Maritime Renewable Energy Potential Choosing as Solution for Energy Availability at the Coastal Region. Study Case: Coastal of Panimbang – Ujung Kulon, Banten, Indonesia

Singgih Adi Prabowo and Adi Surjosatyo

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Singgih Adi Prabowo[1, a)] and Adi Surjosatyo[2, b)]

[1] *Departement of Energy System Engineering, Faculty of Engineering, University of Indonesia, Depok, 16424, Indonesia.*
(*use complete addresses, including country name or code*).
[2] *Departement of Mechanical Engineering, Faculty of Engineering, University of Indonesia, Depok, 16424, Indonesia.*

[a)] *Corresponding author: singgih.adi@ui.ac.id*
[b)] *adisur@eng.ui.ac.id*

Abstract. The Level of necessity and utilization Indonesian people's energy consumption is increasing. Indonesia is one of maritime country where several people have chosen to live in the coastal region. The coastal of Panimbang – Ujung Kulon, Banten, Indonesia have abundant of maritime renewable energy potential such as solar and wind. Potential study of maritime renewable energy in this location aims to predict the amount of electrical energy that can be generated by solar and wind. By designing Large Scale Floating Photovoltaic (LFPV) and Wind Turbine System (WT) with the capacity of 5.5 MWp and 1 MW respectively, are the way to take advantage of the available maritime renewable energy potential. This research, using survey method for obtaining the primary data and using the help of energy calculation software. Primary and secondary data from solar irradiation and wind velocity are used in this research to find out how much energy can be produced by hour and annually. HelioScope is used to calculate annual solar energy produced, meanwhile Homer software is used to find out total energy produced like solar, wind and the utility grid. The electrical energy generated by solar, and wind is 6.835 GWh/year (9.79%) and 0.567 GWh/year (0.812%) respectively, whereas electrical energy that supplied from the grid are 62.415 GWh/year (89.4%). Therefore, maritime renewable energy potential in the coastal of Panimbang – Ujung Kulon, Banten can be supply medium voltage utility grid as much as 7.402 GWh/year or 10.6% of the grid composition. Maritime Renewable Energy integration will have an impact on reduce CO_2 emission up to 6,491.55-ton/year CO_2. This research as a preliminary study to develop studies that will be carried out in the future at this location.

INTRODUCTION

The Level of necessity and utilization Indonesian people's energy consumption is increasing. Electrical energy is energy that generated from primary energy that was converted through mechanical, chemical or another conversion. Electrical energy that generated in the Indonesia majority source power plant that using fossil fuel, where about 48% supplied by coal power plant source [1]. The energy utilization with fossil fuel will have an impact to carbon emission to the environment. One effort to reduce carbon emission is by implementing clean energy, namely renewable energy power plant implementation.

Indonesia is one of maritime country where several people have chosen to live in the coastal region. One of them is on the coast of Panimbang – Ujung Kulon, Banten, which is the object of this research study. The activity and electrical energy use on the coast region are high. Many peoples use the electrical energy for supporting their life, such as a household activity, business, and tourism. To fulfil electricity utilization on the coast of Panimbang - Ujung Kulon region, PT. PLN (Persero) ULP Labuan services peoples for supporting the electricity supply availability in this coastal region. The electricity utility grid that supplied by PT. PLN (Persero) ULP Labuan just only relies on one source of electricity energy, there is Menes substation. Even though if that look to the around condition of nature and potential energy, this location has abundant potential nature energy. The length of medium voltage electrical utility grid from upstream to downstream can reach 88 km [2], therefor can cause the voltage quality to be low due to the voltage drop. The value of voltage drops at the downstream grid is under to 10%, this explains that the condition at the downstream grid is below the national standard, which has been set by the Ministry of Energy and Mineral Resources Republic of Indonesia [3].

Medium voltage electrical utility grid located on the coast of Panimbang – Ujung Kulon, Banten, has abundant of potential maritime renewable energy such as solar and wind energy. The coast of Panimbang – Ujung Kulon has high of potential solar irradiation that reach 1398.6 W/m2. On this coastal location, it has also the surface of the sea that has the low wave [4]. The condition of low wave caused by this location geographically protected by the cape namely Tanjung Lesung. The low wave condition makes it to an interesting object study to build a Large Floating Photovoltaic (LFPV) Power Plant on this location. Besides the high condition of the solar energy potential, this region has wind energy potential categorized as good by wind velocity more to 5 m/s at the height 50 m above the ground [5]. Whereas at the height 100 m above the ground, the average of wind velocity of Banten is 6.56 m/s [6]. The good wind velocity category has a potential to be one object to wind energy utilization as a power plant. Therefore, the coastal of Banten especially on the coast of Panimbang – Ujung Kulon region has abundant of nature energy potential.

