

Evaluation of Micro Hydro Power Plants in Central Java toward Sustainability against Hydrology Condition of Watershed

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Abstract. Land degradation on the upstream of watershed will affect hydrology condition in a way that it will disrupt the sustainability of its existing micro hydro. The purpose of this study is to evaluate micro hydro power plant in central Java toward sustainability against hydrology condition of watershed. This study is using River Regime Coefficient (RRC) approach where hydrology of watershed with coefficient value less than 50 is classified as non-critical, between 50 and 120 is moderate and more than 120 is critical. Result of the study that was done on 33 micro hydro power plants scattered on 9 watersheds is showing that there are 2 power plants on 2 watersheds have hydrology condition in non-critical status (9.09%), 1 power plant on 1 watershed is in between critical and non-critical status (3.03%), 21 power plants on 3 watersheds are in between critical and moderate status (63.64%), 8 power plants on 6 watersheds are in critical status (21.21%) and 1 power plant on 1 watershed is in between moderate and critical status (3.03%).

Keywords: **Evaluation; micro hydro power plant; watershed water system; continuity.**

1 Introduction

As stated in The Act Number 30 Year 2009 about Electrical-Power that primer energy resource already have been set, which there are in the country and/or from overseas had to be utilized optimally according to National Energy Policy (KEN), that is to guarantee the equipping of electrical power which is sustainable, and furthermore it also set that in utilizing it, new energy resource and renewable energy resource. [1]

The policy mention above is in line with the certainty in The Act Number 30 Year 2007 about Energy, that the energy was managed based on the principle of expediency, rationality, efficiency, justice, the increase in added value, sustainability, society welfare, preservation of environmental functions, national resilience, and alignment with emphasis on national capabilities.

Based on Government Regulation Number 79 of the year 2014 about National Energy Policy, the utilization of national energy resources which was directed for electrical power are as follows: Renewable energy resource from energy flow and waterfall, geothermal energy (including small scale/modular), the movement energy and the difference in ocean layer temperature, wind energy, solar energy, biomass and compost, new energy source of solid and gas, gas, coal. [3]

Based on Indonesia Republic Number 30 of Year 2007, about energy, the government has to arrange KEN

as a manual in national energy management, where the purpose of energy management is for reaching energy independence or ensuring energy supply, to improve energy efficiency, to improve people access toward energy for low income groups, and to ensure environmental sustainability. [2]

Changes on KEN according to President Regulation 5 of year 2006 that on 2015 the target is the Energy Mix 2025: Crude oil <20%, Gas >30%, Coal >33%, New Renewable Energy (EBT)>5%, and Energy Elasticity Target <1%. While according to KEN by DEN in 2012 other Principle which will be made as a reference for preparation of KEN is national energy mix target until 2050, national energy mix will be dominated by EBT with the amount of 40 percent which cover water energy, geothermal, trash biomass, Bio-fuels, solar energy, ocean energy, wind energy, and nuclear energy. While for oil, gas, and coal will be at 20 percent range.

As electrical power policy appropriate direction which was organized in RUKD Preparation in Central Java 2015-2020, is in accordance with Central Java Province Government vision and mission that is toward self-contained and independent Central Java in field of energy. Energy independence based with environmental friendly technology in Central Java, can be implemented by improve people interest and investors to develop and make use of new and renewable energy potential which spread throughout Central Java region, to build facilities

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and infrastructure which support electrical power system in Central Java, to improve rural electricity grid program and cheap electricity for poor people, implement supply and demand management policies on load side. [4]

Rural electricity grid is one of government program which can be used to help people which not yet electrified, so they can enjoy electricity. The electrified village ratio in Central Java are already 100%, but until 2014 hamlet (=village) which not yet electrified in Central Java more or less than 2.096 hamlet.

