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Design of a Photovoltaics Stand-Alone System for a Residential Load in Bunaken Island Using HOMER

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Abstract. The purpose of this study is to design a Photovoltaics (PV) stand-alone system for a residential load in Bunaken Island using HOMER (Hybrid Optimization of Multiple Energy Resources). Bunaken Island, the case study location, is a popular tourist spot in North Sulawesi, Indonesia. This island is facing the issue of limited access to electrical energy from the grid. The design and techno-economic analysis in Bunaken island leveraged HOMER software. This software was developed by National Renewable Energy Laboratory (NREL). Furthermore, the results suggested that the techno-economical PV stand-alone system in Bunaken Island could be developed as alternative energy to support electricity as energy security issued for Indonesia.

1. Introduction

Adopting a pro-island energy policy in the small and remote island of Indonesia is essential to support the community, giving them more accessibility to the source of energy. The remote islands usually attract local, national, and international tourists; hence, the development of energy security is necessary as it could lead to better efficiency and environmental sustainability. Moreover, the limited access to electricity from the primary grid on the mainland and the increasing demand from the island communities should be taken into consideration. Therefore, this study aims to design the PV-based energy system for off-grid power supply in remote island communities.

Bunaken Island is a part of Bunaken National Marine Park, one of the top diving sites in Indonesia. The island itself is located in the Latitude: 1°37′4″ S and Longitude: 124°45′6″ E in North Sulawesi, Indonesia. It takes a one-hour boat ride from North Sulawesi's capital city, Manado, to reach this magnificent island with a long stretch of white sand beach, friendly locals, and abundant sunshine throughout the year.

This section presents a literature review in regards to the performance of the power system infrastructure models for island energy demand by utilizing HOMER (Hybrid Optimization of Multiple Energy Resources) software. HOMER software was developed by National Renewable Energy Laboratory (NREL). It has been utilized to evaluate the techno-economic feasibility of the infrastructure models of the power systems. Furthermore, HOMER will handle various technologies of renewable energy supply and assess the configuration options for both off-grid and grid-connected power systems [1].

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Figure 1. The location of Bunaken Island as the remote island from Sulawesi mainland.

Numerous research have examined HOMER implementation for analyzing energy systems models. Dursun et al. [2] used the HOMER software for defining the best option and offer a techno-economic analysis system for fifty homes in a remote communities with micro-grid wind-PV hybrid system. Bekel and Bjorn [3] presented a feasibility assessment for 200 households that power with the stand-alone solar-wind based hybrid energy system. Shaahid et al. [4] explored the techno and economic possibilities of hybrid-wind-PV-diesel power systems to meet the electrical energy demand by using HOMER. Majid et al. analyzed [5] about optimum sizing of PV Systems in Somar, Oman. The community's location needs to be taken into account as the electricity demand might differ depending on the geographical site and cultural habits [6]. Chowdhury et al. [7] studied system and cost analysis of stand-alone solar home systems applied to a developing country. Additionally, many researchers have also examined the solar home system implementation in remote islands and isolated areas. Sharma et al. [8] and Kumar and Ghosh [9] discuss the techno-economic analysis of off-grid rooftop solar PV systems in Bangladesh. Kumar et al. [10] present the design and control of residential off-grid connected PV systems, which they implemented in India. Rujeko and Tsutomu [11] investigated the solar home systems for application in Zimbabwe. Yandri [12] studied development and experimentation on the performance of polymeric hybrid Photovoltaic Thermal collectors. All the studies mentioned before have indicated a great potential to implement the solar energy application for remote and isolated areas, including the islands.

The author of this study has also conducted several kinds of research regarding renewable energy development for island communities in Indonesia, ranging from the techno-economical study of PV-diesel power system in Miangas Island that located in the border of Indonesia and Philippines [13], development of power system infrastructure model for the island communities of Indonesia [14], empowering remote island communities with renewable energy in Talaud Island [15], study the concept of the internet of things enable for remote monitoring of the solar home system [16], and model of solar energy use for island communities in Bunaken [17]. Furthermore, it is found that the issue regarding renewable energy development for island communities in Indonesia is challenging, yet fascinating.