Renewable energy utilization as an electrical energy source is one of more actions to reduce greenhouse gas (GHG) emission, one of which is CO2. To reduce greenhouse gas emissions, PT. PLN (Persero) doing transformation towards energy transition. In transformation value, PT. PLN (Persero) has core value "green" on the program of PLN Transformation [7]. One of that programs, PT. PLN (Persero) has committed to reducing the usage of coal power plant by the retirement of coal power plant start on year 2025 and also built renewable energy power plants [8].

The research about the utilization of renewable energy studies has much done. Rifka Sofianita et al, has researched related to the implementation of renewable energy utilization on the coast of Bungin, Bekasi [9]. The renewable energy usage on the rural will helps to supply the electrical energy to the utility grid. One of the positive impacts is to improve voltage drop value at the utility grid [10] that located away from the electrical energy source. Ramadhoni et al, studied renewable energy integration by the solar and hydro with the utility grid in Yogyakarta. That research contains with the study case from hybrid systems that consist of hydro and solar have connecting to the utility grid [11]. Sumartono et al, modelling the hybrid energy systems in Sumbawa Island and calculating for estimating energy produced by using HOMER. That research resulting the composition of energy produced, such as solar (4.4%), wind turbine (20.3%), hydropower (74.4%), biomass generator (0.8%), two generators set as a backup supply (0.1%) and able to reduce CO2 emission as much 99.75% [12].

By the explanation before, this research has focus studied relate to availability of potential renewable energy on the coast of Banten especially at the coast of Panimbang – Ujung Kulon, Banten. Research related to the study of maritime energy potential can be used as an initial study to develop studies that will be carried out in the future at this location. The limitation conditions of utility grid that caused by limited electricity energy supply was a problem in the coastal region, whereas at that location has much potential energy.

METHODOLOGY

The research methodology is used to carry out research conduct systematically. This research uses several methods of implementation, it has literature study, primary and secondary data collection by doing survey method, design and calculates the capacity of maritime renewable energy which allows, and by doing analysis. Analysis is done by the calculate output power and output energy produced from renewable energy, which then to compare and combined with the electrical energy produce that generated by the utility grid. Research flow diagram shown on Figure 1.