Electrical energy in Central Java was supplied by power plants which are interconnected in JAMALI System (Java-Madura-Bali) and isolated grid kind power plants. Isolated grid power plants which are contained in Central Java consist of: micro hydro power plants (840 kVA), PLTS (482.85 KVA), and PLTD (1,855 kVA) the amount of total power capacity of electrical energy for isolated grid in Central Java until 2014 is 3,117.95 kVA. Central Java Electrification Ratio Target in 2015, which contained in RUKN 2015-2034 draft with the amount of 90.59%, while the target amount which is stated in Renstra ESDM 2013-2018 is 87.42%. RE in Central Java on the actual condition already meet the target mention above. Energy Mix for power plants I Central Java on 2015, consist of: coal 80.69%, EBT 12.80%, gas 3.93%, and oil 2.57%. New and renewable energy which the most widely used in Central Java as potential power plants are waterfalls among others are PLTA (Hydroelectric power plant) with the amount of 31 unit, with an installed capacity of 322.64 MW, while PLTM (Mini Hydro Power Station), and micro hydro power plants (Hydro Micro Power Plan), with the amount of 33 unit, with installed capacity (840 kVA).

Target use of energy mix for power plants in 2025 in accordance with the Government Regulation Number 79 in the year of 2014, about National Energy Policy (KEN) consist of coal around 50%, EBT around 25%, Gas around 24%, Fuel around 1%. Primary energy mix of power plan in Central Java in 2015 is consisting of coal 80.69%, EBT 12.80%, gas 3.93%, oil 2.57%. Portion of EBT utilization mix which is used in Central Java, as power plants are Hydro Power Plant (PLTA, PLTM, micro hydro power plants)with the amount of 88.88%, Geothermal Power Plant (PLTP) 11.02%,the rest is Solar Power Plant (PLTS).[5]

Given the utilization of new and renewable energy that is most widely used in Central Java as a power plan, is a potential waterfall, then the potential is highly dependent on watershed health, where the watershed (watershed) condition is able to provide all the ecosystem's needs [6], one of which is the continuous availability of water (Hydrological conditions) is good. The problems in the field are the existence of an increasing and uncontrolled development movement, in the upstream basin, so resulting in degradation, and have an impact on quantity and the quality of land resources.[7] In relation there to, monitoring evaluation is required [8], measure the success of changing condition of watershed [9], on location of micro hydro power plants mention above and the result will be used as a guide in the next activity about ongoing implementation[10].

The purpose of this essay is to conduct evaluation of Hydro Micro Power Plant in Central Java towards sustainability against Hydrology Condition of Watershed.

2 Materials and Methods

2.1. Location of Study and Data Collection

The location reviewed in this paper covers micro hydro power plants as much as 33 location or as much as 9 Watershed, with the boundary of the northern region coordinates $x = 399089$ $y = 9208745$, east $x = 572138$ $y = 9212365$, south $x = 385487$ $y = 9130271$, west $x = 269555$ $y = 9209151$.

The data used is the river map along with the river area in Central Java and hydrological data (debit) from the Water Resources and Spatial Development Office in 2014 and 2017.



Fig. 1. Map of micro hydro power plants and watershed location in the study area.

2.2 Methods

The approach of the method used in conducting the study of the hydrological condition of the Watershed according to the location of the study is the River Regime Coefficient (RRC) approach. River Regime Coefficient is comparison maximum discharge (Q_{max}) and minimum debit (Q_{min}) in a Watershed.

$$RRC = \frac{Q_{max}}{Q_{min}} \quad (1)$$

Where:

Q_{max} (m^3/sec): the highest annual average daily discharge (Q)

Q_{min} (m^3/sec): the lowest annual daily discharge (Q).

Classification value of RRC to show the characteristic of Watershed is presented on the following Table:

Table 2.1. Criteria for Watershed Management

| Number | RRC Value | Class | Remark |
|--------|-----------|--------|--------------|
| 1 | <50 | Good | Non-critical |
| 2 | 50 – 120 | Medium | Moderate |
| 3 | >120 | Poor | Critical |

High RRC value shows range of runoff value in the rainy season (flood waters) is big, while in the dry season the flow of water is very small or shows drought.

