Model of solar energy utilization in Bunaken Island Communities

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Abstract. The ambitious planning of renewable energy utilization in Indonesia to achieve 23% in the country’s energy mix by 2025 pushes the development of model community using a Photovoltaic (PV) stand-alone system. The issue about island electricity access is happening in Bunaken as one of the famous tourist spots in Indonesia. Island communities are facing limited access toward the availability of electrical energy day and night time. This article aims to develop a model for solar energy utilization in Bunaken island communities for tourism spots. The design and cost-benefit analysis have been done for Bunaken community for lighting and handphone charging. The result indicated that the utilization of PV stand-alone system in Bunaken can be introduced by solar luggage package for the communities who willing to support their small-medium enterprise.

1. Introduction

The utilization of solar energy in island communities is increasing time by time due to the demand for energy electricity access. The challenge in this research is the adoption of new renewable technology that supports the communities in Bunaken as the tourism spot. Similar to a house’s terrace that needs lighting, the small islands in the Indonesian territory need to be properly electrified as well. In order for the security and welfare of the island communities to be well established, the infrastructure of electric energy for the island needs to get more attention [1].

The study aimed to produce a prototype of solar luggage as the photovoltaic stand-alone system to provide lighting and handphone charging. Also, the economic analysis based on cost-benefit analysis was done to calculate the price of the solar luggage prototype. The location of Bunaken island as the tourism spot becoming a target in this research. This coastal area is facing limited access to the electrical energy grid. Based on a survey of this area, it is found that there is no 24 hours electricity supply from the grid. In fact, the community located in this tourist spot has restaurant businesses and needs electricity. Therefore, the solution for independent electricity supply becomes important and urgent.

Geographically, Bunaken island is located between 124004’-124048’ E and 1037’-1047’ N. It takes 30 minutes by boat from Manado, the capital city of North Sulawesi province. The map of Bunaken island is shown in Figure 1.
Figure 1. The Map of Bunaken Island as the Tourism Spot in North Sulawesi Indonesia

2. Literature Review

The potentials of solar energy have been analyzed by authors in the previous research [2,3]. Another reference that is reviewed the usage of the solar home systems in rural Bangladesh [4]. Anwarzai and Nagasaka [5] have done a feasibility study of solar Photovoltaic on the district level for Afghanistan. Rumbayan and Nagasaka [6] reported that generating electrical energy with renewable energy would cost relatively higher. Therefore, it is necessary to set policies and strategies for renewable energy induction's in the archipelago. The aforementioned policies include cooperations with several parties. These parties have been implementing renewable energy technologies, increasing renewable energy-based implementations for infrastructure in several locations [7]. The enhancement of pro-island energy policy in the foremost island as a terrace's adoption is necessary for improving the security, welfare, and beauty of the border region in Indonesia.

Many small islands around the world currently propose to use renewable energy: Fiji and the Hawaiian Islands in the Pacific, the Azores and Canary islands in the North Atlantic, Gotland and Samsoe in the Baltic, Mauritius, and Reunion in the Indian Ocean, as well as Sardinia and Sicily in the Mediterranean. Many small islands have achieved their goal of transitioning to renewable energy [8]. Many studies about development of natural resources potential for small islands such as Ndao, Indonesia [9], Gili, Indonesia [10], Poteran, Indonesia [11] and Banggi, Malaysia [12].

Life Cycle Cost (LCC) analysis is defined as a tool used to compare the ultimately delivered costs of technologies with different cost structures. The function of LCC analysis is to calculate the cost of delivering over the life of the projects, is not only calculate the initial costs or operating cost [13]. The Life Cycle Cost is calculated using Equations (1)-(4). The equation representing the life cycle fuel costs is the life cycle period in a year.

\[
LCC_{Fuel\ Cost} = Annual\ Fuel\ Cost \times \left[ \frac{1 + Fe}{Dr - Fe} \right] \times \left\{ 1 - \left[ \frac{1 + Fe}{Dr - Fe} \right]^{\text{period}} \right\}
\]
where Annual Fuel Cost is the annual fuel expenditure, \( F_e \) represents fuel escalation, \( D_r \) represents discount rate. Recurring maintenance cost is presented by Equation 2.