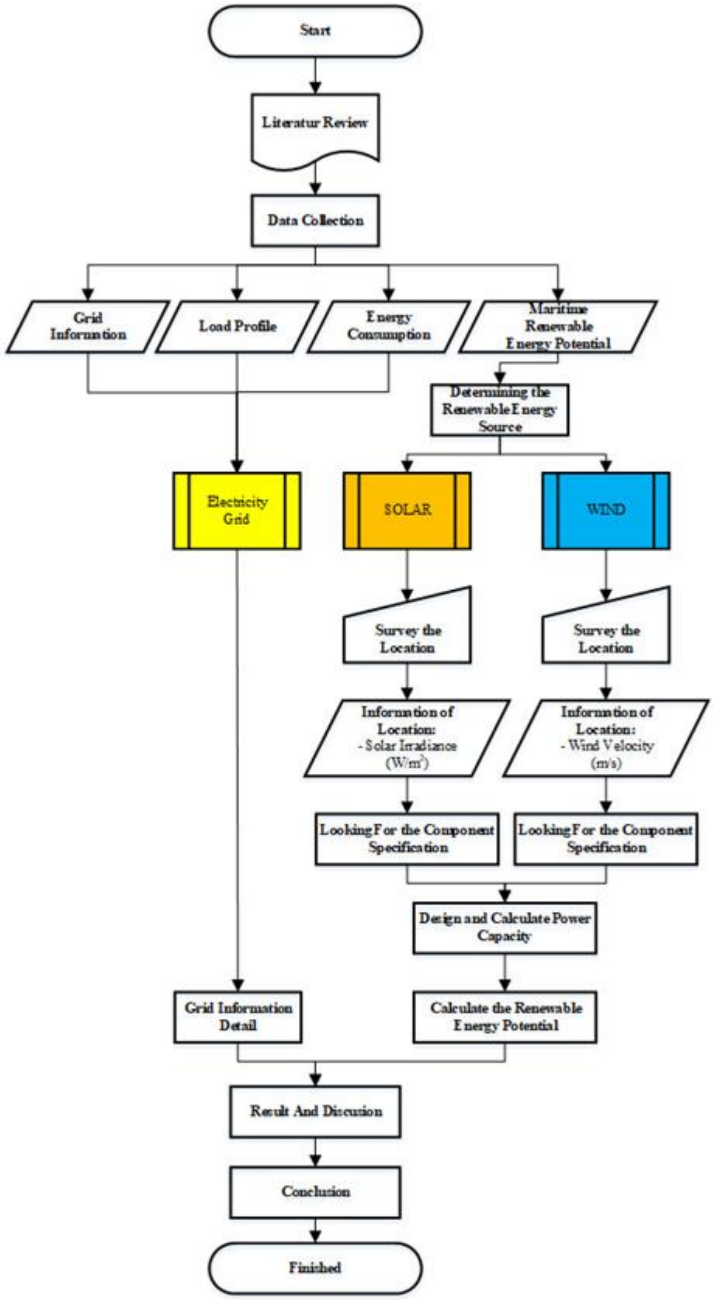


FIGURE 1. Research methodology

Utility Grid Data Collection

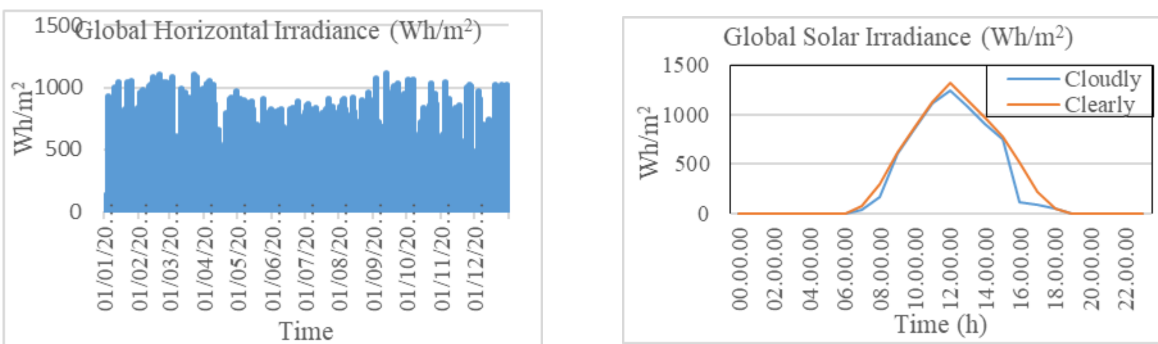
The Utility grid data collection is done by collecting the data related to the condition of the medium voltage utility grid on the coast of Panimbang – Ujung Kulon, Banten. These data, obtained by electricity utility companies in that region such as PT. PLN (Persero) ULP Labuan. The required data are medium voltage utility grid geographical condition, load profile, energy consumption, and the problems have on the utility grid. The load profile and energy consumption of medium voltage utility grid are shown on Figure 2.

(a) (b)

FIGURE 2. (a) Annual load profile of medium voltage utility grid, (b) Annual energy consumption of medium voltage utility grid.

Solar Energy Data Collection and Calculation

The solar irradiation data that used in this research are using 2 types of data as a comparison. Solar irradiation data that used in this research are primary and secondary data. Primary data that used to obtain by means direct measurement of the research location by using device solar power meter. Whereas secondary data that used in this research are the range of solar irradiation data by 10 years (1998-2009) on the form of TMY2, TMY3, or EPW that was obtained by Meteonorm [13] [14]. Primary data are used to analyze solar energy output in the short-term range such as an hourly range in a day. Whereas secondary data are used to analyze solar energy output in the long-term range such annually.



