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Renewable Energy and Maluku's Natural Resources Strategies for Utilizing Local Potential for a Sustainable Future

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Abstract

This study examines the utilization of renewable energy in Maluku Province, emphasizing an integrative approach based on local potential. Maluku, as an archipelagic region, has diverse energy potential, including solar, geothermal, microhydro, wind, and biomass. However, the utilization rate of new and renewable energy (EBT) remains low due to infrastructure, regulatory, social capacity, and economic constraints. This study uses a qualitative descriptive method supported by data from interviews and secondary quantitative data from BPS, PLN, and the Ministry of Energy and Mineral Resources. The analysis was conducted through spatial-sectoral mapping, evaluation of actual obstacles, and formulation of SWOT-based strategies. The results show that almost all regencies/cities in Maluku have significant EBT potential, with suitable utilization in the household, fisheries, agriculture, and public service sectors. The main obstacles include limited interconnection networks, unsupportive investment regulations, low community technical capacity, and small market scale. The proposed strategy emphasizes community-based renewable energy development, integration with natural resource conservation, local community empowerment, and multi-stakeholder collaboration. This study emphasizes the importance of a just energy transition that is contextual to the characteristics of the archipelago.

INTRODUCTION

Global climate change and increasing energy demand have driven the transformation of the world's energy system towards the use of cleaner and more sustainable resources. Indonesia, as an archipelagic country rich in renewable energy (EBT) potential, has set an ambitious target in its National Energy General Plan (RUEN) to achieve 23% of the EBT energy mix by 2025. However, the distribution of renewable energy utilization in Indonesia remains unequal, with Eastern Indonesia, including Maluku Province, facing serious challenges in electrification, infrastructure, and optimal utilization of local energy.

Maluku has an archipelagic geography with hundreds of scattered islands and diverse natural resources. Renewable energy potential in Maluku includes solar power, micro-hydro power from rivers on large islands such as Seram and Buru, biomass from agricultural and fisheries waste, and wind energy in coastal areas and small islands. According to data from the Indonesia Energy Outlook 2023 (BPPT), solar radiation intensity in Maluku ranges from 4.8-5.1 kWh/m²/day, high enough for the development of small-scale and communal solar power plants. However, according to a 2022 report from the Ministry of Energy and Mineral Resources, the utilization of renewable energy in this region has only reached around 2.1% of the total available

potential. Furthermore, the electrification ratio in several districts is still below the national average, while reliance on diesel generators still dominates the local energy system.

A study by Tumiran et al. (2022) highlighted the challenges in electricity system planning in island regions such as Maluku, which require inter-island interconnection for efficiency and renewable energy integration. This study demonstrated that the interconnection of the Ambon-Seram-Haruku-Saparua system could improve the stability and efficiency of the electricity system in Maluku.

However, integrative and contextual studies on renewable energy in Maluku are still very limited. Most previous research has focused on technical aspects of energy potential or on isolated case studies, without comprehensively integrating spatial, socioeconomic, and institutional data. For example, a study by Kurniawan et al. (2024) assessed the tidal energy potential in the Capalulu Strait, North Maluku, but failed to link these findings to institutional implementation strategies or the role of local communities.

Other empirical findings show that renewable energy development in the Indonesian archipelago faces structural challenges in the form of limited infrastructure, policy fragmentation, and less than optimal integration with local economic development (Wurarah, Sangadji, at all, 2025).

This research aims to fill this gap by: (1) mapping the potential for renewable energy in Maluku spatially and sectorally, (2) evaluating actual obstacles in its utilization based on official secondary data from PLN, BPS, and the Ministry of Energy and Mineral Resources, and (3) developing a community-based and sustainable renewable energy development strategy that is in line with local economic development and the characteristics of the islands.

The novelty of this research lies in its multidisciplinary, data-driven approach, which combines mapping of natural resource potential and the formulation of region-based implementation strategies. Furthermore, this research emphasizes the principles of energy justice and local self-reliance as the foundation for developing an energy system that is not only environmentally friendly but also inclusive and contextually tailored to the needs of the Maluku community. Therefore, the findings of this study are expected to provide both theoretical and practical contributions to the literature on energy transition in the Maluku archipelago.

