The Potential of Renewable Energy Generations at Barrang Caddi Island

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Abstract. Makassar is the capital city of South Sulawesi Province in Indonesia, is a city that has dozens of small inhabited islands. This geographical condition causes the distribution of electrification for islands in Makassar City to be uneven and forces the government to supply diesel power plant (Diesel-PP) to these islands as the main source of electrical energy for their electricity needs. One of them is Barrang Caddi Island. This island is not electrified by State Electricity Enterprise or PLN Makassar City. The Makassar City Government has fulfilled the electricity needs on Barrang Caddi Island in the form of Diesel-PP. However, the operation of the diesel generator set is only limited to 8 hours at night which is managed independently by the island community. For this reason, the hope of fulfilling electricity for 24 hours (day and night) on Barrang Caddi Island is by utilizing the island’s new and renewable energy (NRE) potential. One source of NRE is energy from the sun. This paper shows the potential of renewable energy, especially solar energy on Barrang Caddi Island to meet the electrical energy of the island’s people.

1. Introduction
South Sulawesi Province is one of the areas with high availability of electrical energy where this area is supplied by the interconnection system of South Sulawesi, West Sulawesi, Southeast Sulawesi, and Central Sulawesi (South Sulawesi). Currently, the South Sulawesi system has a generator reserve of around 600 MW so that the electrical energy needs in South Sulawesi have been met. However, the condition of the small islands around the island of Sulawesi is different, especially in the city of Makassar. Where Makassar City has dozens of small islands where people can only enjoy electrical energy at night. One of them is Barrang Caddi Island [1]. Barrang Caddi Island is a small island located in Sangkarang District, Makassar City, South Sulawesi Province, Indonesia with a population of 1550 people with an area of 0.57 km². The livelihoods of the people on this island are fishermen, civil servants, businessmen and traders. Currently, the electricity system of Barrang Caddi Island is supplied by a diesel power plant (Diesel-PP) which is managed by the people of Barrang Caddi Island themselves. Diesel-PP on Barrang Caddi Island works at 06.00 pm – 12.00 am and 04.00 am - 06.00
am. Electrical expenses in the form of house lights, rice cookers, televisions, water pumps and refrigerators.

Therefore, it is necessary to plan the provision of generating capacity that is able to supply the electricity needs of the community during the day. This paper is an illustration of efforts to provide the right electrical energy to replace Diesel-PP on Barrang Caddi Island or combine Diesel-PP with other energy sources such as solar power plants (SPP) or wind power plants (Wind-PP) [2]-[6]. Where it is known that the potential for new and renewable energy (NRE) on Barrang Caddi Island, such as solar energy, has an average direct normal solar radiation potential of 4.48 kWh/m²/day [7].

2. Research Method

2.1. Data collection

The information needed in this study was obtained from the results of a direct survey to the people of Barrang Caddi Island by means of interviews and literature studies. 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 SPP. The survey was conducted to obtain a daily electrical load profile on Barrang Caddi Island. The load calculation is carried out by estimating the use of electrical equipment per house on Barrang Caddi Island by paying attention to the operation of the equipment so that a 24-hour operating pattern is formed as shown in Figure 1.

![Figure 1. Electric load curve of Barrang Caddi Island](image)

Figure 1 shows the electricity load curve on Barrang Caddi Island for 350 houses, 2 mosques, 1 public health center/polindes, 1 village head office, 2 schools, street lighting and carpentry houses. The load curve is made with the assumption that Barrang Caddi Island is supplied with a power plant that operates for 24 hours. Based on the calculation results, the total daily energy value is 489 kWh/day or 178408 kWh/year.

2.2. Sunlight data

To calculate the optimal capacity of solar energy potential on Barrang Caddi Island, in addition to data on the average use of electricity during the day and night, the data needed is the amount of output power from the panel [8]. Solar panels are measured by the performance of solar power plants. The more solar radiation on Barrang Caddi Island, the greater the potential for generating electrical energy from SPP on Barrang Caddi Island. Table 1 shows the condition of solar radiation on Barrang Caddi Island throughout the year by the site https://globalsolaratlas.info/map. On the site has been provided about the Global Solar Atlas by the World Bank and the International Finance Corporation. This site is part of an ESMAP initiative that covers biomass, small hydro, solar and wind. The purpose of this
Global Solar Atlas is to provide easy and fast access to global photovoltaic power potential data. Based on Table 1, the direct normal irradiation (DNI) of Barrang Caddi Island is 4479 Wh/m²/day or 4.48 kWh/m²/day. Barrang Caddi Island in Indonesia has abundant potential of solar energy because the island is located in the equator line and a tropical island, so it has abundant potential of solar energy [9], [10].

