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WALL-e (WATERFALL ENERGY): POWER PLANT DEVICES IN WATERFALLS AS A SOLUTION TO THE ENERGY CRISIS ON BAWEAN ISLAND

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Abstract

Abstract—Indonesia is one of the twenty largest countries that use electricity in the world. 80% of energy in the world is also used as energy fulfillment in Indonesia. But unfortunately, the fulfillment of electricity in Indonesia has not been fulfilled. According to the Global Trafficking Framework Report, there're still 14 million Indonesians who don't have access to electricity (ranking 19th out of 20 countries). Indonesia ranks 4th out of 20 countries as the country that uses the most solid energy (fossil-based energy). Solid energy used is almost used up if there are no sustainable programs on renewable energy for the next 23 years. Therefore, it needs concrete steps to create renewable energy. At present Indonesia is being vigorously calling for renewable energy from nature. Indonesia, which is rich in local wisdom, can be managed again so that it's worth more like waterfall. One of the islands in Indonesia that has a waterfall and is experiencing a power energy crisis is a bawean island. Bawean Island is located in the northern part of Gresik district, East Java, Indonesia. The area is a remote area with minimal lighting. Dozens of villages on the island of Bawean have not yet been electrified. In fact, the island has waterfall that can be managed further so it is worth more. The most potential part of generating electricity is the flow of waterfalls. The waterfall will flow into the river around it. A series of WALL-e (Waterfall Energy) consisting of a Tesla Turbine which connects to a generator, is placed on a stream of waterfalls that will flow into the river. Water will go into the circular space inside the Tesla Turbine and move the rotation path in the middle of the turbine with a magnet inside. This rotation will be faster because the energy comes not only from the flow of water but also from the magnet. This rotation will drive the generator so that the generator can produce electricity. The water that goes into the Tesla Turbine still spray out and flow towards the river. The resulting electrical energy is connected with parallel circuits to economize the device and produce maximum stream. Furthermore, the energy stored in the capacitor is used as a source of lighting on Bawean island. The ease of the Bawean island society accessing electricity can help develop the potential of local wisdom, improve the economy, and as a form of technological application in everyday life.

Keywords

Bawean Island, Power Energy, Tesla Turbine, and Waterfall

1. Introduction

ALONG with population growth, needs of energies electricity fulfillment and the ingredients even more big fuel. Recently, Indonesia ranks 4th out of 20 countries as the most widely used solid energy (energy of fossil raw materials). Solid energy used is almost used up if there are no sustainable programs on renewable energy for the next 23

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years. Therefore, it’s needed as like alternative energy that can be regenerated. Besides it could renewable, it also need alternative source energy ecofriendly and the cheapest cost.

Electricity energy have role important in effort to improve quality life and economy growth in Indonesia, see [1]. Indonesia is one of twenty major electricity user countries in the world. But unfortunately, the fulfillment of electricity in Indonesia has not been fulfilled. According to the *Global Trafficking Framework Report* [1], there are still 14 million Indonesians who do not have access to electricity (ranking 19th out of 20 countries). Limitations provision electricity energy is one of obstacles in development and development society especially in the rural area, see [1]. One of example is an area in Gresik district, namely Bawean Island that owns source potential water power relatively stable all along the year because it is near water sources in protected forests. Local society activity still very difficult to develope because without existence of adequate electricity supply although small part of the community get electricity supply from Pembangkit Listrik Tenaga Diesel (PLTD aka. Diesel Power Plant) which is the fuel material from solar. So, on this research will made simulation of the Bawean Island condition with develop ecofriendly power plant, that is Pembangkit Listrik Tenaga Mikrohidro (PLTMh aka. Generator Electricity Power Microhydro) as a source of energy supply. Water source for PLTMh will use flow river sourced of Laccar, Talomon and Gurujukan waterfalls each there are in Sangkapura and Tambak sub-districts. Large Forest protected Bawean is 4,556.6 ha consisting of 3,831.6 ha of forest wildlife reserve and 725 ha of nature reserve forest. This determination based on Surat Keputusan Menteri Pertanian number 762 / Kpts/ Um / 12/1979.

