Potential of developing an energy self-sufficient village through mini hydro powerplant technology

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Abstract. Nowadays, electricity is one of the most important need for the human life. However, in developing countries, there are some areas that are not fully covered by the electrical power. The high cost of distribution is one of the reasons behind the problem. More efforts are needed to distribute the electricity to a remote area, such as a far mountainous region. On the other hand, there is a potential to provide electrical power from a river through the development of mini-hydro powerplant technology. In this study, potential of water power in a mountainous region of West Java Province, Indonesia, is measured. The measurements were taken in three different places of river, divided by the distance from a waterfall. As a result, it is found that the potential power obtained from the rivers are ranged between 17-137 kW, which is enough for lighting up 37-304 houses, indicating there is a potential of developing an energy-sufficient village through mini-hydro powerplant technology.

1. Introduction

West Java Province, Indonesia, is rich in tourism potential. One of those tourist attractions are waterfalls, which are called Curug in the native language of Sundanese. So far, these waterfalls have solely been used as a tourist attraction through their beauty. The beauty of these waterfalls is captured through eye-catching scenery, surrounding nature, clean air or the pleasant atmosphere brought by the waterfalls. Whereas, if investigated further, within these waterfalls, there are waters that fall from a certain height. These waterworks store energy that could be converted into electricity using hydroelectric power plants. Therefore, the Curug in fact has two direct potentials, the first being its tourism potential with its beauty and the second one being the potential energy contained within its water stream. If the two potentials are utilized correctly and optimally, it will be beneficial.

Unfortunately, the idea of utilizing the potential energy clashes with the concerns of the Curug’s caretakers. The caretakers are worried that the usage of these Hydroelectric powerplants would disturb or destroy the natural beauty of the waterfalls. To solve these concerns, a new model of powerplant is needed: a powerplant that would both suffice and support both the potential tourism and potential energy. Based on those reasons, an alternative scheme for Mini Hydro Powerplants in the waterfall areas is proposed. It is expected the scheme would not only harvest the potential energy contained within the waterfalls, but it would also improve tourism potential. The waterfall that has been chosen is Curug Cipurut, located in the base of Mount Burangrang and is a part of the Burangrang Mountain.
Nature Reserve (Figure 1). Because of that, the waterfall is still managed by the Jabar I Natural Resources Conservation Center, with operations in the field being assisted by Sumurugul Village and Wanayasa Village.

Generally, the waterfall is divided into three sectors, which are the main waterfall located in the edge of the cliff with a height of approximately 25 meters, and is located in Sumurugul Village, 10 kilometres away from Wanayasa District, Purwakarta Regency, West Java Province. The area is selected because the waterfall is able to flow throughout the year, and the waterfall is located at a relatively high (700 meters) above sea levels.

![Figure 1. Curug Cipurut.](image)

2. Method

The measurement of water discharge is done by conventional methods, due to the current meter equipment desired to measure the water speed being absent. This method is done by taking samples of water in three different places. The determination of the specific locations is based on the height of the falling water and the volume of the water flow within the river channel.

The amount of electric power produced from the water current could be counted with the equation (1) [3],

\[ P_{net} = gQH_{gross}\varepsilon_o \] ................................ (1)

where
- \( P_{net} \) = net output power system (watt).
- \( g \) = gravity of earth (m/s²).
- \( Q \) = water discharge (m³/s).
- \( H_{gross} \) = gross head (m).
- \( \varepsilon_o \) = system efficiency.
The design of this research is designed so that the steps of research data collection consists of 2 groups of data collection. The first being the collection of data regarding potential water resources by reviewing their water discharge rate, demographics, area as well as socioeconomic factors, and the second being the collection of data on the amount of electricity.

The next step is to prepare a structured and systematic study design as a framework for data and information collection on site. Doing a field survey, which consists of potential water resource data, demographics and area data, socioeconomic data and electrification with the model.

