water-level sensors were calibrated against manual water-level gauges to verify measurement accuracy and siren activation at predetermined thresholds.

The collected data were analyzed using a mixed-methods approach. Quantitative questionnaire responses were examined using descriptive statistics and paired-sample tests to assess changes in participants' knowledge of system maintenance and flood evacuation procedures. Qualitative data obtained from field observations and community interactions were analyzed through data reduction, data display, and conclusion drawing. The qualitative analysis focused on community participation, technical skill development, and ownership of the installed infrastructure. These analyses were used to evaluate the program's implementation outcomes and its contribution to community capacity building and disaster preparedness.

RESULTS AND DISCUSSION

The implementation of the community empowerment program in Sepinggan Raya yielded significant improvements in both physical infrastructure and the community's disaster preparedness. The activities successfully bridged the gap between technological availability and community literacy through the targeted deployment of solar-powered streetlights and an ultrasonic-based Early Warning System (EWS). By integrating the Participatory Action Research (PAR) approach, the program did not merely deliver technological products but facilitated a comprehensive knowledge transfer. The results are evaluated based on three main indicators: the enhancement of community knowledge, the successful operationalization of the renewable energy lighting, and the functional deployment of the flood mitigation technology.

The initial phase of the program focused heavily on socialization and capacity building, which served as the foundation for the subsequent physical installations. Based on the descriptive statistical analysis of the pre-test and post-test questionnaires distributed to the 30 targeted participants, there was a substantial increase in technological literacy and disaster mitigation awareness. Before the intervention, the average comprehension score regarding renewable energy maintenance and flood evacuation protocols was notably low, recorded at 25 %. Following the interactive workshops and hands-on assembly training with the local youth organization (*Karang Taruna*), the post-test average score surged to 60 %. This quantitative improvement indicates that the dialogical communication method and active community involvement effectively answered the research objectives regarding community education.

Regarding the physical infrastructure, the collaborative installation of the solar-powered streetlights successfully addressed the critical issue of inadequate nocturnal illumination. A total of 5 units were assembled and erected at predetermined dark spots along the main village roads. The integration of Passive Infrared (PIR) motion sensors proved to be highly effective;

field observations confirmed that the lights operate at a dimmed capacity during idle periods and automatically switch to maximum brightness upon detecting human or vehicular movement. This smart automation not only optimizes battery life but also provides a zero-cost, sustainable solution to the village's lighting problem, directly enhancing nighttime safety and economic mobility.

Furthermore, the deployment of the EWS along the Sepinggan ditch established a crucial defense mechanism against sudden hydrometeorological hazards. The system, utilizing ultrasonic water-level sensors connected to a central microcontroller and a high-decibel siren, was rigorously calibrated during the installation phase. When tested against manual water gauges, the sensors accurately triggered the siren at the predefined critical elevation thresholds. The active participation of the residents in determining these thresholds and understanding the siren's signals ensures that the community now possesses a reliable tool to maximize their evacuation response time, thereby minimizing potential material losses and ensuring physical safety.

The discussion of these results highlights that introducing appropriate technology in rural settings requires more than just physical deployment. As observed during the collaborative installations, the traditional value of mutual cooperation (*gotong royong*) was revitalized, fostering a profound sense of ownership among the residents. Because the *Karang Taruna* members were directly involved in soldering the circuits, calibrating the sensors, and erecting the poles, they are now equipped with the technical troubleshooting skills necessary for long-term maintenance. This aligns with the expected result outlined in the methodology, proving that combining renewable energy initiatives with disaster mitigation technologies through a highly participatory framework effectively transforms a vulnerable village into a resilient and self-sufficient community

