Analysis of renewable energy implementation in remote areas of Indonesia: study review

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Abstract. Indonesia is the largest archipelago with 17,503 islands where 6000 populated islands and most of the islands are remote areas. This condition causes limited access to energy supplies such as electricity and fuel. Meanwhile, Indonesia has a variety of natural resources including renewable energy sources that have not been applied optimally. It is expected that the utilization of local renewable energy sources can guarantee the availability of electricity in remote areas so that it can support national development and security. To optimize renewable energy in remote areas, the government made Minister of Energy and Mineral Resources Regulation 38/2016 concerning the acceleration of electrification in undeveloped, remote, bordered, and small-populated rural areas through the implementation of small scale electricity supply businesses. To analyses the regulation and other supports, the SWOT method is used to know the impact of the regulation in the remote area. Coordination is needed between the Central Government and the Regional Governments. Also, control and evaluation of existing policies are required so that people in remote areas can get access to electricity optimally.

1. Introduction

Indonesia is an archipelagic nation consisting of 17,503 islands, with 8 large islands, and around 6000 populated islands [1]. Indonesia is bounded by 2 oceans namely the Indian Ocean and the Pacific Ocean and is bordered by several countries namely Malaysia, Singapore, Brunei Darussalam, the Philippines, and Australia [2]. This very complex condition causes Indonesia to have outermost and backward regions that are difficult to get access to energy or other utilities.

Indonesia has potential energy resources, both fossil fuels such as oil, gas, and coal, as well as renewable energy resources such as solar, wind, hydro, geothermal, biomass, and oceans. Renewable Energy Resources that are scattered in various regions in Indonesia have not been used optimally. Based on data from the Ministry of Energy and Mineral Resources, it was noted that the total potential of renewable energy could reach an equivalent of 442 GW for electricity generation, and 200 thousand bpd of the type of biofuel and biogas for various sectors spread across various regions [3]. Considering the potential of this Renewable Energy Resource spread in various regions, it can be expected that remote areas that have not been electrified can obtain electricity by utilizing local renewable energy to increase regional energy independence and national energy security.

Over the past five years, Indonesia has experienced increasing electrification ratios to reach 98.89% in 2019. The increase in electrification ratios is based on how many regions are electrified. Some regions, such as NTT, Maluku, Papua, Central Kalimantan, and Southeast Sulawesi, still have an electrification ratio of less than 95% [4]. The government always strives to raise the electrification ratio
in Indonesia and reach the target of 100% by 2020. Therefore, to achieve the electrification ratio target, remote areas need to be optimally pursued to obtain electricity supply.

Based on Presidential Regulation (Perpres) 131/2015, it is explained that an area that is said to be left behind or remote can be determined from the criteria of the community's economy, human resources, facilities and infrastructure, regional financial capacity, accessibility, and regional characteristics. According to the data in the regulation, there are 122 districts which are known as disadvantaged areas in 2015-2019 [5]. Also, the large number of districts including disadvantaged and remote areas have the possibility of not yet fulfilling access to electricity due to inadequate infrastructure to get to the region. Therefore, the implementation of renewable energy can help meet the electricity supply in disadvantaged and remote areas so that the activities of residents in the region can run effectively and efficiently.

The Exertion of renewable energy implementation needs to be supported by various parties, especially the local government which is responsible for improving the welfare of its citizens through the provision of electricity supply in remote areas. These efforts have been regulated in the Minister of Energy and Mineral Resources Regulation (Permen ESDM) 38/2016 concerning the acceleration of electrification in the undeveloped, remote, border, and populated small islands through the implementation of small scale electricity supply businesses [6]. The regulation can not only improve accessibility, facilities, and infrastructure in the area but also can support the development of the people's economy and regional finance.