3 Results and Discussion

3.1 Potential and Existing Micro Hydro Power Plants in Central Java Province

Potential water energy in Central Java that can be utilize for micro hydro power plants is estimated at 2.9 Mega Watt (MW) or equal to 28900 kVA (twenty eight thousands nine hundred kilo Volt Ampere) which spread in 15 district (Banjarnegara, Banyumas, Purbalingga, Brebes, Pemalang, Pekalongan, Kendal, Kebumen, Klaten, Wonosobo, Temanggung, Cilacap, Jepara, Blora, and Grobogan). The potential of water energy has been utilized by 33 units of micro hydro power plants with the capacity of 840 kVA spread over 10 districts (Pekalongan, Wonosobo, Banyumas, Purbalingga, Purworejo, Temanggung, Magelang, Brebes, Klaten, and Banjarnegara), so that the potential for water energy in Central Java that has not been utilized amounted to 28060 kVA (twenty eight thousands sixty kilo Volt Ampere) or 28.060 MW, where the potential can still be developed. The number of villages or hamlets that have not received electricity by 2016 a total of 1783 villages or hamlets spread in 26 districts or cities (Brebes, Klaten, Purworejo, Banyumas, Banjarnegara, Batang, Boyolali, Blora, Purbalingga, Semarang, Sragen, Kebumen, Kota Surakarta, Kota Tegal, Pati, Wonosobo, Wonogiri, Pemalang, Kota Salatiga, Kota Magelang, Temanggung, Cilacap, Kota Pekalongan, Jepara, Rembang, Grobogan)

3.1 Hydrology Study of Watershed

Based on Indonesian Republic Presidential Regulation Number 12 on the Determination of River Areas, the Watershed in Central Java consist of 10 River Areas and 202 watersheds that is river area Cimanuk, Cisanggarung consist of 5 watersheds (Cisanggarung, Tanjung, Kabuyutan, Babakan, Comal, Kluwut), river area Pemali Comal consist of 32 watersheds (Pakijangan, Pemali, Gangsa, Wadas, Gununglana, Gung, Poh, Cacaban, Conang, Jimat, Brungut, Rambut, Medono, Srengseng, Baros, Loning, Waloh, Comal, Sragilama, Sragibaru, Sengkarang, Kupang, Gabus, Sambong, Sono, Karanggeneng, Boyo, Urang, Kretek, Bugel, Kuripan, Kedondong), river area Bodri Kutho consist of 12 watersheds (Brontak, Kedondong, Kuto, Damar, Pesanggrahan, Bulanan, Blukar, Bodri, Buntu, Kendal, Blorong, Glanggahwaridin), river area Bengawan Solo consist of 1 watershed (Bengawan Solo), river area Jratun

Seluna consist of 69 watersheds (Plumbon, Bringin, Karanganyar, Cilandak, Garang, Siangker, Banjir Kanal Timur, Sringin, Babon, Dolop, Tulung/Setu, Jragung, Tuntang, Tuntanglana, Jajar, Jebor/Gejoyo, Lobener, Kenceng, Serang-Lusi, Seranglana, Bum, Kedung Semat, Rau, Platar, Gandu, Krajan, Ngarangan, Lenggi, Guno, Limar, Kahar, Bakulan/Tayu, Klencer, Parapatan/Pakis, Gading, Pesagen, Sat, Suwatu, Pangkalan, Mojosami, Suwaduk, Gungwedi, Juwana, Jabangbayi, Kletek/Gedong, Randugunting, Widodaren, Anyar, Capluk, Sambung, Panggang, Jambangan, Kiringan, Lasem, Keris, Dukoh, Bonang/Nyamplung, Kladen, Banu, Jatisari, Dalananyar, Sanduk, Grasak, Randualas, Kepel, Kresak, Kesambi, Belitung/Ngepang, Wango), river area Wiso Gelis consist of 27 watersheds (Kanal, Mulyoharjo, Bandengan, Kalirejo, Smanggu, Kalitelon, Sekuro, Cabakan, Kemangi, Semanding, Kalibedah, Kancilan, Balong, Suru, Wareng, Gelis, Bandungharjo, Kelet, Wangkong, Watugede, Celuwah, Klakah, Tewar, Ujungwatu, Bugel, Rantain, Tempur), river area Karimun Jawa consist of 20 watersheds (Kembar, Parang, Kumbang, Nyamuk, Katang, Krakat Besar, Krakat Kecil, Bangkoang, Menyawakan, Cemara Besar, Cemara Kecil, Geleang, Burung, Menjangan Kecil, Menjangan Besar, Karimun Jawa, Sintok, Gosong Tengah, Cilek, Kakamoncong), river area Progo Opak Serang consist of 1 watershed (Progo), river area Srayu Bogowonto consist of 15 watersheds (Bogowonto, Cokroyasan, Wawar, Lukulo, Telomoyo, Mangli, Jintung, Watu Gumulung, Jemenar, Manjingklak, Suwuk, Ijo, Tipar, Serayu, Donan), river area Cintanduy consist of 20 watersheds (Citanduy, Cibeureum, Citotok, Cimeneng, Cikonde, Sapuregel, Gatel, Branalang, Kipah, Panembung, Karanganyar, Tambakreja, Nirbaya, Solokjari, Permisan, Lembongpucung, Solok Permisan, Solokpring, Pandan, Solokdewata).

