Development of Electrification Planning Method with Renewable Energy Technology: Case Study in Central Sulawesi

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Abstract. The equal distribution of electricity facilities is encouraged by Indonesian government, one of which is through the creation of an electrification roadmap for unelectrified villages. This roadmap must align with government's commitment to Net Zero Emission target, therefore Renewable Energy (RE) power plant is the only option for electrifying those villages. PT PLN (Persero), as the state-owned company that responsible for electrification, does not yet have a standard method for selecting RE technology. Central Sulawesi, with its diverse geography from mountains to islands, presents its own challenges for interconnection with South and West Sulawesi or North Sulawesi and Gorontalo electrical systems. A case study in unelectrified villages of Central Sulawesi was conducted to determine the dimensions and indicators for selecting RE technology and developing an electrification planning method.

Keywords: *case study, electrification, planning method, renewable energy, Sulawesi electrical system*

1 Introduction

Central Sulawesi is a region in Indonesia that consists of 13 regencies/cities and 3,195 villages [1]. There are 1.821 villages that have received electricity from PT PLN (Persero), whereas 516 villages use non-PLN electricity, and 818 villages are unelectrified. The region's diverse geography, from mountains to islands, poses challenges for interconnection with other Sulawesi electrical systems. The government's efforts to equalize electricity include funding provisions by ministers and governors, in line with Indonesian Government Regulation No. 25 of 2021. PT PLN (Persero) and the Ministry of Energy and Mineral Resources have created an electrification roadmap for unelectrified villages, targeting a 100% electrification ratio by 2025 [10].

Achieving electrification targets must also consider other factors, such as the selection of power plant types and their environmental impact. Global warming has long been discussed due to its effects on the environment and human life. Rising temperatures, weather anomalies, floods, droughts, and declining air quality impact health and economic capabilities, and are predicted to reduce the

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human population. Energy transition of power plants is one of attempts to prevent greater impacts of global warming, from fossil fuels like coal and oil to renewable energy sources such as water, wind, geothermal, and solar. The step taken by Indonesia to support energy transition is by committing to Net Zero Emission (NZE) target by 2060 and set a target of 23% renewable energy by 2025 [13].

There are 5 dimensions, 14 variables, and 39 indicators in the assessment of electrification in remote areas [4]. These dimensions are sustainable development which are technical, economic, social, environmental, and institutional. Juanpera et al. [5] focused on 4 dimensions: economic, technical, socio-institutional, and environmental, using a total of 12 indicators for all dimensions. Khalid et al. [7] used social, economic, technological, and environmental dimensions but focused on the social aspect, namely customer electricity usage. Zebra et al. [15] used social, economic, technical, and institutional dimensions with a total of 13 indicators for all dimensions. Not all dimensions are applied in studies on electrification planning in remote areas. Studies by Heidari et al. [2], and Hoseinzadeh et al. [3] focused on technical and economic dimensions. Power plant selection based on technical and economic dimensions is done by calculating load demand, investment, operation, and maintenance costs. Data from each dimension is then processed using software to obtain the most technically and economically suitable renewable energy power plant. Juanpera et al. [6] conducted a study on the long-term success of electrification in remote areas and found that more than technical and economic dimensions are needed to support the sustainability of electrification in remote areas.

Currently, PT PLN (Persero) does not have a standard method for selecting the most suitable renewable energy technology for unelectrified and unconnected areas. The dimensions used for electrification planning at PT PLN (Persero) still focus on technical and economic aspects.

2 Literature Review

2.1 Renewable Energy Power Plants

Renewable energy power plants utilize sustainable natural resources, such as sun, which continuously shines and is used as a source for solar power plants (PLTS) [9]. In addition to solar energy, wind, water, geothermal, bioenergy, and ocean waves are also sources of renewable energy. Several renewable energy technologies that implemented by PT PLN (Persero) as of 2023 are Solar Power Plants (PLTS/Solar PV), Biomass Power Plants (PLTBm), Geothermal Power Plants (PLTP), Wind Power Plants (PLTB), Hydroelectric Power Plants (PLTA), Mini-Hydro Power Plants (PLTM) and Micro-Hydro Power Plants (PLTMH).

Solar PV uses solar radiation to generate electricity. The main requirement for Solar PV is that solar panels receive direct sunlight, where even shadows can hinder the power generation [12]. Since sunlight is limited to daytime, batteries are created to store the energy generated by Solar PV to meet electricity demands at night. Batteries can also be used for other renewable energy power plants beside Solar PV.

2.2 Electricity System

PT PLN (Persero) Board of Directors' Decision number 217-1.K/DIR/2005 explains that PT PLN (Persero)'s electricity distribution system is divided into two parts: transmission and distribution. Transmission system involves delivering electricity from power plants to distribution substations, while distribution system involves delivering electricity from substations to customers. Additionally, power plants can distribute electricity directly through distribution networks without going through transmission is also categorized as distribution system. This electricity distribution system is often referred as grid. According to Ruin & Siden [12], isolated or independent systems are a good option to provide better and even cheaper electricity to areas that far from national grid.

