Potentiality of the micro hydro power plant development based on local community capacity: Case Study in Paweden Village, Banjarnegara, Central Java

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Abstract. Every year, electricity demand is always increasing, especially in Indonesia where the deficiency of electrical power plants still becomes an issue. Currently, it is necessary to find other alternative sources of renewable fuels that can be used as power plants. One of the solutions is through the development of Micro Hydro Power Plant. Furthermore, social feasibility related to the ability and willingness of the local community is important to be carried out to develop and manage the micro-hydro electricity sustainably. This study used quantitative data collection techniques through surveys by questionnaires in Paweden Village, Banjarnegara, Central Java. Community capacity analysis is carried out through 3 indicators, such as human capital, organizational resources, and social capital. Spatial analysis is also conducted to find out the affordability of Micro Hydro Power Plant access to the local community. The results showed that the Micro Hydro Power Plant is sufficient to cover 95.87% of the entire Paweden Village area. Related to the electricity needs in Paweden Village, the electricity supply is still insufficient based on the local community opinion. Based on the survey, although the quality of human resources is still limited, the willingness of the community to participate in the development and management of the Micro Hydro Power Plant is considerably high.

Keywords: Banjarnegara, community capacity, micro hydro power, natural resources

1. Introduction
The problem of electricity demand is always increasing annually, particularly in Indonesia, the availability of power plants is still lacking. The availability of electricity is vital in modern life and as one of the benchmarks of the nation's development. Because of the existence of electrical energy, citizens can travel, work, and do activities easily.

Based on the results of the projected electricity demands from 2003 to 2020 conducted by the System Planning Department of State Electricity Company of Indonesia (PT PLN) and the Agency for the Assessment and Application of Technology (BPPT) Energy Team, it is recognized that during this period the average electricity demand in Indonesia grew by 6.5% per year. The highest number of electricity growth is in the commercial sector, which is around 7.3% per year and followed by the household sector with a growth of 6.9% per year. This is very reasonable, considering that to improve the economy in Indonesia, the government is increasing the growth of the tourism sector which will further affect the growth of the commercial sector. For the household sector, the high growth rate of

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electricity demand is triggered by electrification ratios from various regions which are still relatively low. Until now there still several regions in Indonesia that not yet electrified, especially in areas that not bypassed by PLN electricity [1].

Aside from the limited availability of power plants, most power plants still use fossil fuels, such as petroleum, natural gas, and coal. If Indonesia continues to depend on this energy source, problems will arise in the future due to its very limited fuel supply. Therefore we need an alternative renewable fuel source that can be used as a power plant, one of which is hydropower power plants. This matter considering that Indonesia has huge water resource potential and can be utilized as a power plant. [2] noted that 80% of Indonesia's water resources have not been utilized. Based on data from the Ministry of Public Works and Housing (PUPR), the total potential of Indonesia's water resources is 3.9 trillion cubic meters per year, while Indonesia can only manage around 691.3 billion cubic meters. This potential can be utilized to support the agriculture sector, raw water for urban and industrial communities, electricity power plant, and tourism. For the energy sector, the potential of water resources can be utilized for hydroelectric power plant (PLTA) with a total capacity of 75 gigawatts (GW). More than double the power plant development program planned by the government until 2019, which is 35 GW.

On the other hand, the construction of hydroelectric power plants requires considerable costs and energy. However, it can also cause several consequences, including the need for dams with a large area, can cause geological damage, landslides, erosion, and so forth. Therefore, to be able to suffice the electricity demands in rural areas, that are difficult to reach by the electricity network, may utilize the local potential of micro-hydro energy. The construction of Micro Hydro Power Plants in Indonesia continues to grow and the potential of water resources that can be utilized for micro-hydro is quite large and widespread throughout the archipelago. Micro Hydro Power Plant is a type of power plant that uses renewable energy by utilizing small-scale hydropower such as waterfalls or dams on rivers. The inventoried of micro-hydro potential reaches more than 500.00 MW, in the form of micro-hydro potential in rivers and springs, not including the potential in technical irrigation networks spread across Java, Sumatra, Bali, and Sulawesi, including irrigation networks on the islands all over Indonesia [3].