LITERATURE REVIEW

Theoretical Framework of Sustainable Development and Renewable Energy

Sustainable development is a concept that combines social, economic, and environmental dimensions to achieve long-term prosperity. As part of the global development goals, the energy transition to renewable energy sources is a key pillar for reducing dependence on fossil fuels and mitigating the impacts of climate change. Sustainable development theory requires environmentally friendly and equitable energy use, with an emphasis on equitable energy distribution and community empowerment (Sachs, 2015).

A study by Sovacool et al. (2022) introduced the concept of a just energy transition, emphasizing the importance of ensuring equitable energy access, especially in areas previously unreachable by renewable energy. However, a major challenge for an archipelagic country like Indonesia is how to integrate equitable energy policies, taking into account its isolated geography and limited infrastructure. This is also recognized by Chaurey et al. (2020), who

highlight the importance of a community-based approach in achieving a just and effective energy transition.

Previous Studies on Local Energy Utilization in Island Areas

Previous research has focused heavily on renewable energy potential in the Indonesian archipelago, but it is often limited to technical case studies and does not integrate socio-economic aspects. Kurniawan et al. (2024) focused on the tidal energy potential in the Capalulu Strait, but this study did not link this potential to the needs and social characteristics of local communities, which are key challenges in implementing renewable energy.

A study by Tumiran et al. (2022) proposed integrating renewable energy into Maluku's electricity system, but focused primarily on technical aspects and system optimization, without providing insights into policy and community-based management. This highlights a gap in the literature regarding how local energy policies can align with the needs of communities facing geographical and economic challenges.

The Concept of Community-Based Renewable Energy Transition

The community-based renewable energy (CBRE) approach is considered more relevant for remote areas because it allows communities to play an active role in the development and management of renewable energy resources. This model can increase technology acceptance and the sustainability of energy systems (Bhattacharyya & Palit, 2021). CBRE is also considered more adaptive to local conditions and can reduce dependence on large, expensive infrastructure. However, implementing this model requires strong institutional support and policies that support local community empowerment (Sovacool et al., 2022).

In Indonesia, despite the significant potential for community-based renewable energy development, its implementation remains limited to a few pilot projects that do not fully connect technology, policy, and socio-economic empowerment (Chaurey et al., 2020). Therefore, this study aims to develop a more comprehensive CBRE model that looks beyond the technical side to include social and institutional aspects.

National Energy Policy and Its Impact on 3T (Frontier, Outermost, and Disadvantaged) Regions

Indonesia's energy policy, outlined in the National Energy General Plan (RUEN), targets a 23% renewable energy mix by 2025. However, its implementation in the 3T (United and Remote) regions faces various structural and financial barriers. A 2021 study by IRENA noted that 3T regions require a more adaptive and locally context-based policy approach. Given the geographic challenges, national energy policy needs to be supported by local policies that enable the efficient and equitable use of renewable energy.

However, despite policies such as the Village Electrification Program and Integrated Solar Power Plants, implementation in the 3T (United and Remote) regions remains far from ideal. This is due to limited infrastructure and high logistics costs, as reported by ESDM (2022). Therefore, more integrated policies between the central and regional governments are needed to support sustainable renewable energy development in the 3T (United and Remote) regions

METHODS

This research aims to fill the knowledge gap regarding renewable energy in Maluku Province by:

1) mapping renewable energy potential spatially and sectorally
2) evaluate actual barriers to energy utilization based on official data, and
3) formulate a community-based energy development strategy that is sustainable and appropriate to the island context.

To answer these three objectives, a qualitative descriptive approach was used with the support of secondary quantitative data.This research is descriptive qualitative, aiming to provide an in-depth understanding of the potential, challenges, and strategies for renewable energy development in Maluku. This approach is reinforced by secondary quantitative data to ensure the accuracy of the analysis, based on spatial, statistical, and sectoral data from official sources.