The potential thing of small scale electricity generator is PLTMh, which is the implementation from the Green Energy Initiative, namely push renewable energy, efficiency energy and clean energy. The PLTMh development program aims for encouraging economy activities in the society especially in potential sites but not yet optimized. PLTMh has several advantages compared to other power plants, clean for the environment, no consumptive against use of water, more durable (long lasting), its operation costs more small and corresponding for remote area. Based on these conditions, research is carried out with a research focus to provide an overview and initial information about the potential of hydropower as a basis for planning and building PLTMh. This research contain discussion something and planning PLTMh, start from measurement and debit calculation, high waterfall, calculation power output, selection turbine, selection of generators as well as it will describe more location details that are having potential to develope PLTMh, with means it gives away benefits for making PLTMh design in order to increase availability of electricity for rural areas in Indonesia.

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2. Research Methods

The research method used in this study uses data collection techniques with direct observation and literature studies. The first step is to map the flow of the waterfall, map the position of the potential waterfall, and map the distance of the waterfall from the nearest village with the help of Google Earth. After that, determine the value of the current discharge from each waterfall by direct observation using a simple method. This method uses a 1.5 liter water bottle, then dips it on the water surface and determines the time needed until the bottle is fully filled. Following is the flowchart of the methodology that will be carried out in this paper:

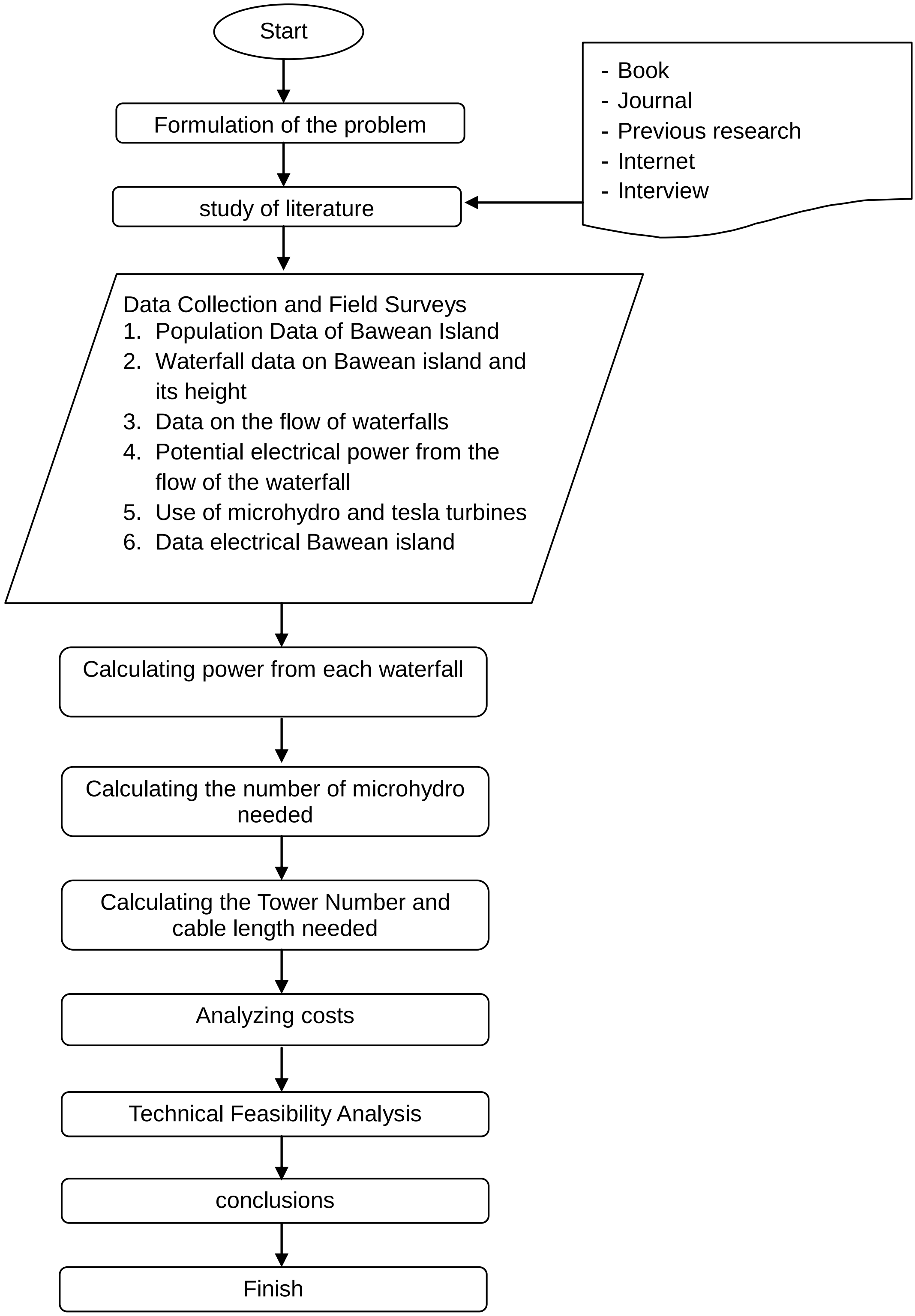

Fig. 1. Flowchart of Research Methods

3. Results and Discussion

Bawean Island is an island in the north of Gresik Regency and is still included in the Gresik Regency. Bawean Island has two sub-districts, namely Sangkapura and Tambak sub-districts. Although it is close to Gresik, the availability of electricity is still inadequate or inadequate for people's daily needs. Electricity can only be felt by the community for less than 12 hours per day. However, Bawean has the latest potential for new energy sources from waterfalls. Bawean has several waterfalls, and there are 3 waterfalls that have the potential to become new renewable electricity sources as an effort to develop Energy Independent Villages.

So far, the Bawean island uses Diesel power plants with a capacity of 1.5 megawatts and 1 megawatt respectively to meet their electricity needs. In addition, there has been a PLTMG with a total capacity of 3 megawatts. The two plants have not been able to supply the electricity needs of Bawean Island, which has a peak load of 4.8 megawatts. Based on BPS data [5], the number of households living on Bawean Island is 24,106 households. This figure is a fairly large number if the total available energy is only 3 megawatts. The PLN data states that the average electricity consumption of customers is 124 Kwh / month, so if calculated in outline electricity is needed as much as 4 kWh / day / KK. There are 7,130 families in Tambak sub-district and 16,976 households in Sangkapura sub-district, so that the total households have 24,106 families on Bawean island, so the total electricity needs are 24,106 x 4 = 96,424 Kwh / day.

The natural potential of Bawean island which can be utilized more is the waterfall. Bawean Island has many waterfalls that have not been utilized optimally, including Laccar, Talomon, and Gurujukan waterfalls. Laccar waterfall is 380 - 500 m from Daun village, Sangkapura sub-district. Laccar waterfall is very suitable to be used again because it has a height of approximately 25 m while the flow has a fairly large discharge as a power plant. The second waterfall is Talomon Waterfall. Talomon Waterfall was chosen because of its heavy discharge and its distance from Suwari village to only 100-400 meters. The third waterfall used is Gurujukan waterfall. Gurujukan is very suitable because the distance to Grejek village is only 500m and to Peromaan village is approximately 700m.These three waterfalls are very suitable to be reused because they are quite close to people's homes so that the operation and maintenance costs can be reduced and their potential as a power plant is very large. From the flow of this waterfall, it can be converted into potential energy which will later be converted into electric power with the help of Tesla Turbine and Microhydro. A series of tools are used as follows:

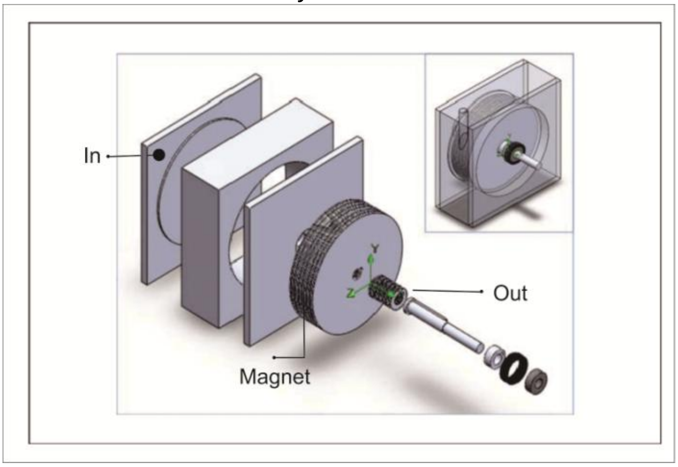

Fig. 2. A series of Tesla Turbine (source : [4])