(a) (b)

FIGURE 3. (a) Annual Global Horizontal Irradiation (GHI), (b) Hourly Global Horizontal Irradiation (b)

The equation that used to calculate electrical energy produced by solar energy in this research shown by equation (1), (2), and (3). Equation (1) is used to calculate how much the power of solar power plant can be produced, equation (2) is used to calculate how much the electrical power can be produced, and equation (3) is used to calculate how much the electrical energy can be produced.

$$P_{PV} = f_{PV} \times Y_{PV} \times \frac{G}{G_{STC}} \tag{1}$$

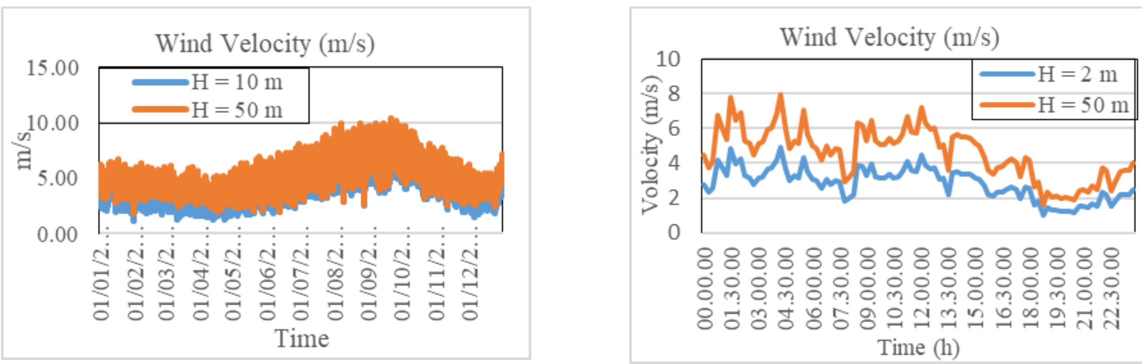
$$P_{electric} = \eta_{system} \times P_{PV} \tag{2}$$

$$E_{electric} = P_{electric} \times t \tag{3}$$

Where P_{PV} is power (kW) that produced from solar energy, f_{PV} is derating factor (%), Y_{PV} is maximum output power (kWp) of solar power plant when operate on standard test condition (STC), G is the amount of solar irradiance at the particular time (W/m^2), G_{STC} is solar irradiance at the standard test condition (1000 W/m^2) [15]. $P_{electric}$ is electrical power was produced (kW), η_{system} is system efficiency (%), $E_{electric}$ is electrical energy was produced (kWh) and t is time (h). This research, in designing and calculating energy generated from solar energy by using HelioScope and Homer application. Both are used to predict electrical energy output that produced by equipment with certain specification.

Wind Energy Data Collection and Calculation

The wind velocity data that used in this research are using 2 types of data as a comparison. Wind velocity data that used in this research are primary and secondary data. Primary data that used to obtain by means direct measurement of the research location by using an anemometer at height 2 m above the sea. Whereas secondary data that used in this research are average of wind velocity data with a range of 10 years (2004-2015), this data was developed by the Ministry of Energy and Mineral Resources (MEMR) in collaboration with Denmark researcher (DANIDA) [15]. Primary data are used to analyze wind energy output in the short-term range such as an hourly range in a day. Whereas secondary data are used to analyze wind energy output in the long-term range such annually.



(a) (b)

FIGURE 4. (a) Annual average wind velocity (m/s), (b) Hourly average wind velocity (m/s)

The equation that used to calculate electrical energy produced by wind energy in this research is shown by equations (4), (5), (6), (7) and (8). Equation (4) is used to calculate how much wind velocity at the particular height, equation (5) is to calculate wind energy density, equation (6) is used to calculate wind power, equation (7) is used to calculate the wind power that was converted by the wind turbine, and to calculate how much electrical energy will be generated are using equation (3).

$$\left(\frac{v}{v_0}\right)=\left(\frac{H}{H_0}\right)^{\alpha} \tag{4}$$

$$\frac{P_{wind}}{A}=\frac{1}{2}\times\rho\times v^3 \tag{5}$$

$$P_{wind}=\frac{1}{2}\times\rho\times A\times v^3 \tag{6}$$

$$P_{WT}=\frac{1}{2}\times C_p\times\rho\times A\times v^3 \tag{7}$$

$$P_{electric}=\eta_{system}\times P_{WT} \tag{8}$$

Where v is wind velocity (m/s), v_0 is wind velocity at the particular (m/s), H is height of the location (m), H_0 is height of the location at the particular (m). α is wind friction coefficient, P_{wind} is wind power (W), ρ is air density

(1.225 kg/m^3), A is wind swept area (m^2), P_{WT} is wind power converted by the wind turbine (W), and C_p is betz constant where maximal value is 0.59. This research, in designing and calculating energy generated from wind energy by using Homer software. Homer was calculated electrical energy generated for one year. Therefore, by the input data that was obtained, the output of electrical energy could be predicted as approach the system for designing at future.