Data collection was conducted through primary sources: Statistics Indonesia (BPS) reports, technical data and reports from PLN, publications and data from the Ministry of Energy and Mineral Resources (ESDM), scientific literature and policy research reports related to renewable energy and regional development. The data collected includes the technical potential of energy (water, solar, wind, geothermal, biomass), electrification ratio, energy mix, energy access level, as well as the geographical and socio-economic challenges of the island region.

The analysis is carried out in stages to answer each objective:

a. Mapping of Renewable Energy Potential

Spatial and sectoral mapping was conducted to identify energy potential in each district/city. The mapping included geographic distribution, resource availability, and the needs of user sectors (households, industry, fisheries, etc.).

b. Evaluation of Actual Obstacles

Barrier analysis is conducted by reviewing data and reports from relevant agencies to identify structural, technical, social, and economic constraints in the utilization of renewable energy, including limitations in infrastructure, financing, and institutional capacity.

c. SWOT-Based Strategy Formulation

The energy development strategy is formulated using a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis approach, emphasizing the principles of sustainability, community participation, and suitability to the Maluku archipelago context. This strategy will consider strengthening local capacity, integration into regional economic development, and long-term energy reliability.

RESULTS AND DISCUSSION

Mapping Renewable Energy Potential in Maluku Spatially and Sectorally

Maluku Province, as an archipelago, has diverse geographic characteristics, climate, and natural resources. The first objective of this study is to map the renewable energy potential in Maluku spatially (location) and sectorally (users).**)**.

Spatial mapping identified the distribution of renewable energy (NRE) potential by administrative region in 11 districts/cities in Maluku Province. The mapping results indicate that 10 of the 11 regions have identified specific NRE potential, as shown in Table 1.

Table 1. Regency, Type of Renewable Energy Potential, Spatial Description of Location

No	Regency/City	Types of Renewable Energy Potential	Spatial Description of Location
1	Hurry	Geothermal (Waeapo-Wapsalit), Solar, Bioenergy	Waeapo, Wapsalit, Central Buru plains
2	South Buru	Geothermal (Waesikat, Batabual)	South of Buru Island
3	Ambon City	Geothermal (Tawiri), Solar	Tawiri, Ambon plains
4	Central Maluku	Geothermal (Tulehu, Oma-Haruku), Microhydro, Bioenergy	Tulehu, Haruku, Tehoru, Wahai plains
5	West Seram	Microhydro, Solar	West Seram river flow and valley
6	East Seram	Bioenergy, Microhydro	Bula District, Werinama District
7	Southeast Maluku	Solar, Wind	Big Kei and Little Kei Islands
8	Aru Islands	Solar, Wind, Bioenergy	The exposed Aru Islands
9	Southwest Maluku	Microhydro, Solar	Wetar and Damar Islands
10	Tanimbar Islands	Solar (indicative), Bioenergy (indicative)	There has been no direct exploration
11	South Seram (in Malteng)	Geothermal (Saparua, Nusalaut, Tehoru)	Lease Island

In the table above, the districts/cities that do not yet have in-depth exploration data such as Tanimbar but have indications of potential based on climate and geography.

Sectoral Mapping: Matching Potential with User Sectors

Sectoral mapping evaluates the match between available energy potential and the needs or dominant user sectors in each region. The main user sectors are classified as: households, MSMEs/small industries, government/public services**like**, and agriculture/fisheries.

Table 2. Energy Types and User Sector Suitability

Types of Energy	Suitable Sectors
Surya	Household (off-grid), education and health facilities, irrigation
Geothermal	City/regional scale power plants
Microhydro	Inland communities, agricultural irrigation
Wind	Remote small islands, fisheries, lighting
Bioenergy	Food processing, household, and agricultural waste-based MSMEs

Table 2In the appropriate user sector, for example, the Tulehu Geothermal Power Plant in Central Maluku Regency is suitable for providing regional-scale electricity (PLTP). This suitability is based on EBTKE (Ministry of Energy and Mineral Resources) data, which states that the Tulehu Geothermal Field has been explored and entered the PLTP development stage with a target capacity of ± 60 MW. Tulehu's location is close to the load center (Ambon City and its surroundings), making it suitable for regional-scale PLTP development.