Banjaranegara is one of the regions that have large water potential where there is a large river, the Serayu River with its tributaries: Tulis River, Merawu River, Pekacangan River, Gintung River, and Sapi River. The rivers utilized as a source of irrigation that can irrigate 9,813.88 hectares of paddy fields. The average wet month is generally more than the dry month with an average rainfall of 3,000 millimeters/year, while the average regional temperature is 20-26° C [4]. Serayu River has extraordinary sand potential. The nature of the river is generally perennial (flowing throughout the year) and is part of the Serayu watershed. This makes the Banjaranegara region very suitable for the development of Micro Hydro Power Plants (MHPP). MHPP is a power plant that uses hydropower as the main media for driving turbines and generators. Micro hydropower, with a scale of power, can be generated from 5 kilowatts to 50 kilowatts. In the MHPP process, the change of kinetic energy (water velocity and pressure), used to move water turbines and electricity generators to produce electrical energy [4].

MHPP developments can increase the electrification ratio in the Banjaranegara region. Based on data from the Official of Housing and Settlement Areas in Banjaranegara, the electrification ratio of Banjaranegara is around 82% or still less than 18% (13,431 households) that don’t have electricity connection [5]. In MHPP development planning, the local community must be placed as a subject as well as an object of development, because it is strictly related to the MHPP sustainability. Accordingly in the MHPP development planning there needs to be a feasibility study both in terms of technical and social aspects. Social feasibility is related to the ability and willingness of the community to build and manage micro-hydro electricity in a sustainable manner. Therefore, the purpose of this research is to see how the potential for developing Micro Hydro Power Plants (MHPP) is based on the capacity and needs of the local community in Paweden Village, Banjaranegara.

2. Methodology
The existence of methodology will construct knowledge becomes something scientific, both on social knowledge and natural knowledge [6]. Based on the data collection techniques, this study applying quantitative data collection techniques using surveys, by determining the number of respondents and collecting data through questionnaires. The survey is usually used in research, where several people
will be asked questions in the form of a questionnaire. After that, the researcher will conclude all the respondents' answers in a statistical calculation that is presented in a table or diagram.

Respondents used as samples were the Head of the Family or representative of the Family aged 15 to 64 years (productive age) who were officially registered as domiciled in Paweden Village. Sampling using simple random sampling technique. Total respondents used as research samples are 32 respondents representing 32 households spread across 3 sub-villages in Paweden Village. In addition to supporting the data, several in-depth interviews conducted with informants according to the research needs. The field survey was conducted on May 2017. Survey location determination was carried out deliberately (purposive sampling). The location criteria used as the case study where the location has a river that has been planned as one of the MHPP development sites in the Banjarnegara Regency. Moreover, the area must have a water source from the forest ecosystem and easily accessible by the community. Paweden MHPP already has a construction permit on the Kali Urang River with a planned capacity of 3,160 KWh. Based on data from the Department of Water Resources and Energy Management of Mineral Resources in Banjarnegara Regency, there are about 35 permits for MHPP development projects in the Banjarnegara region (figure 1).

![Figure 1. Distribution of MHPP Development Licensing Plans in Banjarnegara Regency.](image)

The MHPP is planned to have a capacity of between 100 KWh to 60,000 KWh. Figure 2 shows the capacity plan for each MHPP to be built in Banjarnegara Regency.
Figure 2. MHPP Capacity Plan in Banjarnegara Regency.

One of the MHPP development plans in Banjarnegara Regency is located in Paweden Village with the capacity around 3160 kWh.

3. Analysis Method
This research included as descriptive research. According to [7], descriptive research attempts to provide a description and the explanation of why a social phenomenon arises. This study tries to describe the potential development of a Micro Hydro Power Plant (MHPP) based on the capacity of local communities in Paweden Village, Banjarnegara. In addition to using frequency analysis, analysis is also carried out using a Likert Scale. According to [7], explains that the Likert Scale is a measurement method used to measure the attitudes, opinions, and perceptions of a person or group of people about a certain social phenomena.

