Planning for clean energy utilization in the provision of clean water on Barrang Caddi Island

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Abstract. Barrang Caddi Island has a Diesel Power Plant (Genset) of 340 kVA which is operated by self-management by the local community and cannot meet the electricity needs of the community because the Genset only operates for 8 hours at night. The discontinuity of the Genset operation on Barrang Caddi Island makes the Ready to Drink Water Machine or Arsinum on the island to provide its own electrical energy which is supplied by a 15 kVA Genset machine that operates 24 hours/day. The drinking water produced by Arsinum is clean water but has the potential to produce environmental pollution because the power plant used is diesel fuel. In addition, the cost of electrical energy will also increase due to the increasing price of oil. Therefore, planning is carried out to optimize the operation of Arsinum by making several models of power plants that can supply the machine. From the planning results, it was found that the optimal Hybrid Power Plant (Genset – Solar Power Plant) model to be applied so that it could supply electrical energy of 128092 kWh/year. The advantage of this model is that the operating costs are small and can contribute to renewable energy by 33%.

1. Introduction

Barrang Caddi Island is one of the islands in the Supermonde Archipelago which is located on the coast of the Makassar Strait. Barrang Caddi Island is included in the Makassar City area. The location of Barrang Caddi Island is ± 10.5 km to the west of Makassar City and can be reached by motorboat for ± 1 hour. Barrang Caddi Island which extends from north to south is located at coordinates 05°04'51" South Latitude and 119°19'14" East Longitude. The land area of Barrang Caddi Island is 0.57 km² (Figure 1.) which is entirely surrounded by the sea and has boundaries on the north with Barrang Lompo Village, on the south with Kodingareng Village, on the east with Makassar City, and on the west with Liukang Tuppabiring Village. Barrang Caddi Island has a uniform height above sea level, which is 1.75 m above sea level. Barrang Caddi Island has a tropical climate type, so it is strongly influenced by the marine climate which is usually heterogeneous according to the general conditions of the tropical climate. The average temperature is 31°C with an average annual rainfall of 2144 mm.

Barrang Caddi Island is a small island whose electricity system is an isolated system. Currently, the people of Barrang Caddi Island enjoy electricity from the Diesel Power Plant (Genset) with a total capacity of 340 kVA which is the assistance of the Makassar City Government which is operated independently by the Barrang Caddi Island community. Genset on Barrang Caddi Island operates at 6.00 pm until 12.00 am and 4.00 am until 6.00 am.

Currently on Barrang Caddi Island there are facilities for providing clean water ready to drink or Arsinum [1]. Prior to the construction of Arsinum on Barrang Caddi Island, the island's main water source was obtained by collecting rainwater during the rainy season, and supplied from other areas during the dry season by transporting it using fishing boats. Arsinum is a Seawater Reverse Osmosis (SWRO) technology, it is capable of processing and producing raw, ready-to-drink water without...
cooking by utilizing sea water reverse osmosis technology. The availability of *Arsinum* is the result of collaboration between the South Sulawesi Provincial Government, Makassar City Government, and the Agency for the Assessment and Application of Technology or BPPT so that it can meet the needs of clean water for residents of Barrang Caddi Island. This BPPT *Arsinum* technology can produce 5000 liters of ready-to-drink water per day, or the equivalent to meet the drinking water needs of 2500 people (2 liters per person per day for drinking). This *arsinum* uses the latest technology of filtration system with reverse osmosis membrane equipped with ultraviolet sterilization.

![Figure 1 Barrang Caddi Island location](image)

The *Arsinum* machine operates using electrical energy. The source of the machine's electrical energy comes from the 15 kVA Genset owned by *Arsinum* [1]. Due to the limited hours of electricity from the island's electrical system, the *Arsinum* engine must operate a Genset that uses diesel oil. This is a challenge in itself because fuel is getting more expensive and produces gas emissions that can pollute the environment of Barrang Caddi Island.

Therefore, this paper is an attempt to provide the right electrical energy to replace the Genset or combine the Genset with other energy sources such as Solar Power Plant (Photovoltaic or PV) or Wind Turbine Power Plant (Wind Turbine) or Hybrid Power Plant [2]. Where it is known that the renewable energy resources on Barrang Caddi Island are solar energy with an average daily solar insolation potential of 5.87 kWh/m²/day and wind energy potential has an average of 4.51 m/s.