West Seram and East Seram districts are ideal for microhydro for remote communities and agricultural needs. This example is based on several BAPPEDA studies/interviews as well as EBTKE results and NGO reports such as Hivos and IBEKA, which note the potential for microhydro in West and East Seram, which have hilly contours and small but continuous river

flows, suitable for village-scale power plants (microhydro <100 kW). This suitability will benefit the region (West Seram and East Seram) because these two districts are not yet fully reached by the PLN electricity network, and the agriculture and irrigation sectors are the main activities of the community.

Another suitability, for example, is the potential for solar energy in the Aru Islands, which can be used for cold storage of fish and water pumps. The Aru Islands are a small, isolated archipelago with solar potential of >4.5 kWh/m²/day (data from Surya Indonesia by ESDM). Electricity is essential for cold storage of fishermen's catches, which is their primary activity (results of interviews with community leaders). A study by WWF and PUPUK (2017) shows the potential for implementing PV mini-grids and solar pumps in the fisheries sector.

Mapping of Renewable Energy Potential and User Sectors

The following is the integration of potential and sectoral suitability in the districts/cities of Maluku Province:

Table 3. Districts and Cities with Potential and Dominant User Sectors

Regency / City	**Surya**	**Geothermal**	**Microhydro**	**Wind**	**Bioenergy**	**Dominant User Sector**
Hurry	✔	✔	●	●	✔	Agriculture, household
South Buru	✔	✔	●	●	✔	Household, fisheries
Ambon City	✔	✔	●	●	✔	City electricity, public services
Tual City	✔	●	●	✔	✔	Fisheries, Household and Public Services
Central Maluku	✔	✔	✔	●	✔	Regional grid, irrigation, household
West Seram	✔	●	✔	●	✔	Community, MSMEs, agriculture
East Seram	✔	●	✔	●	✔	Community, household, irrigation
Southeast Maluku	✔	●	●	✔	✔	Fisheries, schools and remote health centers
Aru Islands	✔	●	●	✔	✔	Fisheries, household

Southwest Maluku	✔	●	✔	●	✔	Community, basic services
Tanimbar Islands	✔ (pot.)	●	●	✔ (pot.)	✔ (indicative)	Household, fisheries

Information:

✔ = Potential available

● = Not yet available / not significant / not yet mapped

(pot.) = Indication of potential from secondary data

(ind.) = Bioenergy potential based on agricultural and fisheries sectoral data

With this mapping, spatial and sectoral integration shows that renewable energy development in Maluku must be based on the location, resources, and dominant sectors in each district/city. Renewable energy development strategy in MalukuMaluku needs to consider a community-based decentralized approach as well as a small-medium scale in accordance with the geographical conditions of the archipelago.

Evaluation of Actual Barriers to Renewable Energy Utilization in Maluku

Analysis of Field Findings and Secondary Data

Based on data from BPS, PLN (RUPTL), and the Ministry of Energy and Mineral Resources, and interviews with sample communities, actual barriers to renewable energy utilization in Maluku Province can be classified into four main dimensions: infrastructure, regulation, socio-institutional, and economic. These barriers do not stand alone but are interconnected and reinforce each other, creating a complex ecosystem of obstacles, particularly in remote island regions.

1. **Infrastructure and Connectivity Barriers**
   The electricity system in Maluku remains a dispersed, isolated grid with very limited inter-island connectivity. This hampers the efficient integration of medium- to large-scale renewable energy sources such as the Tulehu geothermal power plant or the potential micro-hydro power plant in West Seram. These findings align with a study by Winarno & Firmansyah (2019), which asserted that eastern Indonesia faces significant challenges in developing energy transmission and distribution systems due to its geographic isolation.
2. **Regulatory and Investment Barriers**
   Regulations that do not affirmatively support renewable energy development in underdeveloped regions are a major obstacle. Lengthy licensing procedures and uncertainty about the selling price of renewable electricity have led to low investor interest. Similarly, a 2021 study from the IESR emphasized that weak legal certainty and unattractive tariff schemes are among the reasons for the stagnation of renewable energy projects in Eastern Indonesia.
3. **Local Social and Institutional Barriers**
   Local communities' capacity to manage renewable energy systems remains low. Many village-scale solar power plant installation programs have stalled due to the lack of permanent management or post-installation technical training. This aligns with IBEKA's (2018) findings that community-based management requires long-term support to maintain system functionality and social acceptance.
4. **Economic Barriers and Market Scale**
   The small economies of scale on remote islands mean that renewable energy potential lacks commercial appeal. The electricity needs of households and micro-enterprises are often insufficient to ensure the economic viability of projects. WWF Indonesia (2017) states that hybrid approaches, such as combining solar power plants (PLTS) and storage for local economic needs (cold storage, irrigation, and small industries), are potential solutions that are still rarely implemented.

