

The Role of Renewable Energy in Improving Resilience to Natural Disasters (Case of the Implementation of Solar Energy Systems in Disaster-Prone Areas in Kupang City, East Nusa Tenggara Province)

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Abstract. This study examines solar power systems in Kupang City, East Nusa Tenggara, a region prone to earthquakes, strong winds, and droughts. Decentralized renewable energy solutions like solar power improve community resilience and disaster preparedness as traditional energy infrastructure becomes increasingly unreliable during disasters. This study examines how solar PV systems can boost energy resilience and disaster management. We collected qualitative secondary data from articles analyzed with NVivo 12 Plus software, focusing on citizens' perceptions of solar energy systems and their potential benefits in disaster-prone areas. The findings demonstrate the importance of solar energy, particularly solar power plants (PLTS), in emergency energy reliability and sustainability. In emergencies, PLTS systems, which operate off the grid, keep healthcare and communication networks running. However, high initial costs, limited technical expertise, logistical constraints, and financial barriers prevent widespread solar technology adoption. To overcome these challenges and improve solar energy infrastructure, governments, the private sector, and international organizations must work together. Solar energy could improve disaster resilience in Kupang but requires significant investment and policy reforms, according to the study.

1 Introduction

As conventional power systems become more disaster-prone, we need resilient, sustainable energy solutions wherein decentralized, grid-independent solar power enhances community resilience. Studies show that renewable energy microgrids are more reliable than traditional generators, which often fail due to fuel shortages and logistical

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issues during long outages [1]. Microgrids can provide continuous power and promote long-term sustainability by integrating solar PV systems with battery storage and other renewable technologies, [2]. Solar energy systems provide reliable and sustainable power, especially in hurricane-prone, flood-prone, and earthquake-prone areas [3],[4]. Solar energy's decentralized nature allows it to operate independently from the main grid, keeping hospitals, communication systems, and emergency shelters running during such events. Solar photovoltaic (PV) systems with battery storage provide reliable backup power without diesel generators, which are difficult to transport during emergencies [5]. Hurricane Sandy shows how solar PV systems can maintain electricity when grids fail conditions. Solar energy is sustainable and improves disaster preparedness in remote areas without grid access [6]. However, deploying solar systems in disaster-prone areas requires technical expertise, high initial costs, and weatherproof infrastructure. Governments, the private sector, and international organizations must invest in resilient solar infrastructure and promote renewable energy adoption to overcome these challenges. Sustainable development and community welfare will depend on solar energy's role in disaster resilience as climate change intensifies natural disasters [7].

Solar energy systems in disaster-prone developing countries and archipelagos are difficult to install. Even though solar technology prices are falling, high upfront costs and financial constraints remain. Installation and maintenance remain expensive, especially in archipelagic nations with fragmented geography and poor infrastructure, which raises logistics costs. Typhoons and heavy rain can damage solar infrastructure, requiring weatherproof systems. Solar energy is unreliable in cloudy or monosomy areas because it depends on sunlight [8]. Batteries are necessary but expensive and difficult to install. Lack of technical expertise in many developing nations makes solar energy deployment difficult, as insufficient training and support undermine project sustainability, especially in remote areas. Inconsistent policies, inadequate government incentives, and land acquisition issues slow solar adoption [9]. Socio-cultural factors like solar technology ignorance complicate matters. Community engagement and education are essential for overcoming these obstacles. High initial costs, geographical challenges, and a shortage of skilled labor make renewable energy transition difficult. Regulatory inefficiencies hinder local solar adoption, emphasizing the need for a comprehensive energy strategy that includes capacity building, regulatory improvements, and community involvement [10].

The research concentrates on Kupang, East Nusa Tenggara, as a result of its high vulnerability to natural disasters, such as earthquakes, strong winds, and droughts. Kupang is prone to disasters caused by extreme weather, which damage local infrastructure and livelihoods (see **Fig. 1**). A study found coastal Kupang City moderately vulnerable to high risks in livelihood, food security, water, and housing [11]. Self-sufficiency and government support have helped coastal farmers and fishermen adapt to climate change. Overall, Indonesia struggles with regulatory, policy, institutional, and sectoral infrastructure resilience. Many institutions struggle with their technical and financial capacity, and regulators and policymakers find it challenging to enforce resilient infrastructure standards in transportation, energy, water, health, and industry sectors. The region's energy infrastructure is inadequate, making it challenging to maintain essential services during and after disasters. Due to high operational costs and fuel transportation and storage difficulties in this remote area, diesel generators often fail.

gathering textual attributes, we employ machine learning techniques to classify its sentiment. This process involves us analyzing the overall sentiment of the news article. This study employs articles composed in Indonesian. We intentionally chose articles published in 2024 from diverse news outlets and governmental publications. The terms "new renewable solar energy" and "PLTS" serve as key concepts, central to the research discourse during the data collection phase. The data set in question constitutes a minor segment of the potential data set. The preceding explanations underscore the constraints related to the utilization of a specific article, especially its capacity to communicate the developments occurring in Kupang to the public. Although the findings provide insight into citizens' perceptions of renewable energy, especially solar power, it is crucial to recognize that they may not encompass the complete online perspective. We recognize the constraints of the study.