However, several obstacles must be faced by implementing renewable energy in remote areas. One obstacle to be concerned about is the limited equipment causing the development of renewable energy in remote areas is not running optimally [7]. Besides, the low financial capacity that socio-economy of the community and the limited human resources will be difficult if there is damage to the power plant [8]. Also, the electricity supply generated from power plant diesel has not been able to meet the needs of the community because of the limited access to fuels in remote areas [9]. Therefore, in this paper, the analysis of renewable energy development policies and its implication will be carried out in remote areas to increase renewable energy use for meeting electricity needs and enhancing Energy Security in Indonesia. Some strategies are needed to optimize the implementation of renewable energy in rural areas based on government regulations.

2. Methodology
This research uses a descriptive qualitative method by conducting a SWOT analysis of renewable energy implementation in remote areas. In energy management, the SWOT framework is usually used to analyze the energy situation of an area or system from existing internal and external factors[10][11]. The SWOT framework can also be used to analyze the application of policies to support renewable energy implementation that can run optimally or not, and analyze the challenges and obstacles faced by these policies. In this study, the use of SWOT was observed in terms of renewable energy potential, regional conditions, economy, infrastructure, policies, and support from the government and related institutions.

Besides, a literature study was also conducted based on several government policies and plans that had been issued related to the development of renewable energy in remote areas. Some research related to the implementation of renewable energy in remote areas also becomes a further approach associated with the government policy and plans which are carried out as an evaluation of renewable energy management that has been utilized in remote areas.

3. Result and Discuss
3.1 Regulations and Programs of Renewable Energy Development
The development of energy in Indonesia is strongly supported by the government with the issuance of Law (UU) 30/2007 concerning Energy. The energy law discusses the fulfillment of energy supply managed by the central and regional government through relevant ministries or institutions to improve the community welfare including in remote areas to provide the security and independence of energy equally and increasing economic growth in all regions sustainably in Indonesia. To reinforce the energy
Electricity supply is one type of energy that is needed by everyone in various regions, especially remote areas. To meet the national electricity supply, the government issued Law (UU) 30/2009 concerning electricity. In this policy, the government is entrusted with ensuring electricity access, especially for disfavoured people, underdeveloped electricity, and people in rural areas (remote and border). Also, the policy has discussed the provision of funds for electricity construction in remote areas by prioritizing renewable energy sources as primary energy and still maintaining its economic growth [13].

To support the implementation of the energy law, the government issued a derivative policy by government regulation (PP) 79/2014 concerning the National Energy Policy (KEN). The regulation encourages renewable energy utilization by setting energy mix targets. The energy diversification is aimed to reduce the use of fossil fuels because its resources are running low and decreasing fuel import such as oil, also reduce the amount of CO₂ emissions effected from non-renewable energy. In this policy, the government provides an energy supply board where renewable energy is targeted to be achieved by 23% in 2025 and 31% in 2050. While in terms of supplying power plants, the government is targeting the installation of 115 GW of power plants with electricity consumption of 2500 KWh/cap in 2025 and increased in 2050 to 430 GW with electricity consumption of 7000 KWh/cap with electrification ratio reaching 100% in 2020 [14]. Also, the policy prioritizes the energy provision for people who do not have access to electricity and other energy in various sectors. Generally, most remote areas do not yet have access to electricity because it is hampered by locations that are sometimes difficult to access. Therefore, the existence of PP 79/2014 strongly supports the supply of energy, especially electricity in remote areas.

To realize this policy, the government issued Presidential Regulation (Perpres) 22/2017 regarding the National Energy General Plan (RUEN). RUEN is one of the government’s plans as a guideline in managing energy nationally to create energy security and independence to support sustainable national development [15]. Besides, RUEN is also a reference in the preparation of the Regional Energy General Plan (RUED) which must be made by each province and district in Indonesia. The RUEN discusses in detail the making of energy supply-demand projections by 2025 regarding the conditions in 2015 from various provinces in Indonesia. The RUEN also makes various strategies and programs that refer to the KEN especially for programs to fulfill electricity access in areas that have not been electrified to increase the national electrification ratio.