Survey and Selecting the Locations

The next method that used in this research is surveyed and selected the location of research. Selecting the location of research divided by two, the location of the potential installation of a large scale floating photovoltaic which has the low sea waves level and selection of wind turbine installation location which has large wind potential. Selected the location of the potential installation large scale floating photovoltaic is determined by an interview with the local people, which related to the historical sea wave level. The location that was chosen located at the gulf of Tanjung Lesung (-6.510450, 105.689163). Selected the location installation of wind turbine determined by looking for data reference that has high wind velocity, these data are caried out by using satellite. After the potential of wind location was obtained, the next step is doing a survey and measure the wind velocity directly to obtain thse primary data in the form of the wind velocity profile within 24 hours. The location that was chosen located in the district of Camara (-6.618229, 105.621185). The location that was chosen to carry out the research is shown by Figure 5.and Figure 6.

(a)

(b)

FIGURE 5. (a) Location of Large Scale Floating Photovoltaic (LFPV) implementation research, (b) Solar irradiation data collection.

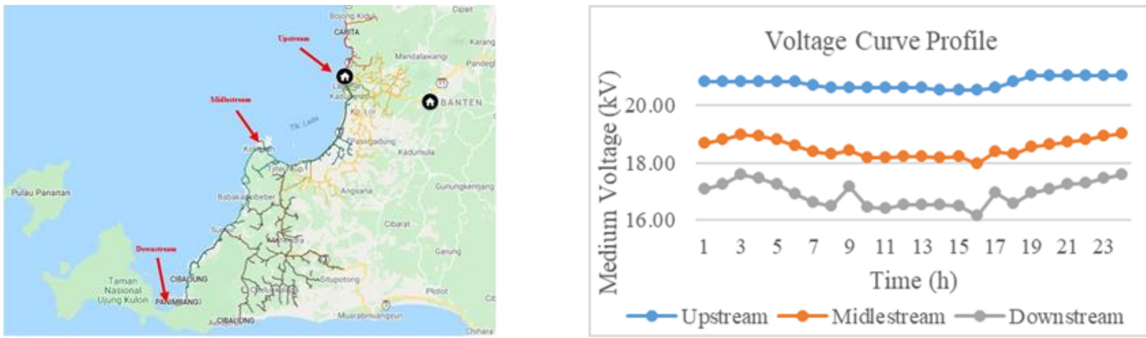
(a)

(b)

FIGURE 6. (a) Location of wind turbine implementation research, (b) Wind velocity data collection

RESULTS AND DISCUSSION

The medium voltage of the utility grid across the coast of Panimbang - Ujung Kulon is supplied by the Panimbang feeder. This feeder was operated by a medium voltage utility grid with 20 kV voltage operation. The Panimbang feeder is supplied by Menes substation, where located at Caringin. The distance medium voltage utility grid on the Panimbang feeder from the upstream to downstream of the grids are more or less than 88 km [2]. The voltage profile of the medium voltage utility grid on the coast of Panimbang – Ujung Kulon is shown in the Figure 7. In the Figure 7, that was shown 3 points such as upstream, middle-stream and downstream. The profile of voltage drop on the Figure 7(b) was shown on the hourly range in a day. The voltage drop profile on the medium voltage utility grid at the coast of Panimbang - Ujung Kulon is shown on Figure 7 (b). On the Figure 7 (b), there are represented the voltage profile at the 3 points such as up-stream, middle-stream and down-stream. The voltage drop profile shown on hourly time range a day. The voltage drop profile shown in the Figure 7 (b) is showing that the voltage drop value at the down-stream of the utility grid is below the 10%. It explains that the condition of voltage value in down-stream of utility grid was bellowed standard according to the national standard which have been set by the Ministry of Energy and Mineral Resources (MEMR) Republic of Indonesia [3].



(a) (b)

FIGURE 7. (a) Map of medium voltage utility grid on the coast of Panimbang – Ujung Kulon, (b) The voltage drop profile of medium voltage utility grid.