This research utilizes a qualitative text-analysis methodology, drawing on secondary data sourced from online news articles and government publications. The data were gathered utilizing the NCapture function in NVivo 12 Plus software, which facilitates the systematic acquisition of online textual content for qualitative analysis. The dataset comprises articles authored in Indonesian and disseminated in 2024 through diverse online media platforms and governmental sources. The keywords "renewable solar energy" and "PLTS" were employed in the data collection process to identify pertinent articles regarding solar energy development in Kupang City. Prior to analysis, the gathered textual data were sanitized and processed to eliminate extraneous content and maintain consistency within the dataset. NVivo was subsequently employed to analyze the textual data by discerning predominant themes and patterns associated with renewable energy discourse. Alongside thematic analysis, sentiment analysis was performed to assess the tone of the narratives regarding solar power systems. The analytical tools integrated within NVivo were utilized to categorize sentiments conveyed in the news articles as positive, negative, or neutral. This process enables the examination of how solar energy initiatives are represented in media discourse. The dataset constitutes merely a segment of the extensive online discourse. Consequently, the results predominantly illustrate media narratives instead of an exhaustive depiction of public sentiment. Nonetheless, the analysis offers valuable insights into the framing of renewable energy and solar power systems in discussions pertaining to Kupang.

3 Result and discussion

3.1 Implementation of solar energy systems in increasing resilience

The Nano Portable Photovoltaic Box shows the relevance and contribution of solar energy systems in increasing resilience to natural disasters in disaster-prone areas. BNPB data showing an increasing trend in natural disasters in Indonesia in the last decade is an essential background in understanding the need for effective and sustainable solutions in disaster management [12]. One effort that can be taken is using solar energy systems, which have been proven to be an environmentally friendly and sustainable alternative. This study links the contribution of implementing solar energy systems with the need for

emergency response equipment that can provide electricity for victims of natural disasters.

In 2015, there was an Urban Climate Risk Management Plan (UCRMP) document, which is a local planning tool that is aligned with the city's Vision development plans, such as the Regional Medium Term Development Plan (RPJMD) and Spatial Planning (RTRW). The UCRMP, rather than existing as a separate document, mirrors the RPJMD Vision, which the local head prepared at the outset. The UCRMP also considers the Regional Government Work Plan (RKPD), Strategic Plan, and derivative planning documents from the regional income and expenditure budget (APBD). The UCRMP incorporates climate change adaptation and disaster risk reduction programs from the government, NGOs, and the private sector. However, the ineffectiveness of climate change mitigation and adaptation in Indonesia, including Kupang City, as outlined in the Regional Action Plan for Greenhouse Gas Reduction at the provincial and district/city levels, can be attributed to the lack of budgeted programs and the absence of effective emission reduction strategies [13].

Disaster management equipment standards set by National Board for Disaster Management (BNPB) emphasize the need for environmentally friendly equipment to avoid negative impacts such as carbon emissions that can increase global warming. Solar energy systems are an attractive option because they do not produce carbon emissions and have a lower environmental impact than conventional generators. The Nano Portable Photovoltaic Box study highlights the ability of solar energy systems to provide electricity in emergencies and disasters. The portability and reliability of this system make it a suitable solution for emergency response needs in disaster-prone areas [14]. In addition, using solar energy can reduce dependence on fossil fuels and make conventional electricity infrastructure vulnerable to damage due to natural disasters. The implementation of solar energy systems can increase resilience to natural disasters in disaster-prone areas by reducing negative impacts on the environment, increasing the availability of electricity in emergencies, and reducing dependence on resources that are vulnerable to disruption due to disasters [6].