Result of analysis with River Regime Coefficient Approach for each micro hydro power plants location as many as 33 locations or 32 watersheds resulted as follows. For location of Purbasari Village micro hydro power plants which is in the Serayu Watershed obtained the value of RRC between (3100.67- 4.19) was categorized the Watershed management were good until poor or moderate to critical. For the location of Tripis Village micro hydro power plants which is in Serayu Watershed obtained RRC value between (177.35- 68.70) the Watershed management condition was categorized as medium to poor or moderate to critical. For the location of Giyombong Village micro hydro power plants which is in Wawar Watershed obtained RRC value between (320.07- 156.23) the Watershed management condition was categorized as poor or critical. For the location of Kalisalak Village micro hydro power plants which is in Tipar Watershed obtained RRC value between (1826.19 - 1050.02) the Watershed management condition was categorized as poor or critical. For the location of Sidoarjo Village micro hydro power plants which is in Sengkarang Watershed obtained RRC value between (425.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For the location of Daleman Village micro hydro power plants which is

in Bengawan Solo Watershed obtained RRC value between (69375.00 - 3582.72) the Watershed management condition was categorized as poor or critical. For the location of Mudal Village micro hydro power plants which is in Progo Watershed obtained RRC value between (65.34 - 4102.00) the Watershed management condition was categorized as poor to medium or critical to medium. For location of Depok 1 Village micro hydro power plants which is in Sragi Watershed obtained the value of RRC between (1912.00 - 121.07) the Watershed management condition was categorized as poor or critical. For location of Curug Muncar Village which is in Sengkarang Watershed obtained the value of RRC between (452.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Songgodadi Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Kapundutan Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Wonosido Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Mendolo Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Timbangsari 1 Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Batar Kulon Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Curug Muncar 2 Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Depok 2 Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Timbangsari 2 Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452.50 - 89.60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Bligo Village micro hydro power plants which is in Progo Watershed obtained the value of RRC between (4,41 - 5,58) the Watershed management condition was categorized as good until poor or non-critical to critical. For location of Igirklanceng Village micro hydro power plants which is in Pemali Watershed obtained the value of RRC between

(2132,00 - 595,00) the Watershed management condition was categorized as good to poor or non-critical to critical. For location of Pesangkalan Village micro hydro power plants which is in Lukulo Watershed obtained the value of RRC between (423,94 - 183,35) the Watershed management condition was categorized as good to poor or non-critical to critical. For location of Sambirata Village micro hydro power plants which is in Serayu Watershed obtained the value of RRC between (177,35 - 68,70) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Kayupuring Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452,50 - 89,60) the Watershed management condition was categorized as medium to ugly or critical enough to critical. For location of Sidomulyo Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452,50 - 89,60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Mendolo Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452,50 - 89,60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Tlogopakis Village micro hydro power plants which is in Sengkarang Watershed obtained the value of RRC between (452,50 - 89,60) the Watershed management condition was categorized as medium to poor or moderate to critical. For location of Gunung Lurah 2 Village micro hydro power plants which is in Serayu Watershed obtained the value of RRC between (1,41 - 18,04) the Watershed management condition was categorized as good to poor or non-critical to critical. For location of Gunung Lurah Village micro hydro power plants which is in Serayu Watershed obtained the value of RRC between (177,35 - 68,70) the Watershed management condition was categorized as medium to poor or moderate to critical. Map of Watershed condition for 30 (thirty) locations of micro hydro power plants can be seen in the figure below:

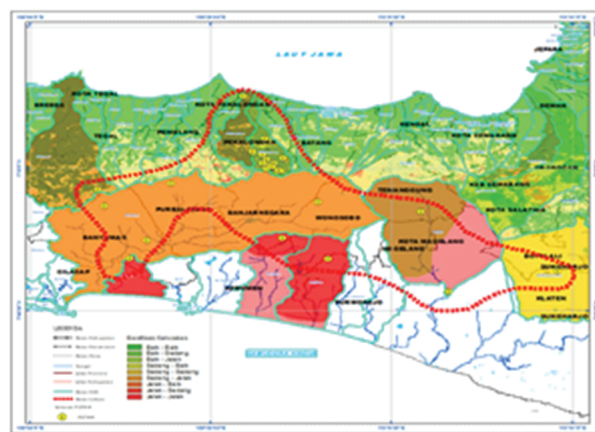


Fig. 2. Map of Hydrology Condition or Watershed Damage.

4 Conclusions

Based on the above description, can be summarized as follows:

- a. Government policy to meet electricity needs, development of other EBT, in 2025 should be greater than or equal to 5%.
- b. There are 33 micro hydro power plants with 840 KVA capacities spread over 9 Watershed.
- c. Hydrology condition of watershed that are in good conditions are in 3 locations and 2 Watersheds (9.09%), which are in micro hydro power plant Bligo Village, Ngluwar District, Magelang Regency (2 units) (Progo Watershed) and micro hydro power plants Gunung lurah 2 Village (1 unit), District Cilongok, Banyumas Regency (Serayu Watershed).
- d. Hydrology condition of watershed categorized as poor-good includes 1 location and 1 Watershed (3.03%) which is in micro hydro power plants Purbasari Village, Karangjambu District, Purbalingga Regency (Serayu Watershed).
- e. Hydrology condition of watershed categorized as poor-medium covering 21 locations and 3 Watersheds (63.64%) which are micro hydro power plants Tripis Village, Watumalang District, Wonosobo Regency (Serayu Watershed), micro hydro power plants Sidoarjo Village, Doro District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Curugmuncar 1 Village, Petungkriyono District, Pekalongan Regency (Sragi Baru Watershed), micro hydro power plants Songgodadi Village, Petungkriyono District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Kapundutan Village, Lebakbarang District, Pekalongan Regency (2 units) (Sengkarang Watershed), micro hydro power plants Wonosido Village, Lebakbarang District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Mendolo Village, Lebakbarang District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Timbangsari 1, Lebakbarang District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Batar Kulon Village, Lebakbarang District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Curug Muncar 2 Village, Petungkriyono District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Depok 2 Village, Lebakbarang District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Timbangsari 2 Village, Lebakbarang District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Sambirata Village, Cilongok District, Banyumas Regency (Serayu Watershed), micro hydro power plants Kayupuring Village, Petungkriyono District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Sidomulyo, Lebakbarang District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Mendolo

- Village, Lebakbarang District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Depok Village, Lebakbarang District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Tlogopakis Village, Petungkriyono District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Wonosido2 Village, Lebakbarang District, Pekalongan Regency (Sengkarang Watershed), micro hydro power plants Gunung Lurah Village, Cilongok District, Banyumas Regency (Serayu Watershed).
- f. Hydrology condition of watershed categorized as poor-poor includes 8 locations and 6 Watersheds (21.21%) namely micro hydro power plants Giyombong Village, Bruno District, Purworejo Regency (Wawar Watershed), micro hydro power plants Kalisalak Village, Kd Banteng District, Banyumas Regency (Tipar Watershed), micro hydro power plants Daleman Village, Tulung District, Klaten Regency (2 units) (Bengawan Solo Watershed), micro hydro power plants Depok 1 Village, Lebak Barang District, Pekalongan Regency (Sragi Baru Watershed), micro hydro power plants Igirklanceng Village, Sirampog District, Brebes Regency (Pemali Watershed), micro hydro power plants Pesangkalan Village, Pogedongan District, Banjarnegara Regency (Lukulo Watershed).
 - g. Hydrology condition of watershed categorized as medium-bad includes 1 location and 1 Watershed (3.03%) namely micro hydro power plants Mudal Vilage, Temanggung District, Temanggung Regency (Progo Watershed).

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