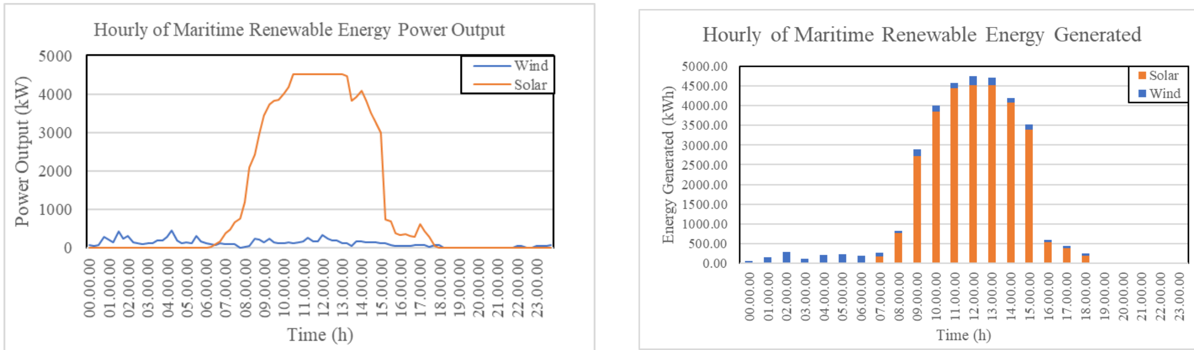
Indonesia is a maritime country that has the second longest coastline, after Canada [16] with a coastline of 99,093 km [17]. Conditions in coastal areas can be said to have good wind potential, especially on the coast of Banten. On the coast of Banten there are areas that have the potential to build Large Floating PV and wind turbines. The potential generation capacity of solar and wind energy that can be built is shown in Table 1.

TABLE 1. Specification of Maritime Renewable Energy Capacities.

Information	Large Floating Photovoltaic (LFPV)	Wind Turbine (WT)
Capacity of Power Plant	5.5 MWp	1 MW
Capacity per Unit	550 Wp	100 kW
Number of Unit	10000	10
Capacity of Inverter	5 MW (AC)	-
Capacity of Inverter per Unit	1 MW (AC)	-
Number of Inverter	5	-

The potential of maritime renewable energy on the coast of Panimbang - Ujung Kulon is abundant and consists of various kinds. Maritime renewable energy sources available on the coast consist of solar and wind energy sources. The hourly power and energy profile that can be produced in a day is shown in Figure 8. This hourly power and energy profile uses calculations of primary data, namely the results of measurements of solar irradiation and wind speed at the site. The electrical power that can be generated by wind energy varies greatly in the hourly range. Wind energy is energy, whose natural source is intermittent so that the electrical energy produced is varied. As for solar energy, the power generated also depends on the presence of solar energy sources. Solar energy is intermittent because it depends on local weather conditions.

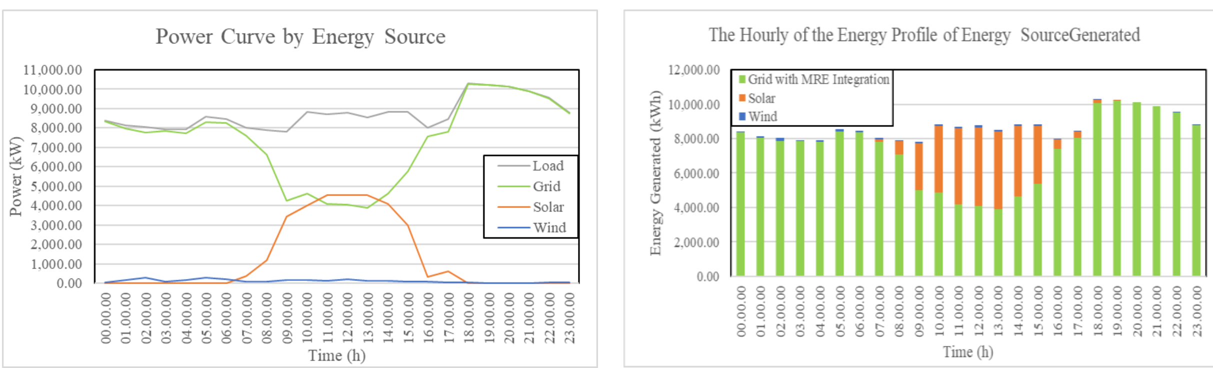
Figure 8 (a) shows the output power of the wind turbine and floating solar power plant. When the renewable energy generator is operating, the wind turbine is capable of producing an output power of 17.82 kW to 289 kW, while the floating solar power plant is capable of producing an output power of 2.26 kW to 4,522.65 kW. Wind turbines are able to supply energy from 00.00 to 18.00 variously. Wind turbines when the time enters 18.00 to 00.00 are relatively unable to supply electrical energy, especially when the peak load is at 18.00 to 22.00. The Large Scale Floating Photovoltaic is able to supply electrical energy only from 06.00 to 18.00. The amount of electricity generated by floating solar power plants depends on the level of local solar irradiation. Figure 8 (b) shows the energy calculation data that can be generated by maritime renewable energy. The figure shows that solar energy dominates the daily energy supply when compared to wind energy.