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\text{Index formula (\%)} = \frac{\text{Total Score}}{Y} \times 100
\]

\(Y = \text{Highest Likert Score} \times \text{Total Respondents}\)

Community capacity analysis is useful to see the social feasibility associated with the ability and willingness of the community to build and manage micro hydroelectricity in a sustainable manner. This is manifested in the form of agreements and willingness to participate. In general, the water potential around the Urang River is abundant throughout the year and the mountainous topography makes it possible for the different heights to increase the energy of the water flow. The electricity generated must be able to meet the minimum electricity needs of the community for lighting and encourage microeconomics independence. The socio-economic conditions of the community and the biophysical potential that exist together will be used as a basis for determining the construction of micro-hydro installations.

Based on [8.], the definition of community capacity is a concept combination of the community and capacity. Community is a member of the society that involved in the system, has a sense of belonging, has relationships and mutual interest understanding. Often based on homogeneity (the similarity of attributes owned by its members), but more importantly is communality (equality). Communality is a condition where there are things shared between members, but not always derived from the attributes owned by members, but based on motivation, goals, desires, blood relations, and mutuality (togetherness). Communities arise because of the geographical similarities in society, such as housing environments, social connections such as certain ethnicities, education, age, or interests. Components of the community start from the lowest level in society, specifically individuals, informal groups, organizations to other higher levels. Community is dynamic, it can change according to the time and place where the community is. Examples of communities in Indonesia are neighborhood association.
(RT)/citizens association (RW), based on work, traditional, rural and religious groups. Communities can also have a combination of similarities, for example, geographical and social relations such as in old cities that contained immigrants from another country [9].

Community capacity is the interaction of human capital, organizational resources, and social capital that exists in certain communities that can be influenced to solve collective problems and improve or maintain community welfare. This can work through informal social processes and/or through organized efforts by individuals, organizations and social networks that exist between them and in the wider system in which the community is part [9]. A good community capacity will be beneficial for the sustainability of a program or planning that will be taken and can avoid conflicts related to the MHPP development plan that will be built in Paweden Village. In addition to social community analysis, spatial analysis is also conducted to determine MHPP's affordability. Spatial analysis is done by combining various data obtained, including data from the Paweden Village Official, statistical data from the Banjarnegara Bureau of Statistics, and spatial data from the Geospatial Information Agency. The data obtained are used to calculate the area that can be reached by MHPP compared to the area of Paweden Village. Spatial data is also used to create MHPP coverage map using the overlay method. This method is used to overlap the 1: 25,000 scale of Indonesian Topographic Map (RBI) with the location of the MHPP development plan. In addition, buffering techniques are used to examine affordability. [9.] states that the length of the distribution network from the point of the power plant to the power receiver (load) is less than 2 km for low voltage (220 V). Therefore, calculated areas that can be reached by MHPP is areas that are less than 2 km from the MHPP site location. The results are then plotted into the map. Descriptive spatial analysis is used to describe these results.

4. Result and discussion

4.1. Paweden Community Condition

Paweden Village located in Sub-District Karangkobar, Banjarnevara Regency. The Village is bordered by Sampang Village (sub-district Karangkobar) in the north, Sijeruk (sub-district Banjarmangku) in the south, Gumelar Village (sub-district Karangkobar) in the east, and Slatri Village (sub-district Karangkobar) in the west. The area of Paweden Village is 180.13 ha, with 15.73 ha of paddy fields, 120.4 ha of plantations (mostly individuals), and 127 ha of forest (63 ha of protected forest and 64 ha of production forest). The climatic conditions in Paweden Village are as follows: this village has an average rainfall of 22 mm, with the number of rainy months is 5 months. The topography of the land is hilly, has a river called Sungai Urang, and 15 points of water spring. Regarding electricity sources, the majority of Paweden Village people use the electricity network of the State Electricity Company (PLN), which is 396 units, while there area 15 families still using kerosene/jatropha/ coconut lamps. Based on the findings of the field, it is known from the number of families that use the PLN electricity network that there are still many families who have not used the electricity network properly by channeling it to other families.

