DEVELOPING A MODEL OF A SUSTAINABLE MICRO HYDROPOWER PLANT MANAGEMENT SYSTEM
A Case Study Kedungrong MHP Purwoharjo Village Samigaluh District Kulon Progo Regency Yogyakarta Province

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Abstract

Yogyakarta Province until 2014 has built a total of 10 (ten) micro hydropower plants (MHP). However, from these ten MHPs, there is only 1 (one) which is still in operation, namely Kedungrong MHP. This Kedungrong MHP was selected as the research area due to its success in managing the MHP so that the electricity generated can be used by its local residents until now. Based on this best practice, the other MHPs which are still under construction or that have 'stalled' should learn from Kedungrong MHP to be able to reoperate so that they will be sustainable.

This research employed mixed methods, between the quantitative research method and the qualitative research method. First, the data were collected using surveys, interviews and observation and then the model of the management system that Kedungrong MHP applies was described and evaluated.

The findings of the research suggest that a sustainable MHP integrates three aspects, namely technical and environmental, social as well as economic aspects. The technical aspects deals with civil, mechanical and electrical components at the stages of planning, developing to operation and maintenance. The social aspects look carefully at community participation at the stages of planning, developing to operation and maintenance. Finally, the economic aspects pay attention to sources and forms of financing at the investment stage, the operation stage and the maintenance stage. In relation to the MHP scale, of those three aspects, the one that has the most significant impact on the sustainability of the MHP is the social aspects.

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1. Introduction

The energy source used as fuel for most power plants use fossil energy sources (oil, gas and coal) as their fuel. High energy consumption can lead to a problem that is the lack of fossil energy and as a consequence the country's energy needs will be highly dependent on imports (Ministry of Energy and Mineral Resources, 2013).

By being aware of this possible condition, it is necessary to change the paradigm of energy management from *energy supply side management* into *energy demand side management*. In the energy supply side management, energy needs are met by fossil energy and renewable energy only as the alternative. While in the energy demand side management, energy needs are met by maximizing the supply and use of renewable energy through energy diversification, i.e. diversifying energy consumption by increasing the utilization of new and renewable energy such as solar power, biomass, wind, water and geothermal energy (Ministry of Energy and Mineral Resources, 2012), and fossil energy is used as a counterweight.

Currently, the development of renewable energy refers to the Presidential Decree No. 5 Year 2006 concerning National Energy Policy. This Presidential Decree states that the contribution of new and renewable energy to the national primary energy mix in 2025 will reach 17%. Today, the discourse has evolved to achieve the higher target share of this new and renewable energy in the national energy mix, i.e. by 25% by 2025, otherwise known as "Energy Vision 25/25" (Ministry of Energy and Mineral Resources, 2010).

In line with this policy, the Government of Yogyakarta Province continued to increase the electrification ratio in 2012 that reached 77.1%. This increase in the electrification ratio was achieved through massive utilization of renewable energy by the local community so that this form of energy can serve as an alternative for areas hard to reach by conventional electricity. In 2013, PT. PLN for Yogyakarta Service Area and Network set an electrification ratio target for this province by 81.42%. However, currently there are 32 hamlets situated in Yogyakarta Province that still have not obtained the access to electricity. These hamlets spread across three districts, i.e. 14 hamlets Kulon Progo Regency, 1 hamlet in Bantul Regency and 17 hamlets in Gunung Kidul Regency.

The potential of hydropower distributes evenly across the regencies in Yogyakarta Province. So far, according to data from the Departments of Public Works and Housing and Energy and Mineral Resources of Yogyakarta Province, hydropower potential that can be exploited for micro hydropower plants reaches 1,673.4 kW.

Of the existing hydropower potential, as many as 10 (ten) MHPs have been built in Yogyakarta funded from a variety of sources. The MHPs esablished in Yogyakarta Province are presented in Table 1.