3. Results and Discussion

3.1. Cipurut River Channels, a runoff from Cipurut Waterfall
The Condition of Cipurut river’s flow that has an 8560 m channel length gets water flow from waterfall runoff which wholly falls to the river. The water discharge sampling is done in three different places, namely the falling point, the rice field area—about 1.5 km from the waterfall, lastly the village—3.3 km from the waterfall. Given the lack of equipment—which is caused by the absence of the current meter—the measurement of the water discharge is done manually by collecting water in a 1-litre container. Data retrieval was done 5 times within the month of August 2019, then, the data is averaged. For each sample retrieval, the collection time is recorded (tables 1-3).

Table 1. Point 1: Cipurut Waterfall, falling point, \( H = 25 \) m.

| n-th Experiment | Volume (Litre) | Time \( \times 10^6 \) second |
|-----------------|----------------|-----------------------------|
| 1               | 1              | 1.43                        |
| 2               | 1              | 1.54                        |
| 3               | 1              | 1.56                        |
| 4               | 1              | 1.45                        |
| 5               | 1              | 1.48                        |

Table 2. Point 2: 1500 m from the waterfall, Ricefields, \( H = 10 \) m.

| n-th Experiment | Volume (Litre) | Time \( \times 10^6 \) second |
|-----------------|----------------|-----------------------------|
| 1               | 1              | 2.87                        |
| 2               | 1              | 3.64                        |
| 3               | 1              | 3.46                        |
| 4               | 1              | 3.17                        |
| 5               | 1              | 3.39                        |

Table 3. Point 3: 3300 m from the waterfall (Village). \( H = 15 \) m.

| n-th Experiment | Volume (Litre) | Time \( \times 10^6 \) |
|-----------------|----------------|------------------------|
| 1               | 1              | 6.37                   |
| 2               | 1              | 6.62                   |
| 3               | 1              | 7.41                   |
| 4               | 1              | 8.33                   |
| 5               | 1              | 7.04                   |

An example of the calculation is taken in the potential point of River Cipurut’s channel, located along with the river’s current, with the length being +/- 3000 m from the CurugCipurut Waterfall. Using the water density of 1 kg/cm\(^3\) or equivalent to 1000 kg/cm\(^3\), a calculation of the theoretical power in those points are done. Using the equation (1) above, with the assumed efficiency is 0.8, an example of the calculation is given below.
For point 1:

\[ P_{\text{net}} = gQ H_{\text{gross}} \varepsilon_o \]
\[ = 9.8 \text{(m/s}^2) \times 699.301 \text{ (m}^3/\text{det}) \times 25 \text{ (m) } \times 0.8 \]
\[ = 137.062 \text{ watt} \]
\[ = 137 \text{ kW} \]

The aforementioned power is water power potential. Using the same method, the data for points 2 and 3 are calculated. The results are shown in tables 4-9.

**Table 4.** Discharge rate calculation results, with fall height, \( H = 25 \) meters.

| n-th Experiment | Volume (lt) | Time (s) | coefficient | Discharge Rate (m³/s) |
|-----------------|-------------|----------|-------------|-----------------------|
| 1               | 1           | 1,43     | 1000        | 699,3007              |
| 2               | 1           | 1,54     | 1000        | 649,3506              |
| 3               | 1           | 1,56     | 1000        | 641,0256              |
| 4               | 1           | 1,45     | 1000        | 689,6552              |
| 5               | 1           | 1,48     | 1000        | 675,6757              |

