Sustainability Challenge of Micro Hydro Power Development in Indonesia

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Abstract. Rural electrification using renewable energy is the best choice for many locations that far away from national grid. Many renewable energy project have been built for rural electrification such as micro hydro power plant (MHPP) and solar photovoltaic (SPV). Sustainability still the main challenge of off-grid renewable energy development for off-grid rural electrification in Indonesia. The objective of this paper is to review sustainability of micro hydro power development in Indonesia. The research method was done by field observation, interview with MHPP management, and reviewing some research about MHPP in Indonesia. Sustainability issues include various aspects that can be classified into 5 dimensions: technical, economic, socio-cultural, institutional, and environmental. In technical factors that lead to sustainability problem are: improper MHPP design and construction, improper operation and maintenance, availability of spare parts and expertise. In the economic dimension are generally related to: low electricity tariff and utilization of MHPP for productive use. In the social dimension are: the growth of consumer's load exceeding the capacity, reduced number of consumers, lack of external institutional support. In the institutional side, it is generally related to the ability of human resources in managing, operating and maintaining of MHPP. Environmental factors that lead the sustainability problems of MHPP are: scarcity of water discharge, conflict of water resources, land conversion over the watershed, and natural disasters.

1. Introduction

Electrical energy is one of the infrastructure to realize sustainable development, encourage economic growth, and increase prosperity, health and educations. Electricity is one of critical inputs for overall development of country and is one of main infrastructure requirements for agricultural, industrial and socio-economic development [1].

Electricity development in Indonesia aims to ensure the sufficient electricity supply, good quality electricity supply with reasonable price in order to improve the welfare and prosperity [2]. Today, there are many Indonesian people who have not been able to access electrical energy. The electrification ratio of Indonesia in 2014 is about 84.4%, there are 15.6% of Indonesian people who have not yet electrified [3].

Electrical energy supply for rural communities or rural electrification is an authority of both central and local governments. The demand for electricity in a remote area can be satisfied by either extending the coverage of the national power grid (the on-grid approach) or constructing and operating stand-alone

power system (the off-grid approach) such as micro hydropower plant, solar photovoltaic, wind turbine, biogas and biomass [4]. The selection of rural electrification methods (on-grid or off-grid) depends on several factors such as distance from existing grid, voltage and capacity of existing grid, load capacity and density, rough terrain, investment cost, operation and maintenance costs, willingness and ability to pay of electricity, and renewable energy potential [5].

The rural electricity program in remote areas by national power grid expansion is not economic. In technical side will create another problem related to power quality i.e. voltage drop, in economic side it is requires a large investment cost. Diesel power plants utilization for rural electrification, is an unfavorable choice today, due to the high fuel costs and environmental problems. Diminishing sources of fossil fuel and environmental concerns are encouraging factor to switch Indonesian power generation sources to renewable energy [7].

Utilization of local renewable energy potentials for rural electrification in the areas that far away from national power grid is the most realistic solution. Indonesia has abundant renewable energy potential, but the utilization is still low. Renewable energy potential includes hydro, wind, solar, biomass, biogas, and geothermal. Indonesia's renewable energy potential data can be seen in table 1 [3].

Table 1. Renewable Energy Potential and Installed Capacity [3]

No	Renewable Energy Sources	Potential (MW)	Installed Capacity (MW)	Utilization (%)
1	Hydro	75.091	4.826,7	6,4
2	Geothermal	29.544	1.438,5	4,9
3	Minihydro/Microhydro	19.385	197,4	1,0
4	Bioenergi	32.654	1.671,0	5,1
5	Solar	207.898	78,5	0,04
6	Wind	17.989	0,3	0,002
7	Air Laut	443.208	8.215,5	1,9

Renewable energy is widely built in Indonesia today i.e. micro hydro power plants (MHPP) and solar photovoltaic (SPV). Indonesia's renewable energy technology data that has been built by central government (Ministry of Energy and Mineral Resources/MEMR only) can be seen in table 1 [8]. Some ministries also have built a lot of MHPP in Indonesia, such as Ministry of Home Affairs, Ministry of Village, Ministry of Forestry, Ministry of Public Works etc. The government, both central and local government, has spent a lot of money every year to develop renewable energy to power up unelectrified villages. By 2017, MEMR has budgeted more than 100 billion rupiahs for renewable energy development for rural electrification [9].