\[
LCC \text{ Maint. Cost} = \text{Ann. Maint. Cost} \times \left( \frac{1+G_e}{D_r-G_e} \right) \times \left\{ 1 - \left( \frac{1+G_e}{1+D_r} \right)^{\text{period}} \right\}
\]

where Annual Maintenance Cost is the annual non-fuel expenditure \( G_e \) represents a general escalation. The equation for non-recurring costs is presented by Equation 3.

\[
LCC \text{ Repl. Cost} = \sum \left[ \text{Item Cost} \times \left\{ 1 + \left( \frac{1+G_e}{1+D_r} \right)^{\text{Ry}} \right\} \right]
\]

where Item Cost is the non-recurring expenditure in present-day costs, \( G_e \) represents general escalation, \( D_r \) is the discount rate and \( \text{Ry} \) is the replacement year.

The Life Cycle Energy Cost is presented by Equation 4.

\[
LCC = \frac{\text{Capital costs} + LCC \text{ Fuel Cost} + LCC \text{ Maint.Costs} + LCC \text{ Repl Costs}}{\text{Period} \times 365 \text{kWh/day}}
\]

in which LCC is the life cycle cost per kWh of energy.

3. The Design of Solar Luggage System

The model of the solar luggage system as the independent power source is considered to be installed in the coastal area of the tourism spot in Bunaken island is described in Figure 2.

\[\text{Figure 2. The Design Model of Solar Luggage of Photovoltaic System}\]

It is planned to develop the independent solar photovoltaic system in the tourism spot of Bunaken island described in Figure 3.
4. The Life Cost Analysis
The Life Cycle Cost Analysis is estimated using Equations (1)-(4). The following economic factors are assumed as the life cycle is 10 years, discount rate (Dr) is 10%, annual inflation or cost escalation (Ge) is 5%. The replacement cost is assumed as zero. Thus the total energy generated by the system is 365 days/year times 350 Wh equal to 1277.5 kWh in 10 years. The scheme of the capital cost of solar luggage system is given in Table 1.

| Material           | Low Price [IDR] | Medium Price [IDR] | High Price [IDR] |
|--------------------|-----------------|--------------------|------------------|
| Photovoltaic panel | 650,000         | 1,160,000          | 1,300,000        |
| Battery            | 1,500,000       | 1,750,000          | 3,850,000        |
| Controller         | 350,000         | 650,000            | 750,000          |
| Lamps              | 100,000         | 200,000            | 250,000          |
| Cable              | 120,000         | 150,000            | 240,000          |
| Total capital cost | 2,720,000       | 3,910,000          | 6,390,000        |
| Recurring maintenance cost | 459,244 | 575,744 | 1,078,887 |
| Grand Total cost   | 5,669,244       | 7,485,744          | 13,731,356       |
| Life Cycle Cost (LCC) [IDR/KWh] | 4,390 | 5,807 | 10,752 |

The Life Cycle Cost for the three schemes, i.e low price, medium price, and the high price of solar luggage packet is shown in Table 1. The cost of Rupiah per KWh is equal to 2 times, 3 times and 5 times compare to the electricity price from the grid that serves by diesel fuel. Even though the price of solar energy is higher than conventional power plants, the utilization of renewable energy is applicable for island communities in terms of energy security and environmental consideration for tourism spots.

5. Conclusion
This study has proposed a model of solar energy utilization in Bunaken island communities. A solar luggage model was developed using solar panels, controllers, and batteries. The solar luggage model with its panel was built for supplying the lighting and handphone charging demand. The model economic was analyzed by cost-benefit analysis. It was found that the solar luggage model developed...
was the potential to introduce for Bunaken island communities to support electrical energy demand for tourism spots. The results from the cost-benefit analysis showed the model was interested to be a business model development for island communities in order to supply lighting and charging on the spot.

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