The purpose of this study is to maximize the flow of water with microhydro and tesla turbines. Micro Hydro is a power plant that comes from water energy. The greater the flow capacity or heightfrom the installation, the greater the energy obtained for produce electricity. MHP is a power plant a type of *run of river* where the *head* (falling height of water) is obtained by diverting river flow to one side of the river , then drain it again to the river in a place with a high difference adjusting. Water supplied to *the power house* (house plants) are usually built on the edge of the river. The water will rotate the turbine blade (*runner*), then the water is returned to its original river. Mechanical energy from shaft rotation the turbine will be converted into electrical energy by a generator [3] .

The next microhydro is combined with tesla turbine. Tesla turbine is the concept of speeding up the frequency of rotation that can be utilized in optimizing the work of an electric generator.The research method used in this study uses data collection techniques with direct observation and literature studies. The first step is to map the flow of the waterfall, map the position of the potential waterfall, and map the distance of the waterfall from the nearest village with the help of Google Earth. After that, determine the value of the current discharge from each waterfall by direct observation using a simple method. This method uses a 1.5 liter water bottle, then dips it on the water surface and determines the time needed until the bottle is fully filled. Calculate the debit value by formula :

$$Q = \frac{V}{t}$$

with,
Q= Flow Rate (liter/s)
V= Volume (liter)
T = time (s)

After that, determine the water flow in each water stream by comparing branches with attention to the width of each stream. Determination of this discharge will be an ingredient in mapping the potential of waterfalls.

Next is the location of each microhydro in the Laccar, Talomon, and Gurujukan waterfalls:

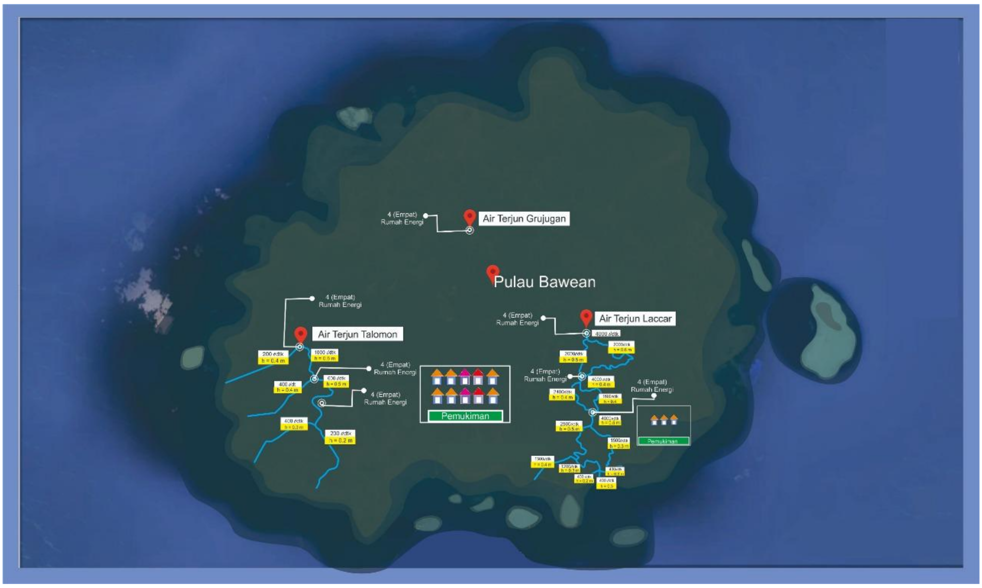

Fig. 3. Distribution of energy houses in Bawean island (source: [6])

This idea chose three waterfalls namely Laccar waterfall, Talomon waterfall and Gurujuk waterfall. The selection of the three waterfalls is due to the proximity and proximity of the residential area and the main point is the value of the potential power produced is very large. The concept is that we choose a number of points to build an Energy House along the flow of the river waterfall.selection of this point by reason of the potential flow to create greater energy. Energy house is a house beside the river flow that will be flowed by river water which is useful for microhydro and energy production sites of Mikrohydro-Tesla Turbine .