Table 2. Renewable Energy Technology Development by MEMR [8]

Year		RE Technology	
		MHPP	SPV
2011	Unit	8	0
	Capacity (kW)	216.4	0
2012	Unit	0	123
	Capacity (kW)	0	4828
2013	Unit	11	121
	Capacity (kW)	1301	5275
2014	Unit	14	87
	Capacity (kW)	651	2650
2015	Unit	14	163
	Capacity (kW)	1193	8795

MHPP is the best choice of renewable energy technology if a location has hydro power potential. There are several reasons why it is very interesting to be developed in Indonesia today. From a technical point of view, MHPP technology is relatively simple, almost every component can be produced in Indonesia. In terms of economy and finance: investment, operating, and maintenance costs are relatively cheap compared with other renewable energy technologies. Water energy is a clean, cheap and environmental friendly of power generation source [10].

MHPP is a hydropower plant with a capacity below 1 MW that come from irrigation channels, rivers or natural waterfalls by utilizing the height of head and water discharge [11]. MHPP is a small power plant that uses hydropower with a capacity below 200 kW [12]. According to UNIDO, MHPP is a power generation system using energy sources from hydropower with a capacity of 500 W - 100 kW [13]. According to JICA, MHPP is a hydropower plant with capacity up to 200 kW [14].

In general, MHPP is a run-off river hydroelectric or has no dam (reservoir) that can be used to store water for a certain period of time (daily, weekly or monthly). The availability of water discharge, at that time used to generate electricity. In MHPP, head obtained is not by constructing a dam, but by diverting some stream flow to one side of the river and dropping it into the same river at a place where the required head has been obtained naturally. The water is deployed to rotate the turbine inside the powerhouse via penstock. The mechanical energy from turbine rotation is converted to electrical energy by a AC generator.

Sustainability is the main issues in the development of off-grid MHPP in Indonesia. Many MHPP projects have failed to address sustainability from the start [15]. The sustainability is determined to start from the planning, construction until operation and maintenance. It is very important to identify sustainability problem of MHPP. The objective of this paper is to review sustainability of MHPP development in Indonesia.

2. MHPP development for rural electrification

Many considerations in the development of MHPP so it can provide optimal benefits and sustainable. The identification of many factors starts from the planning stage: a potential survey followed by a feasibility study of technical, economic, social-cultural, institutional and environmental aspect. The next stage is detailed engineering design (DED) based on feasibility studies and budgets. In the other hand, preparation of community development and management must be done [12].

Social problems sometimes arise at the planning stage. The problem must be solved first before step to the next stage. Coordination of each stakeholder should start from the beginning to establish commitments and formulate the rules of the game among parties. Society should be the subject in every stage of development and not just as beneficiaries. The stages of MHPP development are broadly comprised of: potential surveys; feasibility study; technical design; and preparation of development; implementation of development; commissioning; operation, maintenance, and management. MHPP development process can be seen in figure 1 [12].