According to the data obtained from Ncapture in **Fig. 2**, the contribution of renewable energy, especially solar power plants (PLTS), markedly exceeds that of other emerging renewable energy sources in bolstering resilience to natural disasters. The capacity of PLTS to independently generate significant energy makes it a highly feasible solution for disaster-prone regions. In contrast to steam power plants (PLTU), which are vulnerable to significant disruptions from natural disasters, PLTS offers a more reliable and secure energy source. Moreover, PLTS enhances the community's quality of life by providing uninterrupted access to dependable energy, which is crucial during disaster recovery periods. In Kupang City, East Nusa Tenggara Province, a region susceptible to natural disasters, PLTS can bolster essential infrastructure, including healthcare facilities, communication networks, and emergency services, thereby ensuring their functionality during crises. PLTS systems are both resilient and environmentally sustainable, diminishing greenhouse gas emissions and aiding in climate change mitigation. The decentralized characteristic of solar energy facilitates community-oriented energy solutions, enhancing local resilience and energy autonomy. Investments in PLTS can enhance economic growth, generate employment opportunities, and lower energy

expenses over time, thereby strengthening the resilience and sustainability of disaster-prone regions.

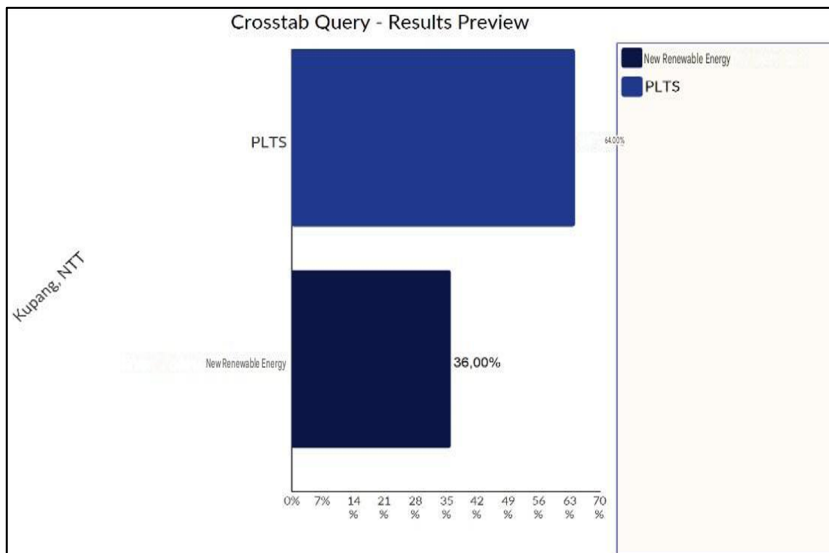


Fig. 2. Crosstab Query Role Energy Renewable in Increase Resilience to Disaster Natural [Source: Results of processing news data in the year 2023 with Ncapture Nvivo plus 12]

3.2 Effective strategies in expanding energy use

An effective strategy for expanding solar energy in disaster-prone areas to increase resilience to natural disasters can be formed through an approach that integrates various aspects. Strengthening renewable energy infrastructure, such as solar-based electric lighting, can be an essential first step. With increasing accessibility to electricity, people in disaster-prone areas can be better prepared to face crises and obtain the necessary assistance more efficiently. Education and training related to the use and maintenance of solar energy systems can improve the understanding and skills of local communities in managing this technology. Through targeted education programs, communities can become more independent in utilizing solar energy and gain maximum benefits from the system, even in emergencies. Collaboration between the government, non-governmental organizations, and the private sector can accelerate the spread of solar energy technology in disaster-prone areas. Support from various parties can help in financing, providing equipment, and developing policies that support the use of solar energy as part of a disaster mitigation strategy [15]. Developing solar power plants (PLTS) in Indonesia holds significant potential but faces economic, policy, and technological challenges. High initial costs, limited financing options, and slow return on investment hinder progress. Ambiguous renewable energy regulations, unclear tariffs, and fossil fuel

subsidies further complicate the situation. Technological challenges, including the need for efficient energy storage and high-cost batteries, also impact development. To accelerate PLTS deployment, Indonesia requires policy reforms, advances in storage technology, and increased financial support to make solar energy a competitive and sustainable alternative to fossil fuels.

4 Conclusion

In conclusion, this study evaluates the implementation of solar power systems in Kupang City to enhance energy resilience and community preparedness in natural disasters. It highlights the potential of photovoltaic systems (PLTS) to provide reliable energy in disaster-prone areas where traditional infrastructure is vulnerable. However, challenges such as high initial costs, logistical issues, and the need for technical expertise are identified. Despite falling solar technology prices, financial constraints and infrastructure limitations hinder wider adoption. Coordinated efforts from governments, the private sector, and international organizations are crucial for overcoming these barriers and enabling solar energy to strengthen disaster resilience in Kupang.

Limitations of the research include reliance on secondary data and qualitative methods, which may not capture the full range of perspectives, especially from marginalized communities. The focus on a specific region limits the generalizability of the findings, and the use of case studies and interviews may not fully reflect broader public sentiment. Future research could include primary fieldwork and broader comparative studies to provide a more comprehensive understanding of solar energy's role in disaster resilience.

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