Table 1. Matrix Kegiatan Proker KKN

No.	Program Name	Activity	Target Group	Expected Output	Date
1	Permit Coordination	Meet with village officials and submit the program proposal.	Village head and village secretary	Official permission to carry out the program and logistical support.	October 22, 2025
2	Disaster Mitigation	Brief residents on the early warning system and evacuation procedures.	Residents of Neighborhood Unit 12 (RT 12)	Improved understanding of early warnings and evacuation procedures, measured through pre- and post-tests.	February 15, 2026
3	Appropriate Technology	Assemble solar-powered lights with motion sensors.	KKN team	Five solar-powered lights ready for installation.	November 4, 2025– February 12, 2026
4	Installation 1 – Flood Detection Device	Install a flood detection device on the riverbank.	KKN team and local residents	A flood detection device installed with a working siren.	February 15, 2026
5	Installation 2 – Solar-Powered	Install solar-powered lights at	KKN team and local residents	Automatic lighting at selected	February 15, 2026

	Lights	poorly lit locations along village roads.		locations.	
6	Occupational Health and Safety (OHS) Training	Train community leaders in equipment maintenance and electrical safety.	Community leaders	An equipment maintenance guide.	February 15, 2026
7	Program Closeout	Hold a ceremonial handover of the assets and sign the official handover document.	Village officials	A signed Asset Handover Record (BAST).	February 15, 2026

Table 2. Matrix K3 Proker

No	Activity Name	Week			
		1	2	3	4
1	Site Survey and Coordination				
2	Procurement of Equipment and Materials				
3	Installation of Streetlights and Sensors				
4	Community Outreach and Training				
5	Evaluation and Final Report Preparation				

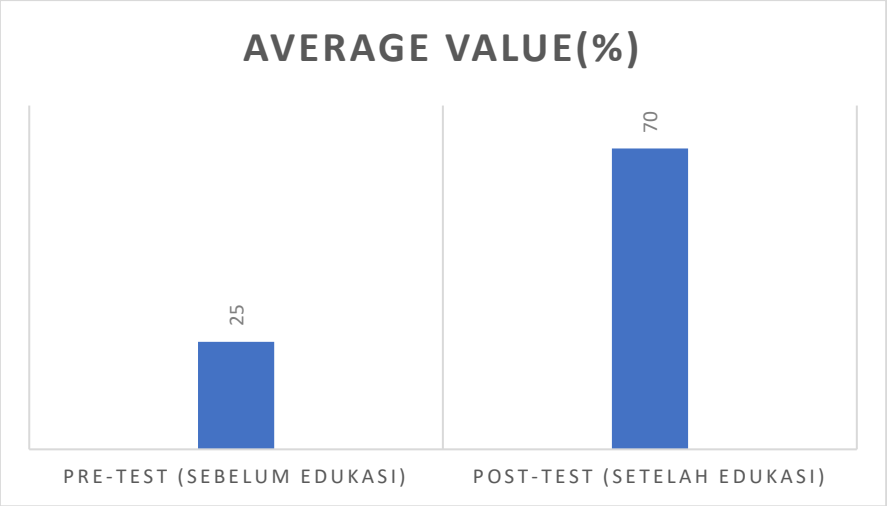
Table 3. Matrix Kegiatan Proker KKN

No.	Program Name	Activity	Target Group	Expected Output	Date
1	Permit Coordination	Meet with village officials and submit the program proposal.	Village head and village secretary	Written authorization to carry out the program and logistical support.	October 22, 2025
2	Disaster Mitigation	Brief residents on the early warning system and evacuation procedures.	Residents of Neighborhood Unit 12 (RT 12)	Improved understanding of early warnings and evacuation procedures, measured through pre- and post-tests.	February 15, 2026
3	Appropriate Technology	Assemble solar-powered lights equipped with motion sensors.	KKN team	Five solar-powered lights ready for installation.	November 4, 2025– February 12, 2026
4	Installation 1 – Flood Detection Device	Install a flood detection device on the riverbank.	KKN team and local residents	An installed flood detection device with a functioning siren.	February 15, 2026
5	Installation 2 – Solar-Powered Lights	Install solar-powered lights at poorly lit points along village roads.	KKN team and local residents	Automatic lighting at selected locations.	February 15, 2026
6	Occupational Safety and Health (OSH) Training	Train community leaders in equipment maintenance and electrical safety.	Community leaders	An equipment maintenance guide.	February 15, 2026
7	Program Closeout	Hold a ceremonial handover of the assets and sign the official handover record.	Village officials	A signed Asset Handover Record (BAST).	February 15, 2026