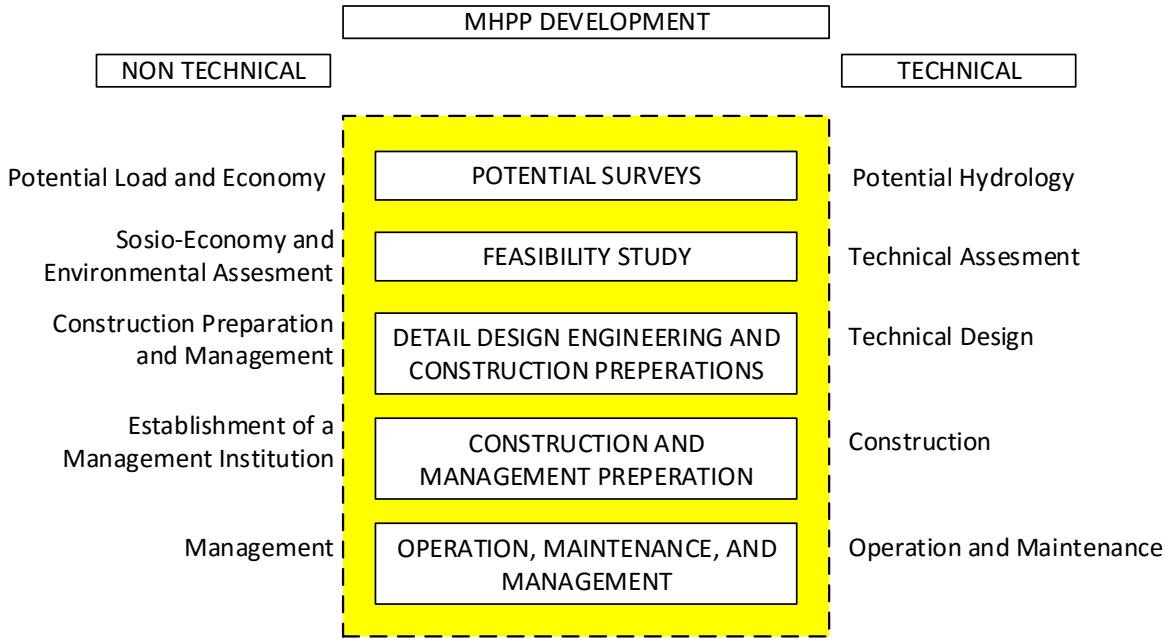

Figure 1 MHPP Development [12]

3. Methodology

There are several research methods undertaken in preparing this paper. The first study was conducted by reviewing various studies that have been done related to MHPP and the problem. Several studies have examined many MHPP locations in Indonesia such as Sumatra, Java, and Sulawesi.

In addition to reviews of various studies that have been conducted, research is also based on field observation at several locations of existing MHPP in Indonesia. There are several locations that have been surveyed such as North Sumatra, West Sumatra, West Java, Yogyakarta, West Nusa Tenggara, Gorontalo, Central Sulawesi, West Sulawesi, and Papua. Surveys are conducted by observing directly the condition of existing MHP and its problems and interviews with management institutions.

The third research method is through in-depth interviews of the management institutions. Interviews with the management institutions of both operators and managers are conducted simultaneously with MHPP training for management institutions in 2017. There are more than 100 MHPP managers and operators from various provinces in Indonesia such as: North Sumatra, Riau, West Sumatera, Lampung, West Java, West Kalimantan, West Nusa Tenggara, East Nusa Tenggara, South Sulawesi, West Sulawesi, Central Sulawesi, Gorontalo, Southeast Sulawesi, West Papua and Papua follow the training.

4. MHPP sustainability review in Indonesia

After the project is completed by the government or donor agencies, the MHPP is usually handed over to the village community. Management, operation and maintenance are carried out independently by the community through MHPP management institution. Operation maintenance and management should be well done so that the supply of electrical energy can be sustainable. The sustainability is not only responsibility of the management institution. Consumers, governments, contractors and manufacturers play an important role in maintaining MHPP sustainability.

The Ministry of Public Works conducts research about sustainability of the MHPP with capacities ranging from 2.5 kW to 120 kW in Lampung, West Java, Central Java and East Java provinces. There are several issues related to the sustainability. Low electricity tariff is ranged between Rp 10.000, - Rp. 20.000, - per month, so it is not enough for operation and maintenance cost. Conflict of water resources for other purposes such as raw water needs for the daily needs of the community. The expansion of national power grid by National Electricity Company (PLN) has caused MHPP customers move to PLN's customers [17].