In 2018, the realization of renewable energy development is still around 8.55% where the total number of power plants has a total electricity supply of 62.6 GW. Based on the RUEN target, it is expected that the use of fossil energy will decrease as shown in the figure above and the development of renewable energy will increase and achieve electricity access in remote areas that can be fulfilled in all regions in Indonesia [16].

![Figure 1. Realization and Targets of National Energy Mix](image-url)
In addition to the RUEN, the government also issued Minister of Energy and Mineral Resources (ESDM) Decree No. 143K / 20 / MEM / 2019 concerning the National Electricity General Plan (RUKN) concerning the KEN target. RUKN discusses a more fulfilling electricity supply and making projections for an increase in electricity supply by up to 20 years. In the RUKN, the fulfillment of electricity specifically for the 3T areas (Frontier, Outermost, and Disadvantaged) is also discussed by projecting an increase in the cumulative number of NRE power plants so that the electrification ratio in the 3T region can reach 100%. It is targeted that by 2020 the total NRE generation for remote areas can reach 394 MW and increase to 1070 MW by 2038 [17]. Projections of increasing electricity supply in remote areas can be seen in the following figure.

![Projected Power Plant for Remote Areas 2020-2038](image)

**Figure 2.** Projected Power Plant for Remote Areas 2020-2038 [17]

To encourage the RUKN target, the government also issued Minister of Energy and Mineral Resources Decree 39K/20/MEM/2019 regarding the Electricity Supply Business Plan (RUPTL) of PT Perusahaan Listrik Negara (PLN). In this case, the Ministry of Energy and Mineral Resources specifically regulates the business plan that must be carried out by PT PLN as a State-Owned Enterprise (BUMN) as well as a national electricity manager to meet electricity supply in all regions in Indonesia. In the RUPTL, the government made a program to accelerate the development of electricity infrastructure including the construction of a 35,000 MW power plant and circuits 46,000 km electricity transmission network that must be carried out by PT PLN. The target also includes efforts to develop renewable energy and fulfill electricity access in remote areas both in terms of electricity generation and transmission networks. Meeting the target is projected for 10 years [18]. Also, in meeting electricity supply-demand, the RUPTL will be renewed annually so that the target is expected to be achieved.

To realize these programs, the government provides an opportunity for the Independent Power Producer (IPP) managers to build renewable energy power plants, especially in remote areas so that PT PLN can be assisted in meeting the 35,000 MW capacity target. In this case, the government regulates the system of buying and selling between PT PLN and IPP so that an electricity sale price from the NRE PLT must be agreed upon by PT PLN. The regulation discusses the NRE PLT special Power Purchase Agreement (PPA) system using the Build, Own, and Operate (BOO) scheme. In this regulation, the purchase of electricity by PT PLN can be arranged under an agreement with the power plant developer (IPP). The regulation is used to attract investors and IPP to build power plants, especially in remote areas.
Furthermore, IPP can be played with regional owned enterprises (BUMD) or the local private industry so that it can help local governments improve access to electricity to communities in remote areas. In this case, the government specifically issued ESDM Regulation 38/2016 on the acceleration of electrification in the rural undeveloped, remote, border, and small island populations through the implementation of electricity supply businesses for a small scale. The regulation regulates the provisions regarding electricity supply business with a system capacity of up to 50 MW. Through these regulations, the government provides opportunities for regional governments, business entities (BUMN / BUMD), cooperatives, and related industries to develop renewable energy as power plants in their regions to increase community productivity and economic growth in the region.