**Table 5.** Theoretical power calculation results with fall height, \( H = 25 \) meters.

| \( \rho \) (kg/m³) | \( g \) (m/s²) | \( H \) (m) | \( Q \) (m³/s) | \( \eta \) Efficiency | Pnet (watt) | Pnet (kW) |
|---------------------|----------------|-----------|---------------|-----------------------|-------------|-----------|
| 1000                | 9.8            | 25        | 699.30        | 0.8                   | 137.063     | 137       |
| 1000                | 9.8            | 25        | 649.35        | 0.8                   | 127.273     | 127       |
| 1000                | 9.8            | 25        | 641.03        | 0.8                   | 125.641     | 126       |
| 1000                | 9.8            | 25        | 689.66        | 0.8                   | 135.172     | 135       |
| 1000                | 9.8            | 25        | 675.68        | 0.8                   | 132.432     | 132       |
| **Average Pnet**    |                |           |               |                       | **131.516.280** | 131.516   |
Table 6. Discharge rate calculation results, with fall height, H = 10 meters.

| n-th Experiment | Volume (lt) | Time (s) | coefficient | Discharge rate (m³/s) |
|-----------------|------------|----------|-------------|-----------------------|
| 1               | 1          | 2.87     | 1000        | 348.4321              |
| 2               | 1          | 3.64     | 1000        | 274.7253              |
| 3               | 1          | 3.46     | 1000        | 289.0173              |
| 4               | 1          | 3.17     | 1000        | 315.4574              |
| 5               | 1          | 3.39     | 1000        | 294.9853              |

Table 7. Theoretical power calculation results with fall height, H = 10 meters.

| ρ   (kg/m³) | g   (m/s²) | H   (m) | Q (m³/s) | η   Efficiency | Pnet (watt) | Pnet (kW) |
|----------|---------|--------|---------|--------------|-------------|-----------|
| 1000     | 9.8     | 10     | 348.43  | 0.8          | 27.317      | 27        |
| 1000     | 9.8     | 10     | 274.73  | 0.8          | 21.538      | 22        |
| 1000     | 9.8     | 10     | 289.02  | 0.8          | 22.659      | 23        |
| 1000     | 9.8     | 10     | 315.46  | 0.8          | 24.732      | 25        |
| 1000     | 9.8     | 10     | 294.99  | 0.8          | 23.127      | 23        |
|          |         | Average Pnet | 23.874.640 | 23.875    |
Table 8. Discharge rate calculation results, with fall height, $H = 15$ meters.

| n-th Experiment | Volume (lt) | Time (s) | Coefficient | Discharge rate (m³/s) |
|-----------------|-------------|----------|-------------|----------------------|
| 1               | 1           | 6.37     | 1000        | 156.9859             |
| 2               | 1           | 6.62     | 1000        | 151.0574             |
| 3               | 1           | 7.41     | 1000        | 134.9528             |
| 4               | 1           | 8.33     | 1000        | 120.048              |
| 5               | 1           | 7.04     | 1000        | 142.0455             |

Table 9. Theoretical power calculation results with fall height, $H = 15$ meters.

| $\rho$ (kg/m³) | $g$ (m/s²) | $H$ (m) | $Q$ (m³/s) | $\eta$ Efficiency | $P_{net}$ (watt) | $P_{net}$ (kW) |
|---------------|------------|---------|------------|-------------------|-----------------|----------------|
| 1000          | 9.8        | 15      | 156.99     | 0.8               | 18.462          | 18             |
| 1000          | 9.8        | 15      | 151.06     | 0.8               | 17.764          | 18             |
| 1000          | 9.8        | 15      | 134.95     | 0.8               | 15.870          | 16             |
| 1000          | 9.8        | 15      | 120.05     | 0.8               | 14.118          | 14             |
| 1000          | 9.8        | 15      | 142.05     | 0.8               | 16.705          | 17             |

Average $P_{net}$ 16.583.705 16.584

3.2. Public Socioeconomic and Electricity condition
The condition of the people surrounding the Cipurut River are mostly farmers, with a scattered and dispersed housing spread pattern, with an average of 10 households, thus with the addition of the Micro Hydro Powerplant, the distribution of loading can be in the form of loading of lighting and household appliances. The requirement of power for lighting from the calculation above from an average of 10 households where the usage in each household of 100 W is predicted to be 1000 W, or equivalent to 1 KW. Household appliances as an addition to the lighting, or for instance agricultural electrification equipment could be used with loading regulation that could be agreed upon, examples being using the power for agriculture electrification equipment in the morning and appliances at night. The table of Electricity needs parameter per household is shown in table 10.
Table 10. Electricity Needs Parameter per Household.