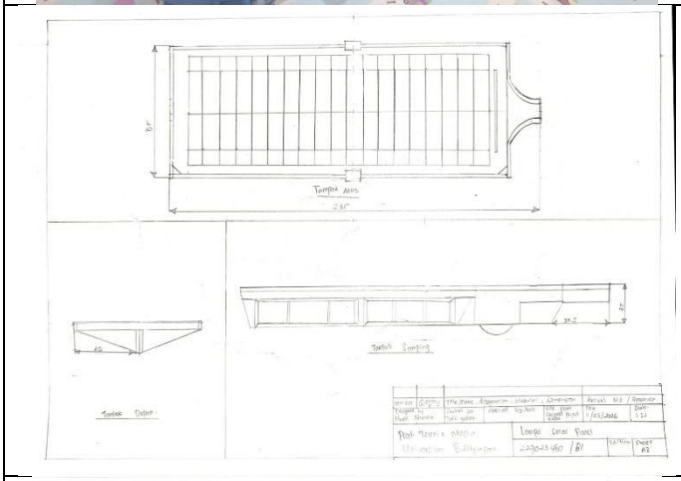
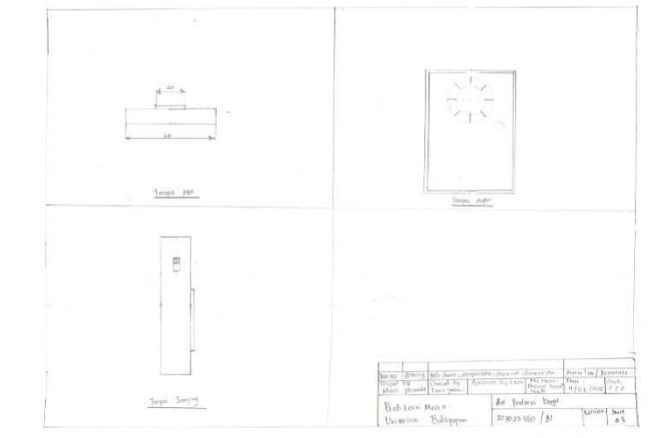
Table 4. Matrix K3 Proker

Activity	Potential Hazards	Risks / Consequences	Preventive / Control Measures	Personal Protective Equipment (PPE)
Transporting Equipment and Materials	Heavy loads and uneven terrain	Muscle injuries or cramps, pinch injuries, and dropped equipment	Use proper lifting techniques and keep the route clear of obstacles.	Work gloves and safety footwear
Installing Solar Light Poles	Working at height and potential pole collapse	Falling from height or being struck by a falling pole	Ensure ladders or scaffolding are stable, use fall protection, and verify that the ground can support the load.	Safety helmet, full-body harness, and safety footwear
Assembling Solar Panels and Sensors	Electrical short circuits	Electric shock and component damage	Keep hands dry, use insulated tools, and verify battery polarity.	Rubber gloves or mechanical protection gloves, as specified in the original table
Installing the Flood Detection Device	Water flow in the drainage channel and slippery footing	Slipping, being swept away, and insect or snake bites	Carry out installation in clear weather when the water is calm, and use a tether line.	Life jacket and rubber boots
Drilling and Installing Sensors	Dust, flying debris, and noise	Eye and respiratory irritation	Wear a mask and safety goggles, and maintain stable footing.	Mask and safety goggles

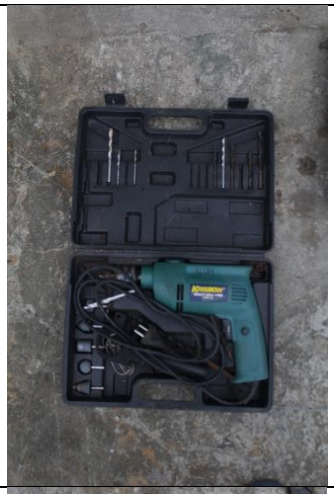
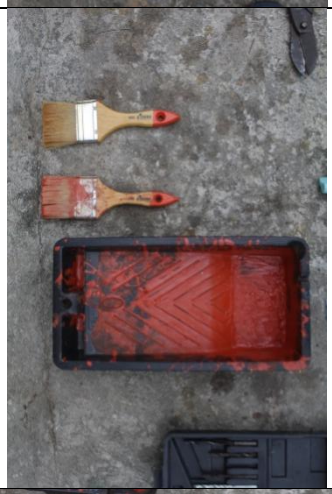
Graphs