(a) (b)

FIGURE 8. (a) Hourly of maritime renewable energy power output, (b) Hourly of maritime renewable energy generated.

The prediction of the power curve of the medium-voltage utility electricity system with calculations using primary data can be shown in Figure 9 (a). The figure shows each power curve based on the power of each energy source and also the system load. The power curve shows that the majority of the grid still supplies medium-voltage utility grid. The output power of wind turbines and floating solar power plants tends to fluctuate and supply power depending on local conditions. At peak load when starting at 18.00 to 22.00, the utility grid plays a very important role in supplying electricity. The supply of grid electricity will decrease when the supply of maritime renewable energy increases. Grid electricity supply will be minimized when maritime renewable energy supplies electricity at its maximum condition. Figure 9 (b) shows a curve regarding the energy supply from each source. This curve is obtained from the calculation of the utility grid primary data and also direct measurements of wind speed and solar irradiation. On this curve, wind, solar and utility grid energy in a day can only supply 1,727.99 kWh (0.88%), 29,576.98 kWh (14.15%), and 177,760.66 kWh (85.03%) respectively.

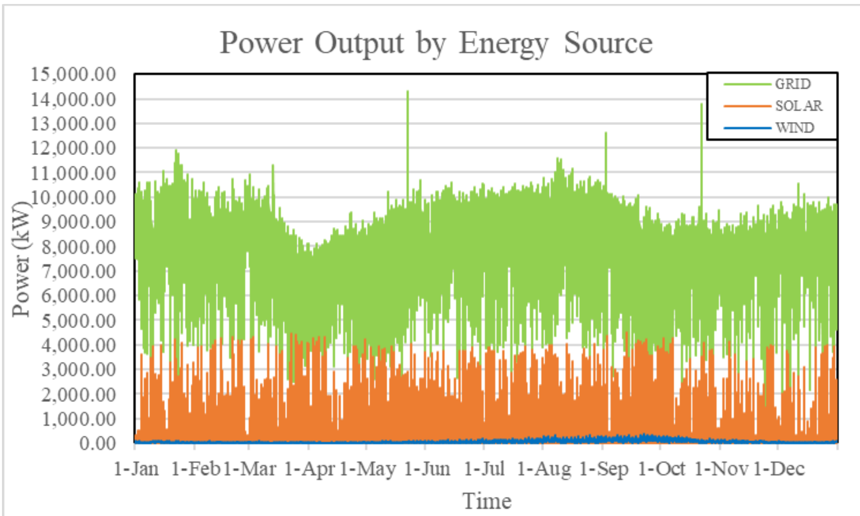


(a) (b)

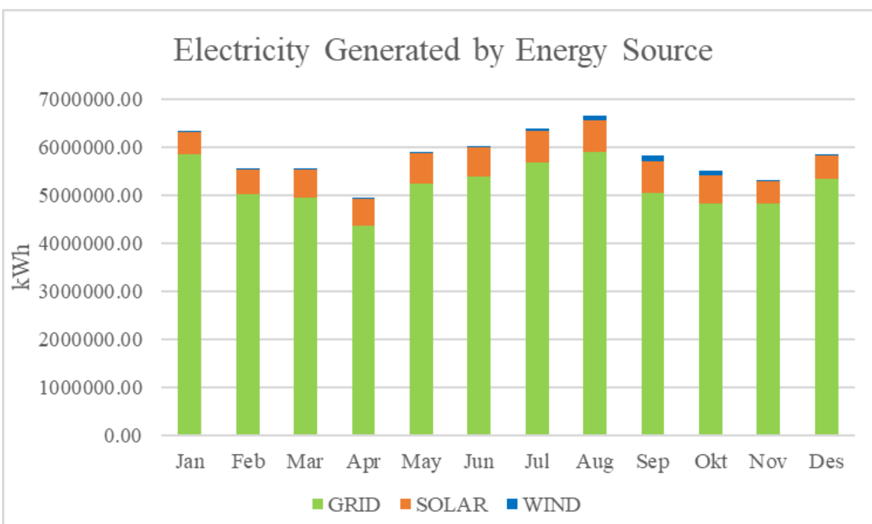
FIGURE 9. (a) Hourly of power curve by energy source (b) Hourly of energy profile by energy source generated.