4.2. Overview of the Respondent

The gender of the respondents surveyed was almost balanced, namely 53% male and 47% female. The age range of respondents ranging from 17 years to 64 years, with the majority of respondents categorized as early adults aged 26-35 years (50%). The majority of respondents' education level is elementary school/equivalent, which is 88%. The majority of respondents' jobs/livelihoods are farmers, which is 44%, in addition to being housewives (28%), village officials (10%), and other occupations. Some respondents have other side jobs such as traders, manual laborers, and other farmers. The average income per respondent per month is still below the Regional Minimum Wage (UMR) standard of Banjarnevara Regency, as many as 47% of respondents who have income below Rp. 1,610,000/month. While respondents with a monthly income above the Banjarnevara UMR only amounted to 6% of the total respondents.

4.3. Feasibility Potential for Paweden MHP

According to [11] there are several criteria for the feasibility of the potential MHPP in an area, namely:
• Consumers: There are prospective electricity consumers around the MHPP installation in a radius of 2 km from the power plant or distribution substation (GD).

• Distance: The length of the distribution network from the location of the power plant to the power receiver (load) is less than 2 km for low voltage (220 V) capacity: The power generated is sufficient for the whole population so as not to cause social conflict, at least 1 Ampere or 200 Watt / KK

• Water discharge: Fluctuations in water source discharge are not too large, and a maximum of 1 dry month in the dry season

• Disasters: Disaster mitigation; The construction is on stable soil, the weir height is no more than 2 meters, and the design head is less than 50 meters.

• Accessibility: Access roads to locations can be reached or can be reached safely and economically.

• Environment: The power plant location does not damage the environment and/or is in a prohibited conservation area

• Economy: The community has a source of money income to finance the operation and maintenance of an MHPP installation

Related to electricity needs in Paweden Village, based on the results of the survey, in the opinion of respondents the electricity supply in each house is still inadequate, this can be seen from the score obtained which is equal to 63.71%. Moreover, respondents' opinions related to electricity supply in the village, the majority answered inadequate (66.67%). The majority of electricity used in respondent homes comes from the State Electricity Company (PLN) electricity grid, and as many as 65% of the majority have a power limit of 450-volt-amperes (VA) (figure 3). Based on the survey results, it is known that as many as 39% of the respondents' houses are still supplying/riding the electricity grid with family or relatives whose homes are close together.

![Figure 3. House electricity limit.](image)

The use of electricity in Paweden in addition to lighting is most widely used for television use (37%), rice cookers (28%), and electric irons (17%) (figure 4). The average monthly electricity payment/purchase is around Rp. 57,586.

![Figure 4. Electronic equipment used.](image)

Based on respondents opinion, the supply and the electricity network are still lacking, aside from the fact that there are still many residents channeling with neighbors, there is no lighting for village roads,
and because there is a regular power outage that is 1-3 times/month. The lack of electricity supply in the village shows that there are still many potential electricity consumers in the vicinity of the planned MHPP installation at a radius of 2 km from the power plant or distribution substation (GD). Based on the survey results, the majority of respondents still need additional electrical power for their houses around 250-500 additional watts (80%).

Concerning the distance, Paweden MHPP’s location is on the Urang River, which is the boundary between the village of Paweden and Sijeruk (figure 5). With a distribution network length of less than 2 km, the power plant is capable of supplying electricity to 9 villages in 4 sub-districts, namely Karangkobar District (Paweden, Gumelar and Slatri), Wanayasa District (Suwidak Village), Pagentan District (Nagasari Village), and Kecamatan Banjarmangu (Desa Kaliunjur, Sijeruk, Prendengan, and Pagerpelah). For Paweden Village, power plants are sufficient to 95.87% of the entire village area. The coverage covers almost all settlements of Paweden villagers. The following figure is a map of the Paweden MHPP Reach for Paweden Village.

Paweden Village has a high potentiality of water resources. This is evidenced by the presence of 15 water source springs. With a hilly land topography, Paweden village has several small rivers and one large river, the Urang river which is the river where MHPP will be built (figure 6). This condition is supported by the average rainfall of 22 mm with the number of rainy months which is five months.
Based on the accessibility, Paweden MHPP will be built on the Urang River, 72.6 m away from the Karangkobar road which is the main road leading to the village of Paweden. Until now for development purposes, access to the location can be reached by four-wheeled vehicles along the Karangkobar road followed by walking from the nearest road to the power plant position. The access road to the location can be reached safely and economically.