Table 1. The MHPs esablished in Yogyakarta Province

No.	Location	Capacity	Source of Fund	Current Conditions
1.	Minggir 1 MHP, Sleman	15 kW	State Budget 2006	Not in operation since 2007
2.	Minggir 2 MHP, Sleman	15 kW	State Budget 2009	Not in operation since 2010
3.	Turi MHP, Sleman	5 kW	State Budget 2004	Not in operation since 2005
4.	Sewon MHP, Bantul	5 kW	State Budget 2003	Not in operation since 2006
5.	Gabusan MHP	1,25 kW	Regional Budget 2010	Not in operation since 2011
6.	Kedungrong MHP, Kulon Progo	30 kW	Regional Budget 2011	Operation until now
7.	Blumbang MHP, Kulon Progo	30 kW	Regional Budget 2013	Under construct-ion
8.	Semawung MHP, Kulon Progo	600 kW	Private Sector 2013	Under construct-ion
9.	Bendo MHP, Bantul	2 kW	Community 2009, 2010	Not in operation since 2010
10.	Singosaren MHP, Bantul	2 kW	Community 2007, 2009, 2010	Not in operation since 2010

The development of a sustainable MHP management system is not easy to implement. Many factors influence it. In fact, much of this MHP system development has failed and caused the buildings 'stalled'. That means that much of this MHP development is carried out but it cannot maintain its sustainability.

The management system development of Kedungrong MHP is expected to provide a model for other MHP system development, especially in Kulon Progo Regency, because at this present in Kulon Progo 2 (two) new MHPs, namely Blumbang MHP and Semawung MHP, are being established. These two MHPs are highly expected to contribute to the procurement of electricity in the area of Kulon Progo Regency and to improve the economic welfare of the local community.

The development of a MHP management system in Kedungrong Hamlet was used as the research area because of this Kedungrong MHP remains operating in a sustainable manner and the electricity generated has been utilized by the local community for public facilities such as street lighting and productive economic activities such as sewing and carpentry that provide optimal benefits to the community. Based on this best practice, the other MHPs which are still under construction or that have 'stalled' should learn from Kedungrong MHP to be able to reoperate so that they will be sustainable.

2. Methodology

This study investigates the development a model of a sustainable MHP management system using an approach of a mixed method, that is a combination between the quantitative research method and the qualitative research method. It began with qualitative data obtained from surveys, interviews and observation followed by the quantitative data by describing and developing the model of MHPs to be used by the other MHPs which are still under construction or that have 'stalled' to be able to reoperate so that they will be sustainable.

Research flow diagram presented in Figure 1.

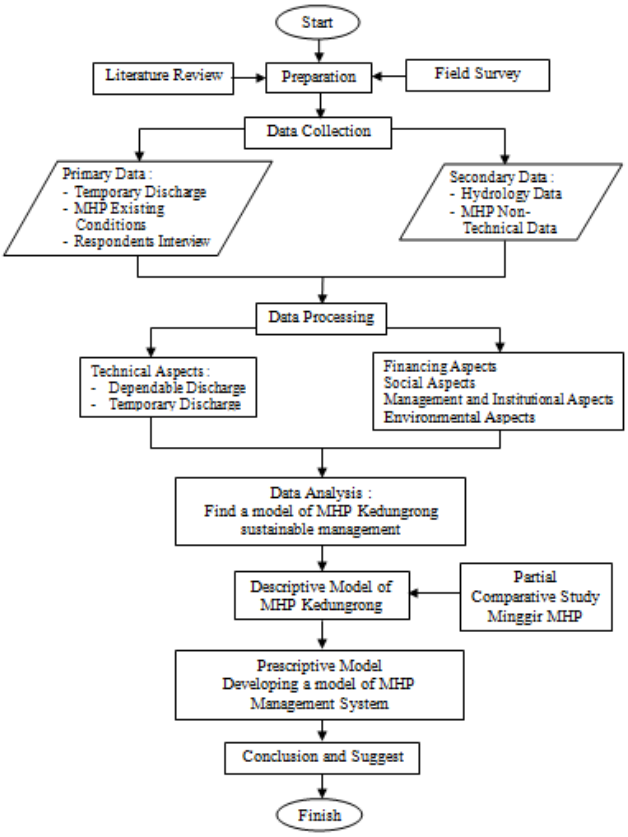

Figure 1. Research Flow Diagram

Research Findings

The