Graphs 1. Comparison of Pre-Test and Post-Test Average Scores Regarding Technological Literacy and Disaster Preparedness

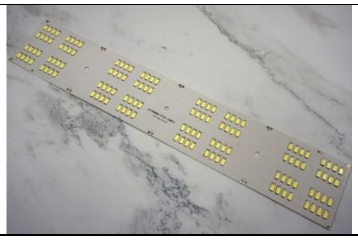
	Village officials welcomed the community initiative outlined in this proposal, which would subsequently be included in the village's coordination agenda.
	Solar-Powered Streetlight Design and Assembly Process
	Flood Detection Sensor Design Diagram

Procurement of Equipment & Raw Materials

NO	Names of Equipment and Raw Materials	Photo
1	**Electric Drill**	
2		
3	**Hacksaw and Wood Saw**	

4	**Scissors, Ruler, Pliers, and Sheet Metal Shears**		
5	**Adhesive Tape**		
6	**Wood Primer**		
7	**Wood Paint**		

8	**Spray Paint**	
9	**Paint Thinner**	
10	**Wood**	

11	**Galvalume Steel Sheet**	
12	**Flood Detection Device**	
13	**Printed Circuit Board (PCB) for LED Lighting with Sensors and Connecting Wires**	
14	**Rechargeable Battery**	
15	**LED Light**	

16	**Soldering Iron and Solder Wire**	
17	**Screwdrivers and Bolts**	

	During the assembly of the solar-powered streetlight, each electrical connection was carefully soldered to ensure a stable flow of current from the battery to the LED light. Meanwhile, the motion sensor was strategically positioned to provide a wide detection angle and responsive motion detection.
	The community outreach activities were conducted in stages through community consultation forums to foster mutual understanding and minimize potential resistance to the proposed changes.

	Following the needs verification process, the equipment was officially handed over to community representatives for immediate use in daily operations.
	The installation of the solar-powered streetlights was carried out collaboratively by the technical team and local residents, reflecting the spirit of mutual cooperation (gotong royong) in promoting energy independence within their community.
	The installation process included mounting ultrasonic sensors and an automatic siren system under the supervision of community leaders to ensure that the equipment was securely installed and protected from physical interference.

CONCLUSION

The community empowerment program in Sepinggan Raya successfully achieved its primary objectives of improving community resilience and disaster preparedness. Through the application of the Participatory Action Research (PAR) approach, the program moved beyond conventional top-down infrastructure provision by promoting active community participation and hands-on technical training. The integration of appropriate technologies, particularly solar-powered streetlights equipped with passive infrared (PIR) motion sensors and an ultrasonic-

based flood early warning system (EWS), addressed the community's needs for improved nighttime visibility and flood preparedness.

The program demonstrated positive outcomes in community technological literacy and disaster preparedness. Participants' comprehension scores increased from 25% before the intervention to 60% after the educational workshops, indicating improvements in their understanding of the installed technologies and related disaster preparedness measures. Furthermore, the collaborative installation process involving the local youth organization (Karang Taruna) and village officials resulted in the deployment of functional solar-powered streetlights and a flood EWS while strengthening community participation and ownership. The practical training activities also equipped residents with basic technical skills for operating, maintaining, and troubleshooting the installed equipment, thereby supporting the long-term sustainability of the intervention.

Based on these findings, local governments and future community empowerment programs are encouraged to consider adapting and expanding this integrated technological approach to other flood-prone communities. Future initiatives could enhance the existing EWS by incorporating Internet of Things (IoT) technologies to enable real-time remote monitoring of water levels through mobile applications. Additionally, continued institutional and financial support from village authorities is recommended to strengthen the capacity of Karang Taruna members to conduct routine inspections, maintenance, and system improvements. These measures could contribute to the long-term functionality of the installed infrastructure and further strengthen community resilience, technological literacy, and preparedness for hydrometeorological hazards.