2.3 Existing Electrification Planning Method

Electrification of remote areas is nothing new for PT PLN (Persero). The method used by PT PLN (Persero) for electrification planning involves three different units: Head Office, Unit Induk (Main Office), and Engineering. Currently Standard Operating Procedure (SOP) regarding the flow, criteria, and feasibility assessment for selecting power plants for electrification has not been made, and electrification planning reports focus primarily on financial feasibility.

2.4 Previous Study

Ilskog [4] developed indicators to assess electrification in remote areas. This development was made alongside the process of selecting electrification methods by decision-makers. Often, decision-makers are not aware of field conditions, so an approach involving various disciplines is needed to detect unavoidable conditions early and provide a clearer picture of the field. There are five dimensions, 14 key variables, and 39 indicators used as benchmarks for sustainability evaluation.

Kumar et al. [8] developed views on various MCDM (Multi-Criteria Decision Making) techniques applied to the selection of renewable energy technologies (RE) and future prospects in the field of RE using five dimensions and 31 criteria. Juanpera et al. [5] developed a multi-criteria procedure to compare the design of on-grid or isolated power plants and technology differences based on 12 criteria

and four dimensions. Rocha et al. [11] described the process and results of weighting and classifying four criteria and 16 sub-criteria for planning RE in the Pacific region of Colombia. Zebra et al. [15] conducted research combining system simulations with 12 indicators from four dimensions. Hoseinzadeh et al. [3] use four dimensions and seven indicators to compare the flexibility of Solar PV and Wind energy systems and the planning scenarios for the city of "Onda," Spain. Heidari et al. [2] added a meteorological dimension and used five indicators to find the optimal hybrid diesel and RE configuration to meet the electricity load needs of remote areas.

Based on previous research, there are six dimensions technical, economic, social, environmental, organizational/institutional, and geographical considered in selecting RE for electrification. Case studies are needed to determine the most appropriate power plants for each region.

3 Material and Method

This research was conducted using a case study method based on Yin's [14] case study research methodology, with the following stages:

1. Generation of Research Plan: Identifying problems, formulating problems, identifying research objectives and benefits, and conducting a literature review.

2. Generation of Research Design: Determining the unit of analysis, developing criteria for interpreting findings, and selecting the case study.

3. Preparation for Research Implementation: Creating a case study protocol.

4. Case Study Implementation: Conducting the case study according to the protocol, documenting the case study implementation, creating a case study database, and compiling a chain of evidence.

5. Case Study Analysis: Determining appropriate analysis techniques and developing conclusions.

6. Case Study Report: Identifying the case study audience and the type of report to create a report according to procedures.

4 Initial Results and Discussion

Initial results of the research is development of an electrification planning method using renewable energy technology can be conducted using six dimensions. The

candidate of RE power plants are those whose technology is already owned by PT PLN (Persero).

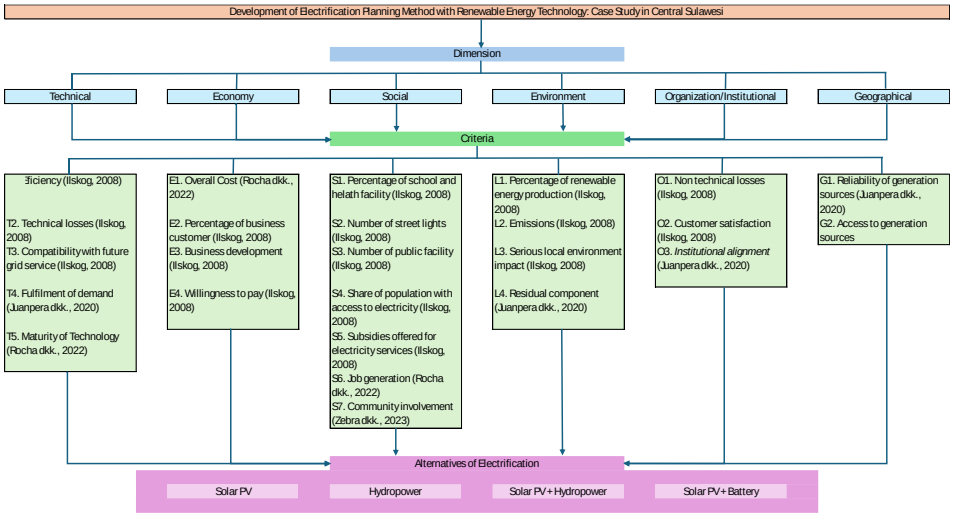

Figure 1 Initial result of study

5 Conclusion

Electricity is a crucial for societal development, therefore making electrification in remote areas are necessary. The diverse conditions of remote areas require different electrification approaches. PT PLN (Persero) electrification planning method for remote areas needs further development hence despite varying regional conditions, there is a consistent method to determine the type of renewable energy power plant for electrification.

Future research can explore technologies not yet owned by PT PLN (Persero), considering the same dimensions and indicators.

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