2. **Method**

2.1. **Data collection**

The information required in this study were obtained by interview and literature studies form and journals. The data obtained is in the form of current electrical energy needs which are predicted for the next 25 years according to the age of the PV. The load profile based on the load profile of the water purification machine on Barrang Caddi Island is 306 kWh per day.

2.2. **Data analysis**

Hybrid Power Plant planning for Arsinum machines on Barrang Caddi Island using the Homer application software. Homer software makes it easy to evaluate the design of power generation systems
for various types of small-scale power plants, both On Grid and Off Grid [3]. This application calculates the energy balance for each system model created [4]. Furthermore, the optimal configuration is determined that can meet the electricity needs as needed, the estimated investment costs, replacement, operation and maintenance, fuel, and interest [5].

2.3. Solar and Wind Energy Potential of Barrang Caddi Island

NASA provides data on the solar energy potential of Barrang Caddi Island an average of 5.87 kWh/m$^2$/day [6]. The highest solar radiation occurred in September at 7.22 kWh/m$^2$/day and the lowest in January at 4.57 kWh/m$^2$/day as shown in Table 1.

| Month      | Clearness Index | Daily Radiation (kWh/m$^2$/day) |
|------------|-----------------|---------------------------------|
| January    | 0.433           | 4.57                            |
| February   | 0.454           | 4.85                            |
| March      | 0.547           | 5.75                            |
| April      | 0.597           | 5.75                            |
| May        | 0.653           | 5.75                            |
| June       | 0.650           | 5.67                            |
| July       | 0.668           | 5.95                            |
| August     | 0.699           | 6.70                            |
| September  | 0.704           | 7.22                            |
| October    | 0.667           | 7.05                            |
| November   | 0.578           | 6.09                            |
| December   | 0.454           | 4.75                            |

Barrang Caddi Island also has wind energy potential, but it is low, with an average speed of 4.51 m/s as shown in Table 2.

| Month      | Average (m/s) |
|------------|---------------|
| January    | 4.36          |
| February   | 4.43          |
| March      | 3.29          |
| April      | 3.36          |
| May        | 4.76          |
| June       | 5.46          |
| July       | 5.92          |
| August     | 6.09          |
| September  | 5.59          |
| October    | 4.25          |
| November   | 3.09          |
| December   | 3.45          |

2.4. Generator Model

The load planning is based on the electrical energy needs of the Arsinum machine with a capacity of 15 kVA which operates 24 hours every day on Barrang Caddi Island. There are 6 (six) models of power generation system configuration that will be applied and analyzed based on the availability of energy potential in Barrang Caddi Island. The models are [7]:

1) Model 1, namely the basic or existing model, where the system is conditioned on the condition of the machine being served by Genset.

2) Model 2, namely PV - Wind Turbine - Genset - Storage - Converter which is a combination of conventional energy and new renewable energy.

3) Model 3, namely PV - Genset - Storage - Converter which is also a combination of new renewable energy and oil fuel energy.

4) Model 4, namely Wind Turbine - Storage - Converter whose energy is sourced only from renewable energy, namely wind energy.
5) Model 5, namely PV - Wind Turbine - Storage - Converter which combines wind energy and solar energy.

6) Model 6, namely PV - Storage - Converter that utilizes solar energy as the only primary energy.

The simulation will be used to determine the optimization results of the electrical system of the Arsinum engine on Barrang Caddi Island with a combination of no new renewable energy (NRE). The electricity system without NRE in this case PV or Wind Turbine is defined by fully meeting the electricity needs of Genset (PV and Wind Turbine generating capacity of 0 kW). Meanwhile, the electricity system with PV and Wind Turbine is defined by meeting electricity needs using Genset, PV and Wind Turbine electricity.

3. Result and Discussion

The results of this research simulation according to the research design are divided into 6 simulation models consisting of Genset, Genset – PV – Wind Turbine hybrid, Genset - PV hybrid, Genset – Wind Turbine hybrid, PV – Wind Turbine hybrid, PV, and Wind Turbine. The simulation results include the capacity of each type of generator, capital cost, operating cost, NPC, fuel consumption, Cost of Energy (COE), electrical energy production, capacity factor, NRE contribution, and excess electrical energy.

