Small Hydropower Potential of Rivers in Sukabumi Regency, West Java, Indonesia

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Abstract. Renewable energy is needed to replace or substitute the conventional energy based on fossil fuel. Hydropower energy is one promising as new renewable energy. The purpose of this study is to estimate the potential energy of small hydropower in four rivers in Sukabumi regency, West Java, Indonesia. The results showed the highest daily maximum electricity capacity was found in Cikaso-parungseah river with 25.06 MW. The lowest daily maximum electric capacity is in Cimandiri-leuwilingsung river with 1.97 MW. The total 3 years’ electric capacity respectively, Cikaso-parungseah river: 41266.86 MWh, Cimandiri-tegaldatar river: 13708.13 MWh, Cimandiri-leuwilingsung river: 10849.11 MWh, Ciletuh-Cipiring river: 6208.31 MWh. Based on this result, Cikaso-parungseah river has big potential to build small hydropower due to high rate of river flow and continuous through the year.

Introduction
Electricity power has been a prominent concern in Indonesia since a long time ago. The electricity demand in Indonesia has increased tremendously in 23 years (1987–2009). The fuel consumption for electricity grew from 6,630 million tons of oil equivalents (mtoe) in 1980 to 11,163 mtoe in 2009 [1]. The tends to use fossil fuel as a resource to produce electricity in Indonesia has summoned many issues such as resource sustainability and pollution. It is known that energy use in Indonesia is still dominated by fossil energy, which is 97.7% (70.4% coal, 17.4% gas and 9.9% oil) from total primary energy produced in 2016 [2]. The Indonesia national energy policy stated that, in 2050, renewable energy will contribute 31% of energy mix, and hydro power is 10% of it [3]. Thus, currently, it is very important to find a way for increasing the renewable energy uses in Indonesia, including hydropower.

The hydropower has been concluded as the best renewable energy resource to be used in Indonesia, followed by geothermal, solar, wind and biomass power [4]. International Hydropower Association (IHA) 2018 status report claimed that hydropower is the world’s biggest source of clean electricity generator. Hydropower is an enabler of other renewable energy sources while providing vital services to manage water and mitigate climate change. IHA reported that with 1,267 GW global hydropower installed capacity in 2017, it is estimated that electricity as high as 4.185 TWh was generated from hydropower in 2017. IHA claimed that it is the highest contribution electricity power from a renewable
energy source [5]. Energy from water in microhydro power plant could be the best economical option for rural electrification in developing countries, such as Indonesia [6]. Indonesia Ministry of Energy and Mineral Resource concluded that the hydropower plants and micro hydropower plants could compete with fossil power plants after conducting a levelized cost of electricity (LCoE) analysis [2]. It is also found that micro hydropower power plant has the lowest minimum payback period than other resources [7].

Hydropower can be classified into several categories. There is no worldwide consensus yet on the size categories of hydropower plant [8,9]. Though, looking at the scientific papers nowadays, hydropower types can be classified as small, medium and large (Table 1) [10]. The upper limit of small hydropower that accepted worldwide is 10 MW although China keep the standard at 25 MW [9]. The guidance to the small-scale hydropower size capacity variation can refer to Table 2 [11]. There is many study conducted which took interest on small-scale hydropower. The main advantages of energy from small-scale hydropower are: 1) it is much more concentrated than wind or solar; 2) it is readily predictable; 3) it is usually continuously available on demand; 4) no fuel and only limited maintenance are required; 5) it is a long-lasting technology; 6) it has almost no environmental impact [9].

### Table 1 Hydropower types [8]

| Type   | Capacity               | Stream          |
|--------|------------------------|-----------------|
| Small  | Less than 10 MW        | Run-of-the-river|
| Medium | Between 10 and 100 MW  | Run-of-the-river|
| Medium | Between 100 and 300 MW | Reservoir       |
| Large  | Greater than 300 MW    | Reservoir       |

### Table 2 Small-scale hydropower types [11]

| Type     | Capacity                        |
|----------|---------------------------------|
| Picohydro| <5 kW                           |
|          | <10 kW                          |
|          | <20 kW                          |
|          | >5 kW and <100 kW               |
| Microhydro| <100 kW                      |
|          | >10 kW and <200 kW              |
|          | <500 kW                         |
| Mini hydro| >500 kW and <2 MW              |
|          | <10 MW                          |
| Small hydro| >100 kW and <10 MW             |
|          | >1 MW and <25 MW                |