In addition to general regulations, other policies are also issued to manage several types of renewable energy power plants either commercially or privately. The management of renewable energy power plants for remote areas is non-commercial because the use of fund sources comes from the National Budget (APBN) or DAK (Special Allocation Fund). Besides, the electricity infrastructure system used is also off-grid in nature. Some power plants that are generally used for remote areas are solar, hydro, wind, biomass, etc. Policies governing NRE power generation infrastructure for remote areas include PerPres 47/2017 on LTSHE, ESDM Ministerial Regulation 5/2018 on Procedures for providing LTSHE for people who have not yet received electricity, and ESDM Ministerial Regulation 12/2018 regarding the implementation of physical activities using NRE (mechanism based on Local Government proposal).

3.2. SWOT Analysis of Renewable Energy Implementation in Remote Areas
Renewable energy development in remote areas has internal and external factors that can support and hinder their implementation. This point will discuss factors related to strengths, weaknesses, hammers, and challenges that affect the development of renewable energy in remote areas.

3.2.1. Strength
Indonesia has abundant natural resources including renewable energy resources in various regions. It was noted that the total renewable energy resources could reach 442 GW consisting of geothermal (17.5 GW), water (75 GW), bioenergy (200 thousand bpd), wind (60.6 GW), Solar 207.8 GW) and Sea (17.9 GW). This renewable energy resource can reduce CO₂ emissions and increase local energy use including remote areas. However, the use of renewable energy resources is still 2.1% (9.4 GW) of the total potentials [17].

Also, the development of renewable energy is strongly supported by the government with the issuance of several related policies such as the national energy mix program, where the development of renewable energy becomes the top priority to support energy security and independence in various regions including remote areas. The policy related to the development of renewable energy for electricity is also explained that both central and regional governments have an important role in meeting the needs of their communities such as access to electricity which is the right of Indonesian citizens.

The renewable energy that always is used as the government program is solar energy. The potential for solar energy in Indonesia is very large with average daily insolation of 4.5 - 4.8 KWh / m² / day [19]. The use of solar energy for electricity generation has been done for a long time, but its application is still limited to small power systems or better known as solar home systems (SHS). This SHS is usually a government aid provided on a subsidized basis and rural communities use it as a means of lighting at night to replace kerosene lamps. In this context, it can be seen that the approach used is top-down so that the development of SHS has been highly dependent on government programs [20].

Other supports were also obtained from various national or international institutions or industries to develop renewable energy in remote areas. Generally, a company has a social responsibility to various parties such as CSR (Corporate Social Responsibility) funds for various social interests. Generally, CSR funds are used for education, community economic productivity, and the environment. For example, Pertamina provides CSR funding for research around the development of renewable energy to support national energy independence and security. Furthermore, some international organizations support renewable energy applications to reduce global warming such as The International Renewable Energy
Agency (IRENA), National Renewable Energy Laboratory (NREL), International Energy Agency (IEA), etc [21][22][23].

3.2.2. Weakness
Most renewable energy resources have an intermittent characteristic, where electricity supply generated from NRE power plants does not always produce electricity optimally. The influence of climate and weather is a factor that is sufficient to affect the number of electricity supplies processed in the NRE power plant. Indonesia has a dry and rainy season. If the area uses solar power plants, then during the rainy season there will be a reduction in the amount of electricity capacity generated by PLTS due to the low intensity of sunlight [24]. Also, if a hydroelectric power plant is used, then during the dry season it will hamper the fulfillment of the electricity needs of the surrounding community due to the lack of electricity capacity generated by micro hydropower plant (PLTMH)[25–27].

Generally, to anticipate the fulfillment of electricity, a hybrid power generation system is implemented. The application of renewable energy power plants can be linked with a grid-connected system is currently being further developed to increase power and system reliability [28–30]. Usually, solar power plants can be combined with wind power plants or with a PLN grid system [31]. This can be applied in remote areas so that people there can get electricity for 24 hours.

The capacity of power plants and the lifetime of renewable energy are also limited. The government program regarding Energy Saving Solar Lights (LTSHE) can provide lighting to every resident's house in remote areas. However, the system has a low capacity and can generally only be used as lighting. Besides, the lifetime of the solar panels can only last up to 3 years. The government program regarding Energy Saving Solar Lights (LTSHE) can provide lighting to every resident's house in remote areas. However, the system has a low capacity and can generally only be used as lighting. Also, the lifetime of the solar panels can only last up to 3 years.