Table 1 shows the intensity of solar radiation starting at 7 am, where sunlight can produce an average of 109 Wh/m² of electrical energy. At 7 o'clock the sun's intensity is still low, because the peak of the maximum solar intensity starts at 10 am at 483 Wh/m² until 14 noon at 496 Wh/m², where the sun shines brightly and the solar panels work at their maximum value, and the intensity of the sun starts disappeared at 19 pm, because the sun was no longer on Barrang Caddi Island.

| Hour  | Jan  | Feb  | Mar  | Apr  | May  | Jun  | Jul  | Aug  | Sep  | Oct  | Nov  | Dec  | Average (Wh/m²/hour) |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|----------------------|
| 07.00 | 45   | 46   | 67   | 110  | 116  | 101  | 55   | 123  | 187  | 203  | 174  | 83   | 109                  |
| 08.00 | 130  | 173  | 218  | 315  | 317  | 306  | 327  | 420  | 431  | 411  | 310  | 179  | 295                  |
| 09.00 | 206  | 245  | 328  | 436  | 431  | 405  | 449  | 546  | 572  | 543  | 433  | 252  | 404                  |
| 10.00 | 263  | 309  | 416  | 513  | 502  | 487  | 541  | 647  | 665  | 644  | 512  | 300  | 483                  |
| 11.00 | 309  | 348  | 468  | 567  | 563  | 536  | 609  | 716  | 725  | 699  | 575  | 341  | 538                  |
| 12.00 | 340  | 392  | 490  | 587  | 591  | 547  | 631  | 740  | 746  | 716  | 594  | 364  | 562                  |
| 13.00 | 345  | 365  | 487  | 582  | 588  | 537  | 604  | 722  | 712  | 689  | 541  | 363  | 545                  |
| 14.00 | 285  | 293  | 411  | 548  | 572  | 528  | 582  | 699  | 646  | 582  | 483  | 319  | 496                  |
| 15.00 | 246  | 233  | 313  | 441  | 489  | 473  | 528  | 648  | 608  | 514  | 392  | 248  | 428                  |
| 16.00 | 173  | 161  | 216  | 281  | 362  | 375  | 445  | 561  | 497  | 390  | 242  | 132  | 320                  |
| 17.00 | 104  | 101  | 129  | 167  | 240  | 269  | 340  | 429  | 359  | 258  | 149  | 73   | 218                  |
| 18.00 | 56   | 59   | 62   | 63   | 73   | 91   | 132  | 174  | 126  | 73   | 51   | 37   | 83                   |

Table 1. Direct normal irradiation (DNI) of Barrang Caddi Island (https://globalsolaratlas.info/map)

2.3. Data analysis
The load profile based on the load profile of the water purification machine on Barrang Caddi Island is presented in Figure 1. The simulation results to be analyzed are system costs, electricity, fuel consumption and emissions, by comparing all simulation results of systems that are considered optimal to other systems.

The calculation of the output energy value of the solar module to determine the potential for solar energy on Barrang Caddi Island is used equation (1). This equation is an equation for the potential to produce electrical energy in a SPP with a capacity of 1 kWp (E_{pot}) [11], [12].

$$E_{pot} = \frac{P_{kW_{max}} \times DNI \times \eta_{inv} \times \eta_{CC} \times \eta_{bat} \times \eta_{cab}}{k \times I_0}$$

(1)

Where; $P_{kW_{max}}$ is the maximum capacity of SPP (kWp), DNI is the average daily DNI of Barrang Caddi Island (kWh/m²/day), $\eta_{inv}$ is Inverter efficiency, $\eta_{CC}$ is Charge Control efficiency, $\eta_{bat}$ is Battery efficiency, $\eta_{cab}$ is the efficiency of the conducting cable, dan $I_0$ is the standard radiation (kW/m²).
3. Results and Discussion

3.1. Electrification conditions of Barrang Caddi Island

Barrang Caddi Island enjoys electricity from Diesel-PP with a total capacity of 340 kVA which is operated independently by the Island community. Diesel-PP which operates for 8 hours. There are 350 households that use electricity every day at a rate of IDR 4000/kWh. The issue that arises regarding the Diesel-PP manager is that the community is not satisfied with the operating time of the generator. The diesel fuel used comes from Makassar City. The management of the Diesel-PP is carried out by 2 operators who are also electricity retribution collectors. Every 10 days people have to pay a usage fee to enjoy electricity. The dues collecting officer is given a fixed fee of IDR1000000/person/month. Electricity from Diesel-PP is usually used by the community for lighting and TV use. Every electricity customer on Barrang Caddi Island has a kWh meter for recording energy consumption. During the day the community uses the Solar Home System (SHS) in their respective homes. There is also to meet his electricity needs by using a privately owned diesel generator for lighting his house and at the same time as a precaution if the Diesel-PP does not operate or is damaged.