ResultsThis study reinforces findings in the literature that the challenges of renewable energy development in the Indonesian archipelago are not merely technical but rather systemic. This is emphasized by the study by Gindroz et al. (2020), which highlights that solutions for renewable energy development in the Maluku region, for example, must be local, decentralized, and supported by collaborative governance between the central and regional governments, and the community. To overcome these obstacles, a multi-level approach is needed: the development of basic infrastructure by the state (off-grid modular system), regulatory simplification, and the establishment of community-based green energy cooperatives. This strategy aligns with the UNDP's Sustainable Energy for All (SEforALL) directive, which recommends renewable energy design tailored to local contexts, particularly in archipelagic countries, and is highly suitable for application in Maluku.

Table 4. Summary of Actual Barriers to Renewable Energy Utilization in Maluku

Obstacle Categories	Description	Affected Areas	Data source
Infrastructure and Connectivity	Limited interconnected electricity networks and accessibility to island areas result in limitations in the distribution and integration of renewable energy systems.	Southwest Maluku, Aru, East Seram	BPS (2023), PLN RUPTL (2021–2030)
Regulation and Investment	Long licensing process, uncertainty regarding renewable energy tariffs, and the absence of a fiscal incentive scheme for investors in underdeveloped areas	Central Maluku (Tulehu), Buru	Ministry of Energy and Mineral Resources, WWF Indonesia (2017)
Local Social and Institutional	Lack of technical and institutional capacity in villages causes operational and maintenance failures in community-based renewable energy systems.	East Seram, West Seram, Central Maluku	IBEKA (2018), field observations
Market Economies and Scale	Small economies of scale and underdeveloped business models make it difficult for renewable energy projects to attract private investors without market guarantees.	Aru Islands, South Buru	WWF and PUPUK (2017), Maluku Bappeda (2022)

Community-Based Renewable Energy Development Strategy

Situation Analysis: SWOT Matrix of Renewable Energy Utilization in Maluku

The utilization of new and renewable energy (NRE) in Maluku Province has complex and unique dynamics due to its geographical characteristics as a scattered archipelago, infrastructure disparities, and potential variability between districts/cities. Therefore, before formulating a community-based NRE development strategy, a situational analysis using a SWOT (Strengths, Weaknesses, Opportunities, Threats) approach is necessary. This analysis combines findings from spatial-sectoral potential mapping, an evaluation of actual obstacles, and a review of the theoretical framework in Chapter II.

Table 5.SWOT Analysis of Renewable Energy Utilization in Maluku Province

Aspect	Description

Strengths	a. There is abundant renewable energy potential in all 11 districts/cities: geothermal (Central Maluku, Buru), microhydro (West and East Seram), solar (Aru Islands, Malra), wind and biomass (MTB, MBD, Tual). b. Availability of initial spatial data and exploration from KESDM and Bappenas. c. There is strong local wisdom and community institutions (customs, churches/mosques, BUMDes) as the basis for community energy participation. d. Some areas are not yet covered by the PLN grid, creating opportunities for the development of locally based off-grid systems.
Weaknesses	a. Limited local human resources in the installation and maintenance of energy systems. b. Inter-island transportation and logistics infrastructure does not yet support the distribution of energy technology. c. Weak coordination between technical agencies at the provincial and district levels. d. Dependence on fossil fuel subsidies remains high and hinders the energy transition.
Opportunities	a. National policies support the energy transition, such as Presidential Decree No. 112 of 2022 and the national energy mix target (RUEN). b. Potential funding from green schemes, international donors, BUMN CSR, and PPP. c. There are opportunities for integrating renewable energy with local leading sectors such as fisheries, agriculture, and tourism. d. Village fund programs can be directed towards financing community energy projects
Threats	a. Project sustainability risks due to lack of training and long-term maintenance systems. b. Global price fluctuations of renewable energy components (solar panels, inverters, batteries). c. Inconsistent changes in national or regional policies towards clean energy. d. The threat of natural disasters and extreme climate events that could damage energy infrastructure. |

