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Comparative study of micro hydro model systems for powering the sub-village of Tulaun Lalumpe Minahasa of North Sulawesi Province, Indonesia

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Abstract: *In this work, we conduct a comparative study to meet the energy demands of a rural village in Indonesia, Tulaun Village, Lalumpe, Indonesia. We utilize different scenarios of rural power systems based on four models of the micro hydro system. The first model of energy-independent village is 100% micro hydro supply. The second model is a combination between micro hydro and the grid. The third model is a combination of micro hydro, grid, and diesel. The fourth model is a combination of 3 sources that consists of micro hydro, solar PV, and battery. The load demand data were obtained based on the communities' electricity needs of 55 households in the village. The Hybrid Optimization Model for Renewable Energy (HOMER) was selected to analyze this techno-economic feasibility study. The best option is the fourth model based on the result in terms of the cost of electricity (COE), and environmental emission consideration.*

Keywords: Micro hydro; Energy Independent Village; HOMER, Indonesia

INTRODUCTION

The purpose of this article was to conduct a feasibility study for electricity provision in the rural remote communities using hydro energy sources and grids in a small village in Indonesia. Lalumpe village is located in the coastal area of Minahasa, North Sulawesi province of Indonesia. To provide an overview of the location of Lalumpe village, the authors have presented an aerial photo in Figure 1.

Fig. 1. The location of study in Tulaun sub-village of Lalumpe village

Tulaun sub-village is the site of the case study that located at a latitude of 050 33' 20.8" north and longitude of 1270 09' 6.8" east. Due to the remote areas, this location faces frequent power outages. Despite that, this area has many local renewable resources, such as two rivers, namely Tulaun river and Kawis river. Thus, renewable energy-based micro-grid systems are the prospect to make the energy-independent village. This study proposes the feasibility of four possibilities of a power system for powering the small village occupied by 55 households.

The structure of this article consists of an introduction, literature reviews, methods, results and discussion, as well as conclusions with a list of recommendations.

2. LITERATURE REVIEWS

Renewable energy and local resources have become a necessity to be examined for the green community. Several existing studies have analyzed economic, environmental, and human well-being perspectives of biomass energy usage and yielded mixed results [1]. For the local resources, the authors have conducted and published a study to encourage the usage of the local timber waste as construction material for timber houses to mitigate the risk of earthquake hazards [2].

Moreover, to evaluate the effectiveness and dependability of these systems, researchers and energy modelers have been employing various tools or programs for the modeling process. The hybrid optimization model for electric renewables (HOMER), developed by NREL (National Renewable Energy Laboratory, USA), is a cost and system optimizing tool for the project feasibility. This software is capable of hourly simulations and can handle all types of new technologies, including PV, wind, fuel cells, hydro, etc. HOMER software has been employed in research and feasibility analyses of the off-grid world's electricity grids. Numerous studies have been conducted by employing single and hybrid energy-based systems. The researcher is utilizing energy modeling software for
the modeling and optimization goals.

Hafez O et al. [3] studied the microgrid hybrid system based on the wind, hydro, solar, and diesel resources for the 1183 kW peak load and 600 base loads of the rural communities. Olatomiwa et al. [4] used HOMER to examine various workable electricity generation plans that included solar, wind, and diesel generators for various areas in Nigeria. According to the study's findings, a hybrid renewable design made up of solar, wind, fuel, and batteries are most practical and carbon-efficient to use.

By taking into account photovoltaic, biomass, hydro, and diesel as resources to generate electricity for the peak load of 55.49 kW, Ankit Bhat et al [5] accomplished optimal planning and feasibility analysis for the rural community. They ran simulations with HOMER and came to the conclusion that a system made up of a 6 kW biogas generator, a 16 kW biomass generator, a 60 kW photovoltaic generator, and a 10 kW diesel generator with storage batteries is a better choice for the study area. Luiz et al. [6] reported a pre-feasibility study of a hybrid PV diesel system for a small village of 100 families. It is found that this hybrid system was supposed to be more cost-effective than that of a diesel-based system which reduces the cost of fuel consumption. Lau et al. [7] conducted a cost analysis for the hybrid (PV-diesel) system considering the load requirements of the residential sector using HOMER software. The system was designed and analyzed for the peak demand of 2 kW for 40 homes.

Bhattacharyya S. et al. [8] analyzed optimal planning and system designing of a small grid system for a Bangladeshi rural community having a based load of 24 kW. This study considered a hybrid system comprising solar, hydro, diesel, and wind resources for power generation. These studies considered the electricity needs at the domestic level but didn't consider agricultural needs such as irrigation and other usages.