In 2012, Energising Development Indonesia (EnDev Indonesia) undertook research about MHPP performance in Indonesia through a key performance indicator (KPI) survey of 20 sites in Sulawesi and 27 sites in Sumatra. The capacity factor of MHPP in Indonesia is relatively low about 6.1%, while electricity availability factor is around 63%. The low capacity factor indicates that the potential of electrical energy that can be produced is very large, but its utilization is very low. The low availability factor indicates a limited operating time. Another result of this study, there are many problems about MHPP sustainability: some MHPP components are broken and not repaired, financial administrations report not yet booked, lack of water supply during the dry season due to land conversion in the upstream of the watershed, and the availability of MHPP spare parts [18].

In 2013 EnDev Indonesia conducted a sustainability study of 32 MHPP units in Sulawesi. There are several problems related to MHPP sustainability: social conflicts between villagers and villagers with MHPP management caused MHPP damage and stop operation, conflict of water resource utilization for agriculture and plantation cause MHPP not optimal in operation. The Expansion of national electric grid will reduce MHPP's consumers, natural disasters such as floods and landslides caused massive damage to the civil components. Another problem is poor quality of civil construction and electro-mechanical components will make MHPP low in reliability [19].

Murni et al. in 2013 conducting sustainable MHPP research at two sites in East Kalimantan. The sense of ownership and community participation in management is key factors that determine the sustainability. Sufficient electric tariff will ensure the availability of operation and maintenance fund. The management has a significant role in operating maintaining and managing the MHPP. Feasibility studies and good technical design produce a reliable MHPP which will be 'the initial capital' of sustainability [20].

Ranzanici in 2013 undertook the research of MHPP sustainability on several sites in Sulawesi Island. High investement costs are required to produce a good quality of MHPP that has a significant impact on sustainability. Problems on social and economic dimensions have a fatal effect on micro-hydro sustainability. The sustainability is a very complex interaction among various aspects: technical, economic, social, institutional and environmental [21].

Purwanto and afifah conduct the research sustainability of 2 unit MHPP in Java. The aim of the research is evaluate MHPP sustainability using sustainable development indicators. The results obtained that both projects performed poorly in the economical dimension and positively in other dimensions. The economic sustainability is facing great difficulties, as the project has no financial scheme, low electricity tariff and also low utilization of electrical energy for productive enterprises [22].

5. Discussion

Development of MHPP has been spending a lot of money either sourced from government budget or grants and loans from various donor agencies. Evaluation of technical, economic, socio-cultural and environmental condition is very important to ensure the sustainability of rural electricity supply. There are many factors affecting the sustainability, which can be classified into 5 dimensions: technical, economic, socio-cultural, institutional and environmental [16].

5.1. Technical Dimension

There are many MHPP built without feasibility studies and proper technical design, it will result interruption in MHPP operation is more often. Improper head and water discharge design, causing MHPP not working optimally.

MHPP should be operated and maintained using proper operating and maintenance procedures. Improper operation and maintenance will cause damage of MHPP component more often. It may disrupt the electric supply for rural communities. Standar operation and maintenance procedures shall be provided by contractor or manufacturer. The operator must conform with standar operating and maintenance procedure.

Another technical factor is maintenance guarantees and availability of spare part. The damage of some components can not be fixed by local operators, so maintenance guarantees from the contractor

and manufacturer is one important factor for electricity supply continuity. Every micro-hydro component have a life time, therefore spare part availability is absolutely needed to ensure sustainability. In general, location of MHPP is in remote areas, so the availability of spare parts becomes the main problem for MHPP.

5.2. Economical Dimension

In many cases the MHPP electricity tariff is set without correct calculation and only by community agreement. Tariff setting is only base on willingness to pay of community. so that the money earned is not sufficient for the operation and maintenance. Finally, the operation of the MHPP will be disrupted, because there are no funds available for component replacement.