From the economic level of society, as previously mentioned the average income per month of respondents is still below the Regional Minimum Wage (UMR) standard of Banjarnegara Regency (47%). However, based on the survey results it is known that as much as 66.21% of respondents are willing to pay routine contributions to the MHPP electricity installation if the electricity is distributed to the community.

4.4. Identification of Rural Community Capacity in Paweden Village

Community has a capital, to support the capacity of communities have. According to [10], there are 3 (three) indicators that determine the capacity of the community, that is human capital, organizational resources, and social capital.

4.4.1. Human Capital. Human Capital/Human resources, is the main capital in the community. The quality of human resources will be in line with the quality of the community. In the case of Paweden Village, human resources, based on their level of education, are generally classified as basic education. The lack of public education will have an impact on the low quality of human resources.

To improve the quality of human resources for managing MHPP, especially related to the development of MHPP in Paweden Village, training and outreach are needed regarding the terms, functions, and management of MHPP. Based on the survey results, the majority of respondents (83%) answered that they were very inexperienced when asked about the terms and functions of the Micro Hydro Power Plant (MHPP). On the other hand, as many as 58.67% of respondents knew enough about the Hydroelectric Power Plant. This shows that some people are well aware that the potential of hydropower can be used as a producer of electrical energy.

Although the quality of human resources still tends to be low, the community's willingness to participate is quite high. The survey result shows that 75.48% of the community agrees when MHPP is built in their village. The majority of respondents are also willing to take part in cooperation to build micro-hydro installations, participate in managing the maintenance of micro-hydro installations, willing to become members of MHPP maintenance groups/organizations, and willing to pay regular contributions for electrical installations.

Community participation and involvement are very important in every development program/project conducted by the government. With participation, it will encourage community independence so that sustainable development is achieved. The high desirability to participate in the MHPP development plan in Paweden Village is strongly influenced by the high public interest in obtaining additional sources of electricity for lighting at night and various other needs. Even though most of the houses in Paweden
Village have been electrified the available supply is still insufficient for the needs of the community. Besides, the lack of electricity networks and the high tariff of PLN (State Electricity Company) makes many residents still share or hijack the electricity network from their neighbors (family or relatives whose houses are nearby) (figure 7).

![Figure 7. Willingness to participate in MHPP development](image)

Community awareness of environmental sustainability is very important so that the development and management of MHPP can run well. Without a sustainable environment and reserves of water stored in the forest, MHPP is difficult to operate optimally. MHPP is very dependent on the volume and cleanliness of river water because if the water discharge is low and the river has a lot of garbage, the MHPP electricity production will decrease.

Management and protection of water and forest resources have to become the main priority of the villagers. The people of Paweden Village treat the surrounding forest area to fulfill the needs of firewood, gardening, and hunting. While the benefits of the river around the village are perceived as water sources for irrigation, cooking, washing, and fishing. On the other hand, the community is also quite aware to maintain the cleanliness and sustainability of the surrounding environment. The majority of respondents' ways to protecting the environment of the surrounding forests and rivers are by not cutting trees carelessly (58%), not burning trash in the forest (42%), and not throwing garbage in the river (84%).

However, the active role of the community to protect or rehabilitate forests have to be optimized. Communities need to be transmitted further understanding related to the benefits and functions of forests and rivers so that the responsibility towards the environment is getting stronger. It is expected that with the presence of micro-hydro electricity, the community's understanding of the role of forests in the catchment area can increase. The community also expected to be more triggered to protect the forest environment so that they are not cut down the trees carelessly and frequently conduct mutual cooperation to clean and maintain the environment and waterways which will be the main source of MHPP.

4.4.2. Organizational resources. The organizational resources discussed here are the resources owned by social organizations, especially in Paweden Village. Community organization resources need to be managed properly to maximize the existing potential. These can be tangible and intangible assets. Tangible assets are assets/resources owned by a group that can be seen in an obvious way. Related to the potential development of MHPP in Paweden Village, the most important tangible asset is the existence of rivers as the main source of power generation. As previously described, in Paweden Village has one of the main rivers that are the water resources of the village community. Urang River has enough water discharge for MHPP to be built, especially during the rainy season the Urang River current is quite heavy. Tangible assets can also be seen from the infrastructure of Paweden Village, the main access road that is close enough to and from the MHPP development plan location, namely Karangkobar Street which is only 72.6 m away. Access to the location can be reached by four-wheeled vehicles along the Karangkobar road followed by walking from the nearest road to the power plant position. The access
road to the location can be reached safely and economically so that the process of MHPP development will be easy and smooth.