The results of this simulation are presented in Table 3. Based on the table, the optimal generating system is the third model Hybrid Power Plant consisting of Genset 15 kW, PV 30.6 kW, Storage 20 kWh, and inverter 14.1 kW. The hybrid power plant model has the lowest NPC compared to other power generation models, which is $569708 and a Cost of Energy of 0.32 $/kWh as shown in Table 3. When compared to the power plant model currently used, namely Genset with a cost of energy of 0.38 $/kWh. As well as a decrease in fuel consumption from 33701 L/year to 22160 L/year this is due to the reduced operating hours of generators that use diesel fuel.

| Parameter Results | Final Conditions with Multiple Scenarios |
|-------------------|-----------------------------------------|
|                   | Genset | PV - Wind Turbine - Genset - Storage - Converter | PV - Genset - Storage - Converter | PV - Wind Turbine - Storage - Converter | PV - Wind Turbine - Storage - Converter | PV - Storage - Converter |
| Generating Capacity |       |                                             |                                    |                                      |                                      |                        |
| - Genset (kW)      | 15     | 15                                           | 15                                  | -                                     | -                                     | -                       |
| - Wind turbine (kW) | -      | 1                                            | -                                   | 419                                   | 1                                     |                          |
| - PV (kW)          | -      | 0.8                                          | 30.6                                | -                                     | 185.1                                 | 187.3                    |
| - Storage (kWh)    | -      | 1                                            | 20                                  | 1572                                  | 309                                   | 299                      |
| - Inverter (kW)    | -      | 0.1                                          | 14.1                                | 97.6                                  | 15.6                                  | 15.5                     |
| Initial Capital ($) | 7500   | 20214                                        | 109393                             | 4690885                               | 662612                                | 656354                   |
| Operating Cost ($/year) | 41782 | 41786                                        | 29222                               | 291389                                | 31867                                 | 30581                    |
| Fuel (L/year)      | 33701  | 33289                                        | 22160                               | 0                                     | 0                                     | 0                        |
| Cost of Energy ($/kWh) | 0.38  | 0.39                                        | 0.32                                | 5.37                                  | 0.67                                  | 0.66                     |
| Net Present Cost ($) | 665666 | 678438                                     | 569708                              | 9280962                               | 1164600                               | 1138075                  |
| Electric Production (kWh/year) | 111690 | 112624                                    | 128092                              | 543338                                | 321033                                | 323637                   |
| Consumption AC load (kWh/year) | 111690 | 111690                                    | 111690                              | 111690                                | 111690                                | 111690                   |
| Renewable Fraction (%) | 0      | 2                                           | 33                                  | 100                                   | 100                                   | 100                      |
| Excess electricity (kWh/year) | 0      | 884                                        | 11928                               | 425237                                | 198738                                | 201382                   |
| Capacity shortage (kWh/year) | 0      | 0                                           | 0                                   | 2331                                  | 2192                                  | 2343                     |
The hybrid power plant (PV - Genset - Storage – Inverter) model produces 128092 kWh/year of electrical energy. The power plant model produces excess energy of 11928 kWh/year. This excess of electrical energy occurs because the production of electrical energy exceeds the demand for electrical energy required by the Arsinum machine and exceeds the ability of the battery to store the energy. To reduce this excess energy can be overcome by adding energy storage (battery) but it can affect the cost of the system which will increase the NPC of the system so that it is no longer optimal. This hybrid power plant model contributes 33% of renewable energy. The presentation of renewable energy will reduce the use of diesel fuel. Decrease in diesel fuel consumption and emissions as a result of less operation of Genset units in hybrid plants. The results of this simulation show that by combining several types of generators, you will get the optimal generation costs and use of renewable energy in the operation of the Arsinum engine on Barrang Caddi Island.

4. Conclusion
Based on the planning simulation, the Arsinum Machine on Barrang Caddi Island, if supplied by Genset, has an energy production cost of 0.38 $/kWh and a diesel fuel consumption of 33701 L/year. This situation is not optimal because there is a more optimal generator model, namely the 3rd model which is a combination of Genset with PV. The PV - Genset - Storage - Inverter hybrid plant consists of Genset 15 kW, PV 30.6 kW, Storage 20 kWh with an NPC of $ 569708. This system has a COE of $ 0.32/kWh. The energy produced is 128092 kWh/year, with fuel consumption of 22160 L/year. This model contributes 33% of renewable energy.

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