This SWOT analysis demonstrates significant strengths and opportunities for renewable energy development in Maluku. However, structural weaknesses and external threats remain major obstacles. Therefore, the strategies formulated must be adaptive to the local context, rely on community participation, and be integrated with the regional economic development agenda based on renewable natural resources.

4.3.2 Strategic Implications of SWOT Results

The SWOT analysis in the previous section provides an overview of the objective conditions for new and renewable energy (NRE) development in Maluku Province. Based on these results, several strategic implications can be formulated as a basis for designing an adaptive, inclusive, and sustainable community-based energy development strategy tailored to the characteristics of the archipelago.

a.Optimizing Local Strengths as the Foundation of Strategy

The existence of renewable energy potential in all 11 districts/cities represents a structural strength not possessed by many other regions. Strategies need to focus on this.*regional clustering based on main potential*: geothermal (Central Maluku, Buru), microhydro (Seram), solar (Aru, Malra), wind (MBD), and biomass (MTB). This allows each region to develop local energy specializations based on its dominant resources.

In addition, strengthening community participation through traditional and religious institutions and BUMDes/Bumo/Bumneg can be a key element in maintaining project

sustainability. The successful experience of a community energy project in NTT (UNDP, 2022) demonstrates that a local institution-based approach can enhance a sense of ownership, encouraging long-term operation and maintenance.

b. Addressing Weaknesses through Capacity and Infrastructure Improvement

Limited human resources and weak inter-island logistics infrastructure require an integrated, cross-sectoral approach. The strategy of training local technicians through a collaborative scheme withUnpatti's engineering school, polytechnics, energy vocational schools, or local NGOs need to be developed. Meanwhile, strengthening the energy supply chain and distribution infrastructure must be integrated into provincial and district master plans.

Inter-agency coordination is also a crucial weakness. Regional governments need to establish*cross-agency EBT coordination team*which is directly connected to the planning sector (Bappeda), energy (ESDM Service), industry.

c. Converting Opportunities into Measurable Policies

Opportunities from national policy, green financing, and the integration of renewable energy with local sectors such as fisheries and tourism must be developed into concrete strategies. For example, the development of off-grid solar power plants on the coasts of Aru and Tual could be directed to support the development of renewable energy.*cold storage*and solar powered fish dryer.

Use of village fundsThe state budget as a stimulus for energy projects should also be included in the village planning guidelines (RPJMDes). This could emulate best practices from other regions, such as Sumba (IEA, 2023), which successfully used the Village Budget (APBDes) to build micro-hydro power plants through a participatory scheme.

d. Mitigation of Threats through Resilient Policies and Risk Projections

The threat of natural disasters and policy inconsistencies can be anticipated with resilient strategies. Every energy project needs to have*disaster contingency plan*, including mapping the risks of earthquakes, floods, and strong winds (particularly in Seram and Ambon). Community-based energy systems should be designed to be modular and easily repairable, with local spare parts available.

Global price fluctuations of energy components also drive the need for*developing a local ecosystem for the production and assembly of simple components*, such as panel mounts, support structures, or recycled used batteries for community energy banks.

Integrative Strategy for Utilization of Renewable Energy and Natural Resources in Maluku

An integrative approach is intended to address the challenges of policy fragmentation, limited infrastructure, and minimal local community involvement in renewable energy projects. In this context, energy utilization strategies cannot stand alone but must be linked to natural resource conservation, community capacity building, and the development of adequate support systems through multi-stakeholder collaboration.