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The authors declare that no financial support was received for the conduct of this research and/or the publication of this article.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article. The implementation of this community empowerment program was conducted purely for academic and social service purposes. The authors do not have any financial, personal, or professional relationships with the manufacturers or suppliers of the solar panels, Passive Infrared (PIR) sensors, and ultrasonic Early Warning System (EWS) components utilized in this program. Furthermore, the funding institution had no role in the design of the activities; in the collection, analysis, or interpretation of the evaluation data; in the writing of the manuscript; or in the decision to publish these results.

AUTHOR CONTRIBUTION

The author contributed to the preparation and writing of this article.

STATEMENT ON THE USE OF GENERATIVE ARTIFICIAL INTELLIGENCE

In the preparation of this manuscript, the authors utilized Artificial Intelligence (AI) solely for the purposes of improving grammar and checking language usage.

REFERENCES

Buchori, I., Zaki, A., Pangi, P., Sejati, A. W., Pramitasari, A., & Liu, Y. (2022). Adaptation strategies and community participation in government-led mitigation projects: A comparison between urban and suburban communities in Pekalongan, Indonesia. *International Journal of Disaster Risk Reduction*, *81*, 103271. https://doi.org/10.1016/j.ijdrr.2022.103271

Douglas, I. (2017). Flooding in African cities, scales of causes, teleconnections, risks, vulnerability and impacts. *International Journal of Disaster Risk Reduction*, *26*, 34–42.

Esposito, M., Palma, L., Belli, A., Sabbatini, L., & Pierleoni, P. (2022). Recent advances in internet of things solutions for early warning systems: A review. *Sensors*, *22*(6), 2124. https://doi.org/10.3390/s22062124

Fathoni, H. S., Setyowati, A. B., & Prest, J. (2021). Is community renewable energy always just? Examining energy injustices and inequalities in rural Indonesia. *Energy Research & Social Science*, *71*, 101825. https://doi.org/10.1016/j.erss.2020.101825

Fatmah, F., Purwana, R., & Bisri, M. F. (2024). Role of Kader Siaga Bencana in the flood management of selected Kampung Siaga Bencana. *Jàmbá: Journal of Disaster Risk Studies*, *16*(1), a1645. https://doi.org/10.4102/jamba.v16i1.1645

Hadi, N. T., Muslim, M. P., Gusti, K. W., & Prasetyo, R. T. (2025). Pemberdayaan masyarakat berbasis energi surya untuk mendukung desa cerdas energi dan meningkatkan kesejahteraan. *Jurnal Inovasi Hasil Pengabdian Masyarakat (JIPEMAS)*, *8*(3), 765–777. https://doi.org/10.33474/jipemas.v8i3.24287

Hasibuan, A., Zahiri, M., Jannah, M., Roid, F., Almunadiansyah, R., Abta, A., & Nrartha, I. M. A. (2025). Design of flood warning prototype using ESP32 module-based ultrasonic sensors. *International Journal of Reconfigurable and Embedded Systems*, *14*(1), 126–135. https://doi.org/10.11591/ijres.v14.i1.pp126-135

Helmi, A., & Muthohharoh, N. H. (2024). Sistem peringatan dini berbasis masyarakat di daerah rawan bencana: Studi di tiga desa di Provinsi Nusa Tenggara Timur, Indonesia. *Sosio Konsepsia: Jurnal Penelitian dan Pengembangan Kesejahteraan Sosial*, *14*(1), 48–64. https://doi.org/10.33007/ska.v14i1.3302

Kaplan, J., & Chalfin, A. (2022). Ambient lighting, use of outdoor spaces and perceptions of public safety: Evidence from a survey experiment. *Security Journal*, *35*(3), 694–724. https://doi.org/10.1057/s41284-021-00296-0

Ks, A. M., Ardiansyah, N. P., Barnadi, Y., & Suryana, A. (2026). Education on solar cell technology to increase clean energy literacy in Cileles Village, Sumedang. *Reka Elkomika: Jurnal Pengabdian kepada Masyarakat*, *7*(1), 80–88. https://doi.org/10.26760/rekaelkomika.v7i1.80-88