The utilization of MHPP for productive use is one solution of low electricity tariff. Electrical energy is mostly used for consumptive activities at the night. In general, during the day the potential of electrical energy is not utilized. The utilization of MHPP energy for productive activities will increase the income of MHPP and community.

5.3. Social Dimension

Socio-cultural issues contribute to the sustainability. Lack of ownership and community participation is one of problem in MHPP. If some component or civil works having damaged, how the community responds to provide support both funds and workforce to repair it. Community compliance with MHPP rules and tariffs is a social capital that needed to maintain the sustainability.

Uncontrolled growth in consumer load often causes MHPP is overload. Overload operation will lead damage of turbine, generator and other components more frequent. It is necessary to adjust the consumer's load during peak load at 18:00 to 22:00. This rule must be followed by every consumer.

National power grid expansion to the location will provide an alternative energy for the community. Quantity and quality of electrical energy usually become a consideration for consumers. In the other hand low electricity tariff will be an attraction for the consumer. If consumer move to PLN, it is important to create an alternative utilization of MHPP. Productive use of MHPP for the small and medium enterprise (SME) is the best solution to keep it still running. SME is is one of the best ways to improve the welfare of the community.

Sustainability is strongly influenced by external institutions support. Policy, empowerment and funding support from external institutions plays important role to determine sustainability. Funding support can be sourced from village funds (Dana Desa), special allocation funds (DAK), as well as from local government revenue budgets (APBD). Government funds should only for large maintenance costs such as repair of civil works due to natural disasters, turbine replacement, and other major maintenance. Other institutions such as manufacturers or workshops play a significant role in maintaining the sustainability. The support of the workshops generally involves the availability of spare parts and experts. In west Sumatera, the workshop sometimes give a soft loan to MHPP for component replacement.

5.4. Institutional Dimension

Institutional issues that determine the sustainability of the MHPP are the capacity of the management. The institutional capability of management includes human resource competency, both operator, and administrative personnel in performing their duties and functions of managing, operating and maintaining the installation. Education and training for managers and operators is one way to improve the capability of MHPP management institutions.

Completeness of a set of rules and infrastructure for management, operation and maintenance will support the sustainability. The set of rules in the organization can be electricity tariff decree, agency decree, articles of association and bylaws, operation and maintenance manual, standing operation procedures (SOP). The infrastructure facilities organization can be office, safety equipment, work equipment, measuring equipment and financial administration report.

5.5. Environmental Dimension

Environmental is great issues in MHPP sustainability. The availability of adequate water discharge throughout the year is a critical point. Well-maintained forest will ensure sufficient water resource availability throughout the year. Land conversion in the watershed will cause decrease of water discharge during dry season.

Conflict of water resources can disrupt the operation MHPP. In general, utilization of water resources for other purposes besides MHPP, such as agriculture, plantation, fishery, industry, and water supply. Regulating the use of water resources is necessary to ensure continuity electricity supply to the community.

Natural disasters is one of factor that can influence the operation of MHPP. In general, MHPP is located in hilly areas so that natural disasters such as floods, earthquakes, forest fires, and landslides often occur. Flood and landslide cause severe damage to civil components. The damage caused by natural disasters generally require high maintenance costs. The availability of operating and maintenance funds sometimes insufficient to repair the severe damage caused by natural disasters.

6. Conclusions

Sustainability is still an important issue in the development of renewable energy for rural electricity in Indonesia today. The sustainability of an MHPP installation is determined from the first time, from the planning and construction stage until operation and maintenance. Feasibility studies and good technical design at the planning stage provide reliable and good quality of MHPP. Involving the community in every stage of development is a necessity that can increase ownership and participation in MHPP management.

In the operation and maintenance phase, there are several factors determining the MHPP sustainability. The main factors are the availability of operation and maintenance fund, the availability of water discharge during the year, and the ability of the management institution to manage the MHPP and external institutional support such as local government and MHPP workshop.

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