So far, the application of Microhydro is only by using baling wheels placed on the surface of the water. With this method, based on our calculations, to meet the electricity needs of the Bawean people need around 7 Micro-hydro in each Energy House. However, if it is innovated by applying tesla turbine to microhydro, 30% efficiency will be obtained and to meet the electricity needs of the bawean people need 4 microhydro in each energy house.

Calculation of Electric Power Potential for each location

1. Laccar Waterfall
   $h1 = 61.7\, ft \approx 25\, m$
   $h2 = 0.4\, m$
   $h1 = 0.5\, m$
   $Q_1 = 4000\, liter/s = 4\, m^3/s$
   $Q_2 = 4000\, liter/s = 4\, m^3/s$
   $Q_3 = 4000\, liter/s = 4\, m^3/s$
   $P_1 = 9.8\ \times Q \times h \times Eff = 9.8\ \times 4 \times 25 \times 80\% = 784\ \mathrm{kW}$
   $P_2 = 9.8\ \times Q \times h \times Eff = 9.8\ \times 4 \times 0.4 \times 80\% = 12.544\ \mathrm{kW}$
   $P_3 = 9.8\ \times Q \times h \times Eff = 9.8\ \times 4 \times 0.5 \times 80\% = 15.68\ \mathrm{kW}$
   P total = 784 + 12.544 + 15.68
   = 812.224 kW
   Efficiency using tesla turbines is obtained
   130% x 812.224 kW = 1055.8912 kW
   With working hours of 24 hours, the total potential power generated is:
   $P = 1055.8912 \times 24 = 25341.3888\ \mathrm{kWh}$
2. Talomon Waterfall
   $Q_1 = 2\, m^3/s$
   $Q_2 = 1\, m^3/s$
   $Q_3 = 0.6\, m^3/s$
   $h1 = 1\, m$
   $h2 = 0.6\, m$
   $h1 = 0.5\, m$
   $P1 = 9.8\ \times Q \times h \times Eff = 9.8\ \times 2 \times 1 \times 80\% = 15.68\ \mathrm{kW}$
   $P2 = 9.8\ \times Q \times h \times Eff = 9.8\ \times 1 \times 0.6 \times 80\% = 4.704\ \mathrm{kW}$
   $P3 = 9.8\ \times Q \times h \times Eff = 9.8\ \times 0.6 \times 0.5 \times 80\% = 2.352\ \mathrm{kW}$
   $P_{total} = 307.328 + 27.65 + 6.92$
   $= 22.736\ \mathrm{kW}$
   Efficiency using tesla turbines is obtained
   130% x 22.736 kW = 29.5568 kW
   With working hours of 24 hours, the total potential power generated is:
   $P = 29.5568\ \times 24 = 709.3632\ \mathrm{kWh}$
3. Gurujukan Waterfall
   $h_1 = 4\, m$
   $Q_1 = 0.9\, m^3/s$
   $P = 9.8\ \times Q \times h \times Eff = 9.8\ \times 0.9 \times 4 \times 80\% = 28.224\, kW$

Efficiency using tesla turbines is obtained
130% x 28.224 kW = 36.6912 kW
With working hours of 24 hours, the total potential power generated is:
$P = 36.6912 \times 24 = 880.5888 \text{ kWh}$

So that, the total electrical energy produced by **Wall-e** is obtained $25341.3888 + 709.3632 + 880.5888$ = 26931.3408 kWh/day if there is one microhydro installed in each energy house.

Calculation of the number of microhydro needed

The electricity needs of Bawean Island are 96,424 kWh/day (based on calculation above) with electricity obtained from **Wall-e** equal to 26931.3408 kWh/day, so it takes as much microhydro for each energy house as :

$$\frac{96.424}{26931.3408} = 3.58036 \approx 4 \text{ pieces}$$

Details of the distribution of microhydro as follows:

Laccar Waterfall: 25341.3888 Kw → 3 points x 4 microhydro = 12 microhydro
Talomon Waterfall: 709.3632 Kw → 3 points x 4 microhydro = 18 microhydro
Gurujuk Waterfall: 880.5888 Kw → 1 point x 4 microhydro = 18 microhydro