3.2. The potential of solar energy to meet electricity loads on Barrang Caddi Island

The potential of solar energy on Barrang Caddi Island has the potential to be used as a power plant because the daily average solar radiation value is 4.47 kWh/m²/day, with the largest solar radiation being 6.43 kWh/m²/day in August, and the lowest is 2.50 kWh/m²/day in January. Based on Table 2 which shows the results of the calculation of the potential production of electrical energy per year generated from SPP with a capacity of 1 kWp on Barrang Caddi Island of 4359.52 kWh/year, with the percentage of effective solar radiation for a year is 80.27% or 293 effective days from 365 days.

The electrical energy potential of 4359.52 kWh/year is obtained from calculations using Equation 1. Based on the average daily solar radiation value of Barrang Caddi Island in January of 2.50 kWh/m²/day, standard radiation of 1 kW/m², inverter efficiency of 0.90 , charge control efficiency is 1.00, battery efficiency is 0.90, conductor cable efficiency is 0.90 and k value is 1.1, so for SPP 1 kWp can produce electrical energy as much as 2.97 kWh/hour. If it is assumed that the effective hours of sunlight are 5 hours per day (between 10 and 14 hours), then the energy production of SPP per day is 8.29 kWh/day. From this calculation, we can analyse that in January the energy produced by SPP in one day is 8.29 kWh. The value of electrical energy generated arises as a result of the efficiency of solar panels, losses in the power cable network used to install solar panels, losses from the inverter, and losses from the battery. So that the total energy production of SPP is 207.27 kWh/month in January, where it is assumed that the number of effective days for SPP in January is 25 days.

Table 2 shows the results of further analysis for the months of February to December. SPP with a capacity of 1 kWp on Barrang Caddi Island will generate electricity of 4359.52 kWh/year. The total electricity demand for Barrang Caddi Island is 489 kWh/day in a year. The SPP capacity to meet the demand for electrical energy on Barrang Caddi Island is 295 kWp. So if you use a solar cell module with Pmax is 300 Watt, then the number of modules needed to be installed is 983 modules.

4. Conclusion

Based on the data and simulation results in the form of calculations, it is concluded that the Diesel-PP on Barrang Caddi Island has not been able to meet the electrical energy needs of the people on the island. To meet the shortage of electrical energy due to the minimum operating hours of existing generators, then this can be met by developing a power plant from solar energy in the form of SPP. The potential for solar energy on Barrang Caddi Island with an average daily solar radiation value of 4.48 kWh/m²/day which can produce electrical energy of 4359.52 kWh/year for SPP with a capacity of 1 kWp.
### Table 2. The Potential of Solar Energy on Barrang Caddi Island

| Month      | Day | DNI (kWh/m²/day) | Production Energy kWh/day | kWh/month | kWh/year |
|------------|-----|------------------|--------------------------|-----------|----------|
| January    | 31  | 2.50             | 8.29                     | 207.27    |   |
| February   | 28  | 2.73             | 9.03                     | 198.65    |   |
| March      | 31  | 3.61             | 11.95                    | 298.64    |   |
| April      | 30  | 4.61             | 15.28                    | 366.62    |   |
| May        | 31  | 4.84             | 16.05                    | 401.28    |   |
| June       | 30  | 4.66             | 15.42                    | 370.20    |   |
| July       | 31  | 5.24             | 17.37                    | 434.33    |   |
| August     | 31  | 6.43             | 21.29                    | 532.25    |   |
| September  | 30  | 6.27             | 20.79                    | 498.95    |   |
| October    | 31  | 5.72             | 18.96                    | 474.02    |   |
| November   | 30  | 4.46             | 14.77                    | 354.37    |   |
| December   | 31  | 2.69             | 8.92                     | 222.92    |   |

kWh/year 4359.52

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