Kashif et al. [9] compared the performance of the system and shows that system is techno-economically viable based on the net present cost and cost of energy for the electrification of remote rural areas in Pakistan by HOMER analysis.

Due to the significant influence that regional geography and cultural norms have on the patterns of energy consumption, the location of the community is of the most importance [10]. Optimizer HOMER can determine the most efficient and cost-effective system for the specified load and conditions by making use of the optimizer's one-of-a-kind algorithm [11]. Two different kinds of simulations were run on microsystems to illustrate the modeling capacity of the program [12]. These simulations compared the results of HOMER modeling to those of actual measurements.

The author has had success conducting feasibility studies on several different locations using HOMER. These locations include Talaud Island and Bunaken Island. Acquiring models of a hybrid power plant system that consists of PV-Wind-Diesel-Battery can be done to fulfill the requirements of the Miangas island community [13]. Rumbayan et al [14] studied the model of a solar home system on Bunaken island using HOMER.

It may be challenging to study the feasibility of micro hydro energy for powering the rural coastal areas that are locally available. The study area is conducted in the Tulaun sub-village of Lalumpe village in Minahasa district as it has two rivers, namely Tulaun and Kawis. Also, this result of the study is expected as the recommendation for energy-independent village programs powered by renewable energy.

3. METHODS

The methods used in this feasibility study are consisting of initial problem assessment and Pre-HOMER assessment. Then resources demand and system design are the next stage to do for performing the techno-economic analysis.

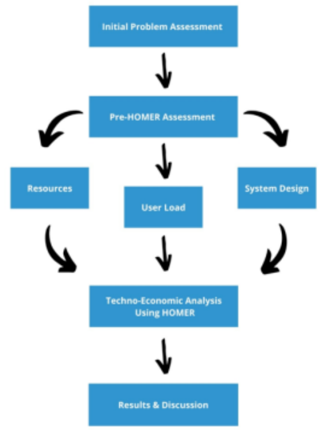

Fig. 2 The methods used in this study

An initial problem assessment has been conducted in a remote village to provide the prospect solutions for the community load. Then a Pre-HOMER analysis was performed by assessing the load requirements for the community in the sub-village and the available hydro energy resources in the location. After that electricity energy demand data was input to the software interface and analysis was performed for the four possibility schematics system. Techno-economic analysis was performed in the HOMER software for the 4 schematic systems to obtain and discuss in this study.

The daily electric load profiles of the sub-village community are shown in Fig. 3.

Fig. 3. The Daily Load Profile for Sub-Village Communities in Tulaun

In Figure 3, it can be observed that community electricity demand is not high as compared to the urban areas. The electricity consumption in this fishery village community is due to the lighting, fans, and small water pumps. The primary electricity consumption in this fisherman sub-village is due to the households' need for lighting, fan, television, rice cooker, and refrigerator.

4. RESULTS

The results of three power system schematics that have been performed in the HOMER are presented as follows:

a. Schematic 1

The power system of schematic 1 has been designed that consist of 100% micro hydro power source as described in Figure 4.

Off-grid electricity generation using renewable energy technologies has become a more reliable source to fulfill the needs of rural areas by considering the availability of the resources.

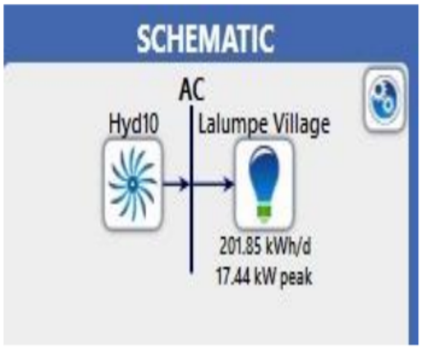

Fig. 4. The power system schematic that supply by 100% micro hydro

This schematic has been focused on using single source-based renewable energy technologies like micro hydropower systems. The simulation result of the HOMER analyzed has been presented in Figure 5 and Figure 6.

Fig. 5. The simulation result of HOMER for the schematic 1

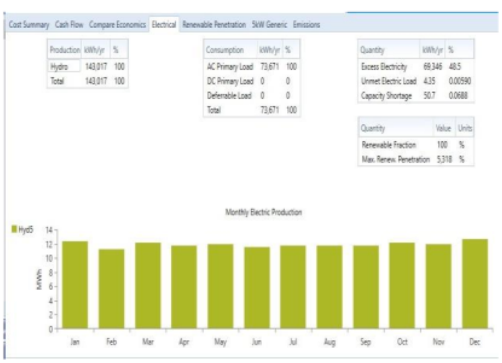

Fig. 6. The monthly of electrical production of Schematic Model 1

Based on the HOMER simulation result, the cost of energy was 1032 Rupiah/KWh and the net present cost (NPC) was 1,459,000,000 Rupiah.

This 100% renewable system is generating about 144,949 kWh/year with excess electricity generation of 71,277 kWh/year making the village energy independent of renewable energy power by micro hydro.

b. Schematic 2

Renewable source based systems have inconsistent supply issues, due to intermittent characteristics under varying climatic conditions, which influence the energy production. To overcome this issue and provide energy supply in reliable ways, these renewable source based systems can be combined with grid power.

The power system of schematic 2 has been designed that consist of micro hydro and grid as the power source to the village as described in Figure 7.

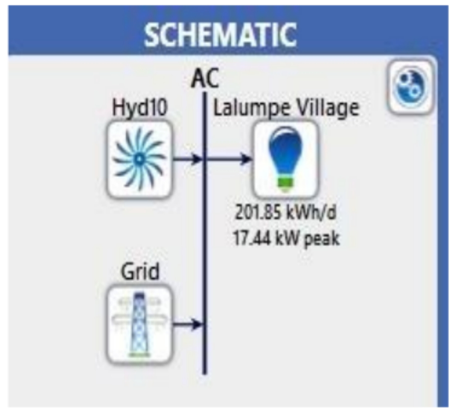

Fig. 7. The power system schematic that supply by 100% micro hydro and the grid power

This schematic has been focused on using single source-based renewable energy technologies like micro hydro power systems as well as the grid. The simulation result of the HOMER analyzed has been presented in Figure 8 and Figure 9.

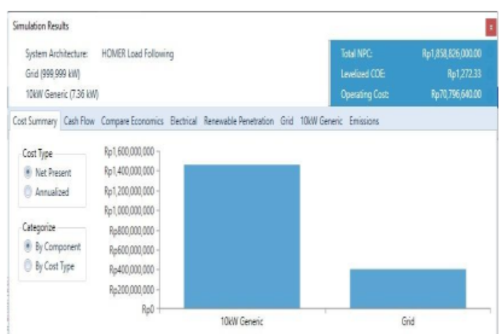

Fig. 8. The simulation result of schematic 2

This hybrid system provides electricity to the village at a cost of energy (COE) of 1272 Rupiah/kWh and a net present cost (NPC) of about 1,858,826,000 Rupiah for rural communities' demand. From Figure 9, it can be observed that the fraction of renewable energy is about 76% of the power supply to the village electricity demand.

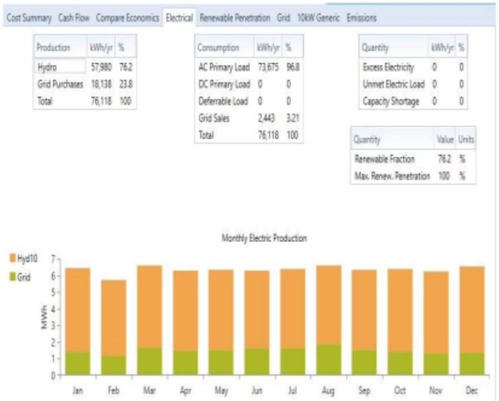

Fig. 9. The monthly of electrical production of Schematic Model 2

Moreover, the system has a reasonable cost of energy for the price of PLN grid is about 1500 Rupiah per KWh. These hybrid renewable systems are a more effective and reliable source of energy, the government of Indonesia can play a significant role to overcome energy crises by facilitating rural areas with such systems.

c. Schematic 3

The power system of schematic 3 has been designed that consist of micro hydro, diesel and grid for powering the village as described in Figure 10.

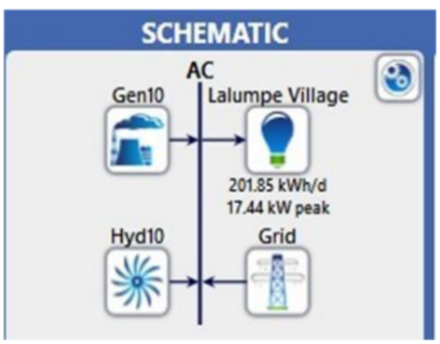

Fig. 10.The power system schematic that supply by micro hydro, diesel and grid

This schematic model has been combined using several sources such as micro-hydro, diesel, and grid power systems. The simulation result of the HOMER analyzed has been presented in Figure 11 and Figure 12.

The results obtained from cost analysis revealed that the combination of 10 kW hydro, grid, and diesel generator was the highest cost for this case study with a cost of energy (COE) of 2,000 Rupiah and the total net present cost (NPC) of Rupiah 3,000,000,000. From Figure 12, it can be observed that the fraction of renewable energy is about 74% of the power supply to the village electricity demand.

For schematic 3, the emission due to diesel utilization has been calculated by the software and presented in Table 1.

Fig. 11. The simulation result of HOMER for the schematic 3

Fig. 12. The monthly of electrical production of Schematic Model 3

Table 1. The Emission of schematic-3 due to diesel utilization

	Value	Units
Carbon Dioxyde	15,279	Kg/year
Carbon Monoxyde	43.1	Kg/year
Unburned Hydrocarbon	1.57	Kg/year
Particulate Matter	2.51	Kg/year
Sulfur Dioxide	55.5	Kg/year
Nitrogen Oxydes	69.3	Kg/year

d. Schematic 4

The power system of schematic 4 has been designed that consists of micro hydro, solar Photovoltaics, and battery for supplying the electricity village load as described in Figure 13.

This schematic model consists of a hybrid system that integrates renewable energy sources in the form of micro-hydro and solar power. The simulation result of the HOMER analyzed has been presented in Figure 14 and Figure 15.

The results obtained from cost analysis revealed that the combination of 5.89 kW hydro, solar HYD 182 kW, Canadian Solar 312 kW and battery Ritar 540 string was the lowest cost for this case study with cost of energy (COE) of 661 Rupiah and the total net present cost (NPC) of Rupiah 935,145,700. The renewable fraction can be 100% from this hybrid model system for powering the village.

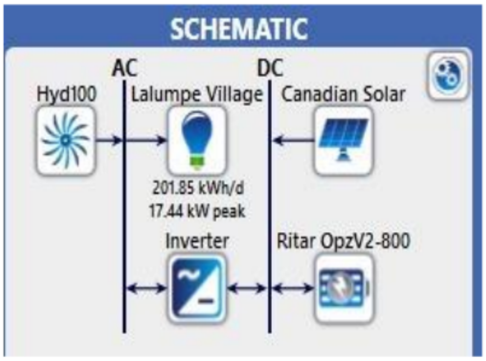

Fig. 13. The power system schematic that supply by micro hydro, solar and battery

Fig. 14. The simulation result of HOMER for the schematic 4

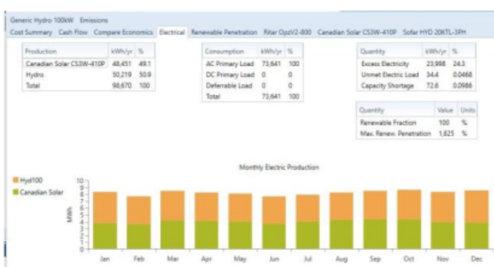

Fig. 15. The monthly of electrical production of Schematic Model 4

Table 2. The comparison of schematic 1, 2, 3 & 4

Model	COE	NPC
100% Microhydro	Rp. 1032	Rp. 1.45 M
Micro hydro +Grid	Rp. 1272	Rp. 1.8 M
Micro hydro +Grid +Diesel	Rp. 2033	Rp. 3 M
Micro hydro +Solar+Battery	Rp. 661	Rp. 0.9 M

This study compares the performance of the proposed system and indicates that the system is techno-economically viable based on the net present cost (NPC) and cost of energy (COE). The summary of comparison in terms of schematic model, cost of energy and net present cost has been presented in Table 2.

It is found that the lowest cost in term of COE and NPC belong to the fourth model that power by 100% renewable energy consist of micro hydro, solar energy and battery.

4. CONCLUSION

This study presents a feasibility analysis of four schematics for powering the sub-village community of Indonesia, the case study in Lalumpe village. Different system configurations of the supply power system were analyzed in HOMER by simulating a power model schematic. The first village power model uses 100% hydro resources, the second system uses hydro and grid power, the third system uses hydro, grid, and diesel, and the fourth system uses micro-hydro, solar PV, and battery. The best solution based on the cost analysis is a 100% fraction of renewable energy that combination of micro-hydro, battery and solar PV power sources.

The power renewable source based on micro hydropower proposed in this study can be employed in remote rural areas to make energy-independent villages.

Further analysis of the detail of technical work for the micro hydro feasibility study should extend to implement the plan.

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