The electricity consumption in the West Java Province and Banten Province distribution area for 2013 until 2022 has been projected and concluded that the average growth of electricity power consumption is 7.03% per year [12]. There are 9 hydropower plants installed already in West Java region. Two of them are the largest capacity hydropower installed in Indonesia. Most of the large hydropower plants in West Java situated around the capital city of the province, Bandung. There are two hydropower plants situated in Sukabumi Regency: Ubrug plant and Cibadak plant [1]. Ubrug hydropower plant capacity has been degraded from its initial installed capacity because of the lowered water discharge due to land use changes on the watershed [13]. The increases of electricity power demand every year and the lowered water discharge of existing hydropower make it a necessity to plan some new additional reliable hydropower plants.
The purpose of this paper is to find out the potential capacity of hydropower in several rivers on watersheds in Sukabumi District, West Java. The rivers are Ciletuh, Cimandiri, and Cikaso, which their catchment area are 81 km², 608.2 km², and 487.2 km², respectively. The expected outcome of this study is the information on the possibility for installing hydropower plants on those rivers based on the potential capacity result.

Materials and Method
The research was conducted in Sukabumi Regency, West Java, Indonesia in July-August 2018. Discharge data was provided by Publics work office of west Java (Dinas Pekerjaan Umum). The data are use is data from four rivers (Cikaso-parungseah, Cimandiri-tegaldatar, Cimandiri-leuwilisung, Ciletuh-cipiring) from 2007-2009.

![River distribution in west java province](image)

Figure 1 River distribution in west java province

The calculate the power converted from flow rate to electricity using equation:

\[ P = Q \times \rho \times g \times H \times \eta \]

Where,
- \( P \) = electric power watt
- \( Q \) = flow rate (m³/s)
- \( \rho \) = water density (1000 kg/m³)
- \( g \) = acceleration of gravity (9.8 m/s²)
- \( H \) = waterfall height (m = 7 meter)
- \( \eta \) = global efficiency ratio (0.71 (usually between 0.7-0.9))

Results and Discussion
In Indonesia electricity commonly already be the fundamental need. However, currently fossil fuel still the main source of the energy. The negative impact over using fossil fuel is accelerating the green house emission such as CO₂, where CO₂ is one factor influence the increasing air temperature [14]. Flow duration curve is the data was arranging from the biggest flow rate to the lowest flow rate of river. The results show, in the figure 2, the flow rate from Cikaso-parungseah have the highest flow rate in high
flow rate and in low flow rate. The lowest flow rate was found in Ciletuh-cipiring river. In high flow, Cimandiri-tegaldatar have high flow rate, but in low flow Cimandiri-leuwilisung have high flow rate compared to flow rate in Cimandiri-tegaldatar. In figure 3, the monthly average of flow rate. All river gives same pattern of flow rate. High flow rate in January to July with peak flow rate in April or March. The low flow rate was found in June-September, with the lowest flow rate in August and September.

In 2007, total electricity in Cikaso-parungseah was 11440.51 MWh, Cimandiri-tegaldatar 5615.66 MWh, Cimandiri-leuwilisung 4088.54 MWh and Ciletuh-cipiring 2333.11 MWh. In Cikaso-parungseah, Cimandiri-tegaldatar, Cimandiri-leuwilisung the highest electricity is in April with 2769.8 MWh, 1086.94 MWh, and 580.04 MWh respectively. In Ciletuh-cipiring the highest in March with 663.67 MWh. In 2008, total electricity in Cikaso-parungseah was 15849.36 MWh, Cimandiri-tegaldatar 3328.75 MWh, Cimandiri-leuwilisung 5152.64 MWh and Ciletuh-cipiring 2392.32 MWh. In Cikaso-parungseah, Cimandiri-tegaldatar, Cimandiri-leuwilisung the highest electricity is in March with 2280.95 MWh, 799.59 MWh, and 707.55 MWh respectively. In Ciletuh-cipiring the highest in January with 432.76 MWh. In 2009, total electricity in Cikaso-parungseah was 16164.33 MWh, Cimandiri-tegaldatar 4763.72 MWh, Cimandiri-leuwilisung 2157.66 MWh and Ciletuh-cipiring 1786.65 MWh. The highest electricity is in February for Cikaso-parungseah, Cimandiri-tegaldatar, Cimandiri-leuwilisung, Ciletuh-cipiring with 2883.81 MWh, 1089.87 MWh, 348.10 MWh and 732.55 MWh respectively.