This article is structured as follows: introduction in section 1, problem statement in section 2, methodology in section 3, analysis and discussion in section 4, as well as the conclusion in section 5.

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2. Problem Statement

Bunaken Island is unique and well-known as an exceptional location of tourism in North Sulawesi, Indonesia. However, the island is categorized as a remote island because it is separated from the mainland of Sulawesi. Furthermore, the island's location has also contributed to the lack of electricity access to the grid. For instance, as shown in Figure 2, many homestays have been developed by the government to support tourism activities in Bunaken island. While it is a good initiative, there is an issue of not having reliable electricity access to facilitate their operation for 24 hours continually.

Figure 2. A homestay in Bunaken Island with size 2x2 meters.

The problem that needs to be resolved through this research is how to provide an alternative option to design a PV stand-alone system for a residential load in Bunaken Island, as a proposed plan of the introduction of a renewable energy system.

By providing the latitude and longitude information of Bunaken Island to HOMER software, the solar energy potential in terms of Global Horizontal Irradiation and Clearness Index data of NASA can be obtained and shown in Figure 3.

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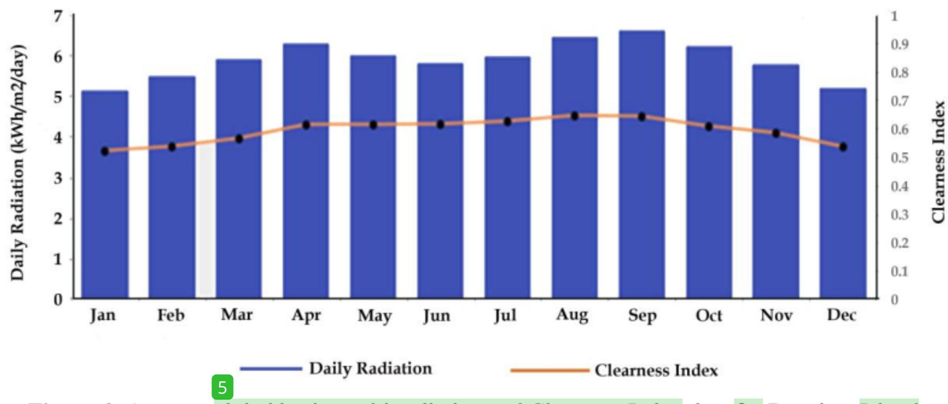

Figure 3. Average global horizontal irradiation and Clearness Index data for Bunaken Island.

According to the obtained data, daily average GHI is 5.9 kWh/m2/day. As depicted in Figure 3, the daily average GHI for each month varies from the minimum 5.14 kWh/m2/day in January to the maximum 6.45 kWh/m2/day in August.

3. Methodology

The methodology used in order to solve the problem by using HOMER software to get a simulation for several possibilities of the system model into the chosen model in the location of Bunaken Island, North Sulawesi, Indonesia.

Initially, a survey was conducted for a typical residential load in Bunaken Island. The typical residential load for a small homestay for two people is listed in Table 1.

The solar home system design with proposed load in a small homestay is depicted in Figure 4.

Table 1. Typical residential load consumption for a small homestay in Bunaken Island

Loads	Power Rating [Watt]	Number of Devices	Operating [hours/day]	Total Energy Demand [Wh]
Lamp	5	3	10	150
Rice Cooker	300	1	0.5	150
Mini Fan	50	1	3	150
Television	100	1	3	300
Mini refrigerator	50	1	20	100

The Solar Home System (SHS) is commonly intended to supply DC and/or AC electrical appliances. A battery system, PV modules, a PV charge controller, and an inverter make up the system. The generated DC power is collected in the battery, which would be converted into AC power to supply the small homestay's AC loads.