This strategy is based on six main aspects that complement each other: utilization of renewable energy, conservation of natural resources, community empowermentlocal energy, infrastructure and technology strengthening, collaboration between stakeholders, and education and research. Each aspect has key objectives and activities that support the achievement of inclusive and sustainable energy development in Maluku.

Table 6. Integrative Strategy for Utilization of Renewable Energy and Natural Resources of Maluku

Aspect	Objective	Main Activities	Expected Output

1. Utilization of Renewable Energy	Reducing dependence on fossil fuels	-Construction of solar, wind and hydro power plants.	- Provision of sustainable renewable energy
2. Conservation of Natural Resources	Conservation of natural resources for sustainability	- Sustainable management of forests, coasts and seas	- Ecosystem is maintained, biodiversity increases
3. Local Community Empowerment	Improving the capacity of local communities	-Renewable energy skills training, entrepreneurship	-Increasing community capacity and income
4. Infrastructure and Technology	Building effective energy infrastructure	-Development of renewable energy-based electricity networks	- Wider and more efficient energy access
5. Stakeholder Collaboration	Increasing collaboration between government, private sector and community	- Partnerships with the private sector for renewable energy investments	- Mutually beneficial and sustainable cooperation
6. Education and Research	Increasing energy-related research and innovation	-Local research related to renewable energy potential in Maluku	-New technology that can be applied in Maluku

This approach is based on the framework**sustainable development**(WCED, 1987) which emphasizes the importance of balancing economic, social, and environmental aspects in resource management. The emphasis on local community participation is also consistent with the concept of community-based renewable energy (Walker & Devine-Wright, 2008), which emphasizes that the success of energy projects is determined not only by technological suitability, but also by the level of social acceptance and involvement.

Several previous studies, such as those conducted by**Anindita et al. (2020)**and Simangunsong et al. (2021), show that renewable energy projects in Eastern Indonesia tend to fail to achieve long-term sustainability due to weak integration with community socio-economic needs and a lack of local capacity building. This research seeks to address this by formulating a strategy that combines community training, ecosystem conservation, and institutional strengthening as a mutually reinforcing unit.

Furthermore, multi-stakeholder collaboration is crucial, as emphasized by González & Vázquez (2017) in their study of renewable energy in peripheral European regions. They emphasized that without synergy between local governments, communities, academia, and the private sector, energy projects often fail to meet sustainability targets.

By integrating these principles, the strategy developed in this study not only addresses the technical needs of energy provision but also strengthens the social and ecological dimensions of regional development. This is an important contribution to the literature on energy transition in island and underdeveloped regions.(3 T).

CONCLUSION

This research provides empirical and conceptual contributions to renewable energy utilization in Maluku Province, through an integrative approach that combines spatial, sectoral, social, and institutional dimensions. Three main conclusions can be formulated as follows:

Mapping of Renewable Energy Potential in Maluku shows that almost all regencies/cities in Maluku have significant potential for renewable energy development, particularly solar, biomass,

and microhydro power. Regions such as Central Maluku, West Seram, and Buru have a relatively comprehensive combination of potential, while the Aru Islands, Southeast Maluku, and the Tanimbar Islands show dominant solar and biomass potential. Sectoral mapping also shows that the agriculture, fisheries, and household sectors are the main users of this clean energy potential, depending on regional characteristics.

An evaluation of actual barriers to renewable energy utilization revealed a number of structural and technical challenges, including limited basic infrastructure, a lack of consistent policy support, limited local human resource capacity, and suboptimal collaboration between the government, the private sector, and communities. The uneven electrification ratio and high dependence on fossil fuels, particularly in the 3T (frontier and remote) regions, indicate the need for more targeted and data-driven interventions.

The community-based and sustainable renewable energy development strategy formulated in this study emphasizes the importance of a cross-sectoral approach that integrates renewable energy-based power plant development with natural resource conservation, local community empowerment, adaptive energy infrastructure development, and strengthening local research and innovation. This approach is contextual and sensitive to the geographical conditions of the archipelago, while simultaneously enabling sustainable local economic strengthening.

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