The power curve calculated from hourly primary data obtained at the research site, such as solar irradiation and wind speed can be useful for describing the characteristics of a maritime renewable energy generating system. The obtained power curve can also function to predict and represent a general picture of the characteristics of maritime renewable energy on the coast of Panimbang - Ujung Kulon. Figure 9 (b) shows that solar energy supplies more electrical energy than wind energy. Solar energy is able to supply electrical energy optimally during the day, while wind energy is almost able to supply electrical energy all the time with varying values.

In this research, the results obtained in the form of the amount of electrical energy that can be generated from maritime renewable energy for a year based on the need for electrical energy on the coast of Panimbang - Ujung Kulon. The total electrical energy that can be generated in a year is obtained by performing calculations with the help of Homer and Helioscope software. In this calculation, predictions or estimates of energy that can be generated in a year are obtained using secondary data. Figure 10 shows the production of electrical energy from solar, wind and utility grids monthly in a yearly prediction. Based on the simulation results, the electrical power that can be generated in a year by the solar energy is 0.02 kW to 4.511.83 kW. The electrical power that can be generated in a year by wind energy is 6.22 kW to 366.85 kW, and the electrical power that can be supplied by the grid utility is 0 kW to 14,293.63 kW. The simulation results for a year's output power are shown in Figure 10 (a). The electrical power that can be supplied by wind is relatively small when compared to the grid and solar. Wind power will be maximum when in September, where in that month the wind frequency in September is so high that it can generate electricity up to 366.85 kW. The maximum electric power will reach 4,511.83 kW in September. In other words, the electrical energy produced from renewable maritime energy will operate maximally when it is in September, where in that month the conditions of solar irradiation and wind speed are relatively high. This states that the electrical energy generated from solar and wind depends on the weather and geographical conditions, both of which are dependent on local conditions.



(a)



(b)

FIGURE 10. (a) Annual power output by energy source, (b)Annual electricity generated by energy source.

Figure 10 (b) shows the total electrical energy that can be supplied from each energy source each month. The energy demand on the coast of Panimbang – Ujung Kulon is very high when it is in August. Electrical energy produced by solar is relatively high from May to October, while electrical energy generated by wind is relatively high from

August to October. This shows that electrical energy generated from Maritime renewable energy will help supply electrical energy in August where the energy demand in this coastal area is quite high. The total electrical energy that can be supplied by solar and wind for a year based on Homer's calculations is 6.835 GWh/year (9.79%) and 0.567 GWh/year (0.812%) respectively. Electrical energy supplied by the grid is 62,415 GWh/year (89.4%). The total electrical energy produced by maritime renewable energy is 7,402 GWh/year (10.6%), which can reduce CO_2 from the utility grid electricity system by 6.49 tons of CO_2 per year.

CONCLUSION

This study examines the potential of maritime renewable energy on the coast of Panimbang - Ujung Kulon with a large enough potential for wind and solar energy. The research was conducted using a survey method for primary data collection and also analysis using secondary data. Homer and Helioscope are used to calculate energy production from solar and wind energy for a year based on secondary data that has been obtained. From the results of the research, the amount of electrical energy that can be produced by solar and wind is 6.835 GWh/year (9.79%) and 0.567 GWh/year (0.812%) respectively. The utility grid supplies electricity needs in the coastal area of Panimbang-Ujung Kulon by 62,415 GWh/year (89.4%). The total electrical energy produced by maritime renewable energy is 7,402 GWh/year (10.6%), which can reduce CO_2 from the utility grid electricity system by 6.49 tons of CO_2 per year.

In this research, a graph of the power profile that can be supplied by solar, wind and utility grids is obtained in the hourly range. The graph can be used as a reference profile and reference data when this system will be implemented in the future. The utility grid provider, namely PT. PLN (Persero) ULP Labuan can use power profile graph data to find out the grid system when maritime renewable energy is connected to the utility network. From this data, it can be used as further processed data related to the effect of power supply from maritime renewable energy to improve voltage drops at the end of the medium voltage utility network of PT. PLN (Persero) ULP Labuan. And this research can be considered in the use of energy storage systems when the electrical system receives a large amount of electrical energy when the need for electrical energy is minimal which can be used at peak loads.

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