Also, the high cost of building a power plant is due to the high price of generators and difficult access to which electricity prices in remote areas are more expensive. Generally, the equipment used to build a power plant is mostly obtained from abroad. It also affects the maintenance costs that must be incurred. on the other hand, the government still provides subsidies on fuel. Then, it can hamper the development of renewable energy in Indonesia. This happens because people prefer to buy electricity at a cheap price even though it is diesel.

3.2.3. Opportunity
Access to electricity from renewable energy can increase socio-economic productivity and education so that people in remote areas can improve their welfare because it becomes easier to carry out an activity, especially at night. If NRE is developed by local cooperation or BUMD, the profits will return to the community. Besides, the development of renewable energy has the support of various parties so that it can improve other infrastructure such as access to transportation to supporting progress in the region.

In general, remote areas also have abundant natural potential, for example, oil palm plantations. The community can contribute to making biofuel from crude palm oil as an alternative fuel and can be used to generate electricity. The community can benefit from palm oil waste and reuse it as electricity for the manufacturing process or housing in the vicinity [32]. The potential investment from various sectors (tourism, manufacturing, etc.) because of electricity access that has been available in the region can provide employment opportunities for the surrounding community. And finally, efforts to develop renewable energy in remote areas also have the potential to increase national energy security and independence. In this case, the government does not need to worry about depleting fossil fuel dependency, because NRE can produce electricity independently and reduce CO₂ emissions [33].

3.2.4. Threats
In terms of threats, the development of renewable energy can experience difficulties due to limited costs and human resources for the maintenance of power plants. Generally, regional governments in remote areas have limited APBD funding sources due to slow economic growth in the area. Regional budget
funds can also be used for other more urgent purposes so it will be difficult if the NRE power plant is damaged due to limited funds and equipment. The existing human resources are also still limited due to the low mastery of technology so that it can be a threat to non-functioning NRE power plants because they are not maintained and damaged.

Another threat of developing NRE in remote areas is the limited capacity of regional resources (HR, financial, and technology). Because access is quite difficult to make efforts to develop the region, efforts to improve human resources and the economy are very slow. Especially for technology requires good access to get to remote areas.

In 2018, there were 507 villages plus 1246 village splits that did not have access to electricity [17]. This can occur due to the difficulty of traveling to the village due to limited access to transportation that must be taken. Generally, power plants that are grants from the government through relevant ministries or institutions only provide facilities in the form of power plant construction. Meanwhile, in terms of maintenance and operation, it is left to the Regional Government or the local community. If the local government does not have enough funds for maintenance and repairs, the power plant will be stalled and left just like that so that people will not get access to electricity again. Government subsidies related to energy are also still not on target because generally subsidies are used for people in urban areas who have easy access to various needs, not people in rural and remote areas who still do not have access to electricity at all.

In this case, the threat can occur due to inappropriate coordination from each stakeholder such as the central government, regional governments, ministries, and related institutions. This has led to misunderstanding and blaming each other on technical issues that cannot be overcome so that the NRE power plant cannot be operated permanently. The management system of NRE power generation also tends to be low due to various limitations and capabilities.