Calculation of Tower Number and cable length needed

In the distribution of electricity in the island of Bawean, a distribution system is needed using an electricity distribution tower. Bawean Island has an area of 196.3 km^2 [4], the total tower needed to supply electricity on Bawean Island is

$$total\ tower = \frac{area\ of\ Bawean\ Island}{coverage\ area\ of\ each\ tower} = \frac{196.3}{20} = 9.815 \approx 10$$

Fig. 4. Distribution of electric towers in the Bawean island (source: [6])

The total cable length needed to flow electricity on Bawean island is obtained from the total distance between each tower and the distance of tower to the local village. Can be seen in **Fig. 4**, the total distance between towers is 38.42 km. Meanwhile, the distance of the tower to the local village counts a total of 100 km with a distance of 10 km each, assuming that each tower flows to the nearest 10 villages with a distance of the tower to one village a maximum of 1 km (based on interview result). So that the total cable length needed to supply electricity throughout Bawean Island is 138.42 km or 138420 m.

Cost Analysis

Cost planning at the Microhydro power plant installation which is installed on a stream of three waterfalls on Bawean island. The **Wall-e** series is compiled based on prices obtained from various internet sources. This cost analysis is designed with the aim of getting the selling price of electricity generated by each energy house to PLN or the cost per kWh. The following is the cost plan of Microhydro power generation:

A. Fixed Cost (FC)

TABLE I
FIXED COST (FC)

No.	Information	Cost
1	Microhydro fees	
	28 MH @ 10000000	280000000
2	Generator	
	7 Houses Energy @ 25000000	175000000
3	Cost Transmisi	
	a. Cable (138420 m)	5536800000
	b. Installation	2000000000
4	power work	
	a. 1 head Project	2076300000
	b. 3 Technicians @ 300000000	900000000
	c. 15 Staff @ 40000000	600000000
	Total	11568100000

B. Variable Cost (VC)

TABLE II
VARIABLE COST (VC)

No.	Information	Cost Unit	Total Cost
1	Care	833.3333 x 12 months x 7 MH	700,000
2	Cost Operations (technicians)	750,000 x 12 months x 1person x 7 MH	63 million
	Total		13.3 billion

Total Cost = FC + VC = 11.5681 billion + 133 million = 11.7011 billion
As known :

- Power from Wall-e = 107725.3632 kWh
- Total Wall-e operating time = 365 days (assuming 1 year = 365 days)
- Amount of kWh per year
  = average power per year x operating time
  = 107725.3632 x 365
  = 39319757. 568 kWh

- Electricity price per kWh

  $= \frac{\text{total cost}}{\text{number of kWh per year}}$

  $= \frac{11701100000}{39319757.568}$

  = 297.5883048048807 $\approx \mathrm{Rp.}\,300$,-/kWh

  (cheaper than the normal price of PLN Rp.1457/kWh).

Technical Feasibility Analysis

Location

From the previous assessment, the location chosen as the Microhydro-Tesla Turbine Power Plant is around the flow of the Laccar waterfall, Talomon and Grujuk and will be distributed throughout the Bawean area. This distribution will take place quite complicated because most of the villages are far from the waterfall, so complex installations are needed so that the entire Bawean island can be electrified.

Electricity

Power calculation data is obtained every month of the year. Then it is necessary to analyze the ability of the power supply with the average power in a year. The average power produced in a year is approximately 39,319,757,568 kW by relying on seven Energy Houses contained in several potential points. With this power can supply as much:

$$Supply\ ability = \frac{Total\ power\ in\ a\ year}{Power\ requirements\ per\ family\ in\ a\ year}$$

$$= \frac{39.319.757{,}568\ kWh}{4kWh\ x\ 365}$$

$$= 26931.3408\ kWh$$

from the results of calculations, it is known that the Microhydro-Tesla Power Plant Turbine can meet the needs of the community as many as 26931 households.

4. Conclusion

a. Based on the results of the analysis carried out it was found that the Microhydro-Tesla Turbine Power Plant was applied on Bawean Island where the design to be applied contained 7 generating energy houses so that the electricity produced was 39.319.757,568 kilowatts.

b. On average in one year the Microhydro-Tesla Turbine Power Plant that is applied in the Bawean Island area is able to supply as much as 26931,3408 households.

c. Microhydro-Tesla Power Plant This turbine is able to become an alternative source of electricity besides PLN as the main energy source on Bawean Island

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