| Electricity Parameter            |   |
|---------------------------------|---|
| Electrical System Voltage       | 220 volt |
| Current limiter                 | 2 ampere |
| Connected electric capacity     | 450 watt |

**Usage**

| Usage                          |   |
|--------------------------------|---|
| 3 lighting spots @20 watt      | 3 x 20 watt = 60 watt |
| 4 lighting spots @10 watt      | 4 x 10 watt = 40 watt |
| Total for lighting             | 100 watt |

**Backup power needs**

| Home appliances                |   |
|--------------------------------|---|
| Electronic appliances          | 200 watt |
|                                | 150 watt |
| Total                          | 450 watt |

3.3. *Data Analysis*

From table 1, it is observed that the discharge produced is relatively high compared to the data on Tables 2 and 3. This is due to the direct discharge from the source, which is Cipurut Waterfall. However, this large discharge has disadvantages, which is the distance to the villager’s settlements is quite far away, around 3-4 km with a hilly land contour, so to install pipes or create canals with conditions like that would be very costly. Also, the maintenance of the installation pipes would be very costly. The advantage of the data from Table 1 is that the discharge would produce a large output power, considering the fall height is also significant—around 25 meters. The potential power generated is 132kW.

For point 2 form table 2, it is observed that the discharge is almost reduced by half. This may be the consequence of the water being partly absorbed by the soil, and additionally also going into wormholes, which are small channels located along the river channel. The height of the falling point was still around 10 meters, which produces a theoretical power potential of about 23,875 kW. Even so, the excess waters from the turbines could be utilized by the public for household uses or irrigating their fields. Point 2 was located in the middle between the waterfalls’ path and the village.

For point 3, the location is in the villager’s settlements, which is around 3300 meters from Cipurut Waterfall. Measurement is done on the highest point, and there is a 15-meter height difference with the lowest point in the village. With an average discharge of 141.02 m3/sec, a power potential of around 17kW is generated. The advantage of a powerplant located in the villager's settlements is that the costs for power cable transmission can be cheaper. But, due to the location of the settlement—which is located on the slope of the mountain—then the excess water can’t be used for the villager’s showering and washing needs, because the water is directly discharged to the valley.

4. **Conclusion**

Based on the results of the experiment and the study of discharge obtained, the availability of sufficient water sources with the length of the main channel being less than 8560 m, has 3 potential points.

The potential water power produced at raining seasons is around the range of 17 kW to 137 kW. Using the potential power of 17 kW, it is concluded that the Mini Hydro Powerplant is categorized as a micro powerplant, not a mini powerplant.
From the power extracted from the potential energy in the water, the ability of the powerplant to powerhouses could be calculated using a simple equation which is as follows:

\[ P_{net} = \frac{137,000 \text{ watt}}{450 \text{ watt}} = 304 \text{ Houses} \]

\[ P_{net} = \frac{24,000 \text{ watt}}{450 \text{ watt}} = 53 \text{ Houses} \]

\[ P_{net} = \frac{17,000 \text{ watt}}{450 \text{ watt}} = 37 \text{ Houses} \]

Whilst, the number of houses in the Cielungsing Village +/- 150 houses. This deficiency of power has to be supplemented using other resources, for instance, adding or replacing the water supply for the Cipurut River channel. If not, then it needs to be assessed from solar, wind, or biogas energy sources.

The research on electricity self-sustainability is important because the national energy demand has not been able to cover all of its citizens. If the people can produce their own energy, then the electrification rate in Cileungsing Village could be 100% and provide positive effects to the villager’s activities.

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