Table 1. SWOT analysis results of renewable energy implication in remote areas

| Strength | Weakness |
|----------|----------|
| • The potential for renewable energy resources in remote areas is very abundant (solar, biomass, wind, water, etc.). | • The ability to supply renewable energy electricity is intermittent. |
| • There is support for the development of renewable energy from the government. | • Limited capacity and the lifetime of the renewable energy power plant. |
| • There is support from national and international institutions for the development of renewable energy | • Capital expenditure is quite expensive. |

| Opportunity | Threats |
|-------------|--------|
| • Increase economic productivity and welfare of people in remote areas. | • Limited capabilities and equipment are available to carry out maintenance of renewable energy power plants. |
| • Support from the wider community in the use of renewable energy. | • Having potential use of renewable energy development funds for other purposes. |
| • Access to other infrastructure can be increased by the supply of energy to remote areas. | • The mastery of renewable energy utilization technology is still low. |
| • Attract investment to support economic development in remote areas. | |
| • Increase Energy Security and Independence by reducing dependence on fossil energy. | |
3.3. Strategies and Realization of Renewable Energy Development in Remote Areas

The abundant renewable energy sources throughout Indonesia, including remote areas, are a great potential force to be developed. The existence of a source of electricity in remote areas is expected to be able to improve the welfare of the people and the economy in that region. To improve the welfare of society fairly and equitably, several government policies and programs have been made to support electrification efforts in remote areas. It is necessary to have good coordination from each stakeholder in fulfilling access to electricity and developing NRE in remote areas. The role of local governments in supporting access to electricity is very important because the management of NRE power plants is likely to be left to the surrounding community. Coordination with the Ministry of Energy and Mineral Resources and PT PLN is also important so that access to electricity can be distributed to community houses and training related to NRE management from the surrounding community will be very helpful in maintenance and maintenance. NRE power plants so that people can enjoy access to sustainable electricity.

Apart from inter-regional government management, the Ministry of Energy and Mineral Resources and PT PLN, it is also necessary to coordinate with other ministries or agencies such as the Ministry of Public Works and Public Housing or the Ministry of Transportation in supporting road access or transportation to remote areas. The community needs to be allowed to get access to electricity and also access to transportation that can connect to each region. Access to electricity and roads can improve the community’s economy so that it is more prosperous.

In terms of the funds that must be spent on developing NRE in remote areas, it is quite expensive, so the use of national renewable energy sources is still very low (2.1%). Moreover, the economic capacity of the people in the region is still very low. In this case, the government needs to provide special allocation funds that are more targeted with strict supervision and evaluation so that the management of these funds is not used for other purposes. These funds can be given to local governments and in collaboration with PT PLN so that NRE development can be carried out optimally. Apart from that, the government also needs to attract the attention of investors or IPPs to be able to build renewable energy power plants in remote areas by providing returns that are also beneficial for investors. In general, remote areas have beautiful scenery and a wealth of unspoiled natural resources that can attract investors to set up industries there and have the potential to provide employment opportunities for the surrounding community [34].

Besides, in terms of technology used for renewable energy development, some still use imported goods. This is necessary to increase the percentage of the Domestic Component Level (TKDN) in making NRE generators. The central government can coordinate with the ministry of industry or related SOEs to support the development of TKDN so that the use of funds for purchasing components in power plants is cheaper but still of high quality.

The efforts to utilize natural resources in remote areas can be used as alternative energy. The management is easier for the local community to understand because utilizing surrounding natural resources can improve the process of building power plants in remote areas. The regional owned enterprises or entrepreneurs in the surrounding area can take advantage of these opportunities to generate profits from managing energy sources needed by the community [35].

4. Conclusion

The implementation of renewable energy in remote areas, especially electricity, has basically been carried out by both the government and business entities or related institutions. Various policies and regulations have been made to increase electricity access in remote areas so that the national electrification ratio is expected to increase to reach 100% by 2020. Various policies and programs are made by the government to provide electricity supply and improve electricity infrastructure in remote areas for the achievement of prosperity and prosperity. Population in the region. However, there is a need for SWOT analysis related to some of the problems that occur in the management of NRE power plants. Basically, this problem can be overcome by coordinating, monitoring, and evaluating various related parties, especially the central and regional governments so that there are no mistakes in managing
it. Increasing private and non-profit investment as well as public funds is also a good opportunity for the community to improve the socio-economy of people in remote areas.

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