Lestari, M., Wahyono, U., Ratnaningtyas, D. I., Haeruddin, Afriansyah, M., Aningsih, M., & Bontoala, F. S. (2026). Pemberdayaan siaga bencana melalui flood early warning system untuk menggairahkan ekowisata Air Terjun Wera. *Surya Abdimas*, *10*(2), 240–249. https://doi.org/10.37729/abdimas.v10i2.7204

Nugraha, D. K., Harja, H. B., Setiawan, H., Hadiani, D., & Fathurohman, M. (2023). Pemasangan penerangan jalan umum tenaga surya (PJU-TS) di Desa Sukamandi, Sagalaherang, Subang. *Kumawula: Jurnal Pengabdian kepada Masyarakat*, *6*(3), 763–771. https://doi.org/10.24198/kumawula.v6i3.44841

Pramudita, R., Fauzan, M. R., Purnama, W., Rizqulloh, M. A., Ardiansyah, N. P., & Pawinanto, R. E. (2024). Capacity building of Majalaya Village through training on designing flood detection systems for village youth in an effort to mitigate flood disasters. *Reka Elkomika: Jurnal Pengabdian kepada Masyarakat*, *5*(3), 280–290. https://doi.org/10.26760/rekaelkomika.v5i3.280-290

Prilandita, N., Sagala, S., Azhari, D., & Habib, A. (2022). Rural renewable energy development: Lessons learned from community-based renewable energy business model in East Sumba, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *1015*(1), 012017. https://doi.org/10.1088/1755-1315/1015/1/012017

Putra, D. P. E., Zam Zam, E. P. F. Z., Fitrianita, D., Putra, A. J., Majid, F., & Sigit, A. B. (2026). Kajian keterkaitan tingkat kekritisan daerah resapan air terhadap kejadian banjir di Kota Balikpapan. *Jurnal Geosaintek*, *12*(2), 191–205. https://doi.org/10.12962/j25023659.v12i2.9064

Rahmani, S., Murayama, T., & Nishikizawa, S. (2022). Socio-economic impact of a solar water pumping system in a rural community in Indonesia. *Journal of Sustainable Development of Energy, Water and Environment Systems*, *10*(3), 1090403. https://doi.org/10.13044/j.sdewes.d9.0403

Rana, I. A., Bhatti, S. S., & Jamshed, A. (2021). Effectiveness of flood early warning system from the perspective of experts and three affected communities in urban areas of Pakistan. *Environmental Hazards*, *20*(3), 209–228. https://doi.org/10.1080/17477891.2020.1751031

Silalahi, D. F., Blakers, A., Stocks, M., Lu, B., Cheng, C., & Hayes, L. (2021). Indonesia's vast solar energy potential. *Energies*, *14*(17), 5424. https://doi.org/10.3390/en14175424

Uttley, J., Canwell, R., Smith, J., Falconer, S., Mao, Y., & Fotios, S. (2025). Does darkness increase the risk of certain types of crime? A registered report article. *PLOS ONE*, *20*(6), e0324134. https://doi.org/10.1371/journal.pone.0324134

Wahid, A., Parenreng, J. M., Kusnandar, W. C. K., Adi, P. D. P., Mahabror, D., & Sariningrum, R. (2024). Telegram bot-based flood early warning system with WSN integration. *ILKOM Jurnal Ilmiah*, *16*(2), 151–160. https://doi.org/10.33096/ilkom.v16i2.1699.151-160

Wijaya, I. K. K. A., & Siagian, R. C. (2024). Development of an early warning system using social media for flood disaster. *Jurnal RESTI (Rekayasa Sistem dan Teknologi Informasi)*, *8*(1), 169–180. https://doi.org/10.29207/resti.v8i1.5087

Wimordi, C., Yudianto, D., & Wijaya, O. T. (2026). Flood early warning systems: A literature review of concepts, evolution, and implementation in Indonesia. *Media Komunikasi Teknik Sipil*, *32*(1), 130–142. https://doi.org/10.14710/mkts.v32i1.84709