Flow duration curve in Cikaso-parungseah is higher compere to other rivers, because Cikaso is a big watershed. Cikaso have area 86340.09 ha. For build hydropower need information of rate of water flow, based on the rate of water flow could predicted the potential of electricity. Based on FDC figure 2 and potential electricity in table 3-5, Cikaso-parunseah have highly potential compare to other rivers. And Ciletuh-cipiring is river strongly no recommended to build hydropower. For the total potential electricity Cimandiri-tegaldatar have high potential electricity compared to Cimandiri-leuwilisung. However, the important thing in build the hydropower is not only the total electricity but also the continuity. Cimandiri-leuwilisung have advantages in continuity compared to Cimandiri-tegaldatar.

In this research only analysis 3 years’ data, It still low number in quantity. Because in 3 years’ data cannot be use to predict in long term period (10 years). The results of this research show there are increasing and decreasing the total potential of electricity. In Cikaso-parungseah the total electricity was increase year by year, but in Cimandiri-tegaldatar, Cimandiri-leuwilisung, Ciletuh-cipiring total potential electricity was decrease year by year. The other hand, the monthly peak electricity every year was changes, may be caused by changing in strating time of rainy season or dry season. In Indonesia some area the timing of change of season was change caused by global climate change [15].

![Figure 2 Flow duration curve of flowrate from four rivers](image-url)
Figure 3 Monthly average flow rate from four rivers

Table 3 Electricity potential from four rivers in 2007

|          | Total electricity in 2007 (MWh) |
|----------|---------------------------------|
|          | Cikaso-parungseah | Cimandiri-tegaldatar | Cimandiri-leuwilisung | Ciletuh-cipiring |
| Jan      | 901.81             | 533.52               | 382.03               | 217.36           |
| Feb      | 880.62             | 655.79               | 470.57               | 227.73           |
| Mar      | 1297.21            | 866.54               | 513.56               | 663.67           |
| Apr      | 2769.81            | 1086.94              | 580.04               | 305.18           |
| May      | 1648.25            | 651.25               | 371.51               | 137.29           |
| Jun      | 583.21             | 413.30               | 310.87               | 63.96            |
| Jul      | 340.87             | 171.38               | 202.05               | 30.26            |
| Aug      | 214.14             | 66.41                | 150.96               | 16.96            |
| Sep      | 207.11             | 15.47                | 182.51               | 28.28            |
| Oct      | 146.07             | 139.01               | 203.21               | 48.12            |
| Nov      | 504.95             | 281.68               | 264.76               | 122.97           |
| Dec      | 1946.45            | 734.37               | 456.49               | 471.33           |
| Total    | 11440.51           | 5615.66              | 4088.54              | 2333.11          |

Table 4 Electricity potential from four rivers in 2008

|          | Total electricity in 2008 (MWh) |
|----------|---------------------------------|
|          | Cikaso-parungseah | Cimandiri-tegaldatar | Cimandiri-leuwilisung | Ciletuh-cipiring |
| Jan      | 1954.95             | 104.36               | 554.88               | 432.76           |
| Feb      | 1408.49             | 272.62               | 566.11               | 387.33           |
| Mar      | 2280.95             | 799.59               | 707.55               | 418.05           |
| Apr      | 2021.29             | 770.71               | 503.72               | 174.36           |
| May      | 564.33             | 218.75               | 323.36               | 94.03            |
Hydropower is one of renewable energy which has high potential in Indonesia. However, the hydropower in Indonesia was dominated with Dams hydropower system [1]. In the West Java, there are nine Dams hydropower namely PLTA Ubrug, PLTA Bengkok, PLTA Cibadak, PLTA Cikalong, PLTA Saguling, PLTA Cirata, PLTA Jati Luhur, PLTA Lamajan, PLTA Parakan Kondang. Almost in Indonesia the hydropower was build in Dams area. In Japan already study about the potential of river channel potential to support renewable energy in future [16]. Moreover, in Thailand also already adopt the run-river hydropower [17]. Estimation the potential of electricity from the hydropower was strongly depend on the flow rate of the river. In future need more deep study to modelling the flow rate of river influence by change of climate and also the change of the land use in upstream. Because changing forest cover, land cover will influence the total discharge or flowrate of water in the rivers [18].

**Conclusion**

The conclusion of this research is that small hydropower generation using water way (river) have high potential to substitute the conventional energy. The highest daily maximum electricity capacity was found in Cikaso-parungseah river with 25.06 MW. The lowest daily maximum electric capacity is in Cimandiri-leuwilingsung river with 1.97 MW. The total 3 years’ electric capacity respectively, Cikaso-
parungseah river: 41266.86 MWh, Cimandiri-tegaldatar river: 13708.13 MWh, Cimandiri-leuwilingsung river: 10849.11 MWh, Ciletuh-Cipiring river: 6208.31 MWh. Cikaso-parungseah river has big potential to build small hydropower due to high rate of river flow and continuous through the year.

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