Intangible assets are various non-physical resources created by groups and their members. One of them can be seen from the existing institutions in the Paweden Village. Community institutions in Paweden Village include Village Deliberation Institution (LMK), Tourism Awareness Group (Pokdarwis), Farmers Group Association (Gapoktan), Youth Organization (Karang Taruna), Family Welfare Empowerment (PKK), Mosque Prosperity Board (DKM), Village Community Empowerment Institute (LPMK), and others. Based on the survey results, as much as 63.75% of respondents perceived that groups/organizations in the village classified as having an active role in the community. However, the respondent's participation in the membership of community groups/organizations is around 57.50%. Based on the respondent's opinion, the groups that played the most active role in the village were Gapoktan (39%), Youth Organizations (32%), and PKK (20%).

Gapoktan is one of the community institutions considered to be the most active role in Paweden Village. This is because the majority of the population earns a living as farmers, so the role of the Gapoktan is considered to be very important and quite active in community activities, especially those related to agriculture. Respondents also considered that Youth Organization (Karang Taruna) and PKK were quite active in social activities. Some of these social groups can be social agents in village development. Concerning the MHPP development, the role of active community groups can influence the community to participate in both the planning and management of MHPP in the future.

4.4.3. Social Capital. Social capital has an important role in the development of social, cultural, economic, and political. Fukuyama states that trust is a core element of social capital. This signifies that the success of development in all aspects must be based on the existence of trust, and then it requires to be able to create continuity of trust to accumulate. Social capital has a wide dimension regarding everything that makes a community allied to achieve a common goal based on togetherness and it is bound by values and norms that grow and be obeyed [10].

Various collective actions based on high trust will increase public participation in various forms and dimensions, especially in the context of developing community growth and especially improvement in the economic aspect. Individual trust level comes from values, including: (a) religion or beliefs, (b) skill, and (c) broad-mindedness, which has become the accepted norm in society. In Paweden Village, trust arises from the similarity of religion or beliefs and the similarity of livelihoods. Based on the 2015 Paweden Village profile data, it is known that 100% of Paweden’s population is Muslim. This makes the values adopted by the community following the values practiced in Islam. Furthermore, the majority of Paweden people are farmers, especially salak farmers (80%). The majority of the population also knows each other, so the level of trust is quite good. One example of a good level of trust in terms of sharing electricity use. There is a number of residents who distribute/ride the electricity network between one house to another house. There are values and norms formed related to the rules of sharing electricity payments, rules on electricity usage, time of electricity usage, and so forth.

Furthermore, strong social capital can be seen from community activities, especially those related to environmental management. Based on the survey results it is known that there is a routine community service program to clean the village environment. This activity was conducted cooperatively and all elements of the community were involved. These activities usually held once a month. Reforestation and river cleaning activities are also held occasionally. These activities are very beneficial if it is held more routinely when an MHPP will be built in Paweden Village. Based on the survey, the community also willing to do community service for waterway and turbine maintenance activities if MHPP established in their environment.

5. Conclusion
Overall, Paweden resident has not completely used electricity from the State Electricity Company (PLN). The electricity capacity in each house is still insufficient. Based on the survey results, the majority of respondents still need additional electrical supply around 250-500 watts for their domestic needs. The Paweden MHPP, when assembled, will cover the entire Paweden settlement.

Based on the capacity and needs of the local community in Paweden Village, the majority of respondents are willing to work together to build micro-hydro installations, participate in managing the maintenance of micro-hydro installations, willing to become members of MHPP maintenance
groups/organizations, and willing to pay regular contributions for electrical installations. The role of active community groups can stimulate the community to participate both in planning and managing MHPP in the future. However, there is one obstacle, individual awareness to protect the environment is still lacking. This can be overcome by the role of social groups in Paweden who actively enforce environmental preservation activities such as cleaning up the surrounding environment, planting trees in the forest, and cleaning rivers.

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