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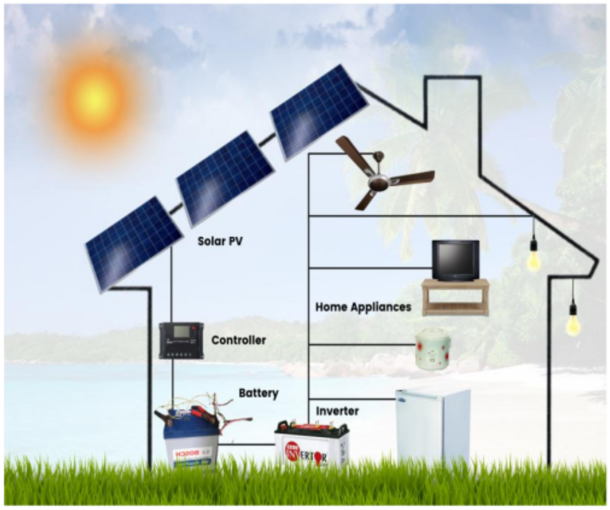

Figure 4. The design of the solar home system for a small homestay.

In this proposed case, the energy demand per day for a small homestay is considered to be 1000 Wh for additional demand. The schematic of the solar home system to be analyzed in HOMER software is displayed in Figure 5.

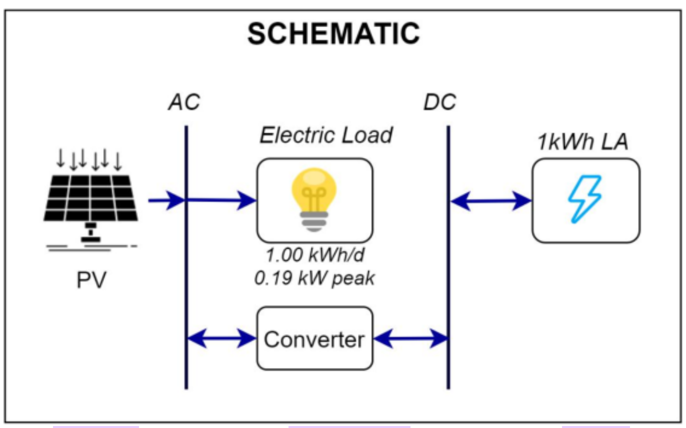

Figure 5. The proposed schematic of the solar home system.

4. Results and Discussions

The result of HOMER optimization is shown in Table 2.

Table 2. The result HOMER optimization in this study

Architecture				Costs				System	
PV [kW]	Genset [kW]	Battery [1 kWh]	Converter [kW]	NPC [$]	COE [$]	Operating Cost [$/year]	Initial Capital [$]	Renewable Fraction [%]	Total Fuel [L/year]
0.293	-	2	0.165	$1.044	$0.232	$ 39.25	$542.51	100	0
0.300	0.210	2	0.155	$1.253	$0.269	$ 47.05	$651.77	95.8	6.89
-	0.210	1	0.158	$2.764	$0.592	$196.47	$252.43	0	134
0.688	0.210	-	-	$3.983	$0.854	$249.62	$792.50	0	162
-	0.210	-	-	$4.407	$0.945	$336.55	$105.00	0	223

The result indicates several options can be proposed for a residential load in this location to supply the electricity demand for a small homestay in Bunaken Island. The optimal results for architecture, cost, and total fuel can be obtained through HOMER analysis. The results show only one option for a 100% solar energy supply in this case. It is shown a proposed homestay load can be supplied by 300 watt PV panels, 165 Wh Converter, and two batteries. The cost of this solar home system is shown at 1044 $ as Net Present Cost (NPC), 0.232 $ for Cost of Energy, 39.25 $/year for operating cost, 542.5$ for the initial cost. The cost of energy by SHS off-grid is double higher than the price of electricity from the grid. However, the introduction and utilization of this system are reasonable for Bunaken island in terms of energy security and environmental issue.

5. Conclusions

The way to introduce and implement solar energy use in Bunaken Island has been proposed by using a simulation in HOMER. The result shows that 0.293 KW capacity of stand-alone PV, with COE as 0.232 $, NPC as 1044$, operating cost as 39.25 $ as well as payback of 1.5 years can be independent supply for a household with the proposed load is 1 kWh/d, and 0.19 kW as a peak for a small homestay in Bunaken Island. For environmental consideration, this proposed design with a 100% renewable energy fraction indicates benefit advantages as no emission result by this stand-alone PV system. Furthermore, the Solar Home System (SHS) technology is well-fitting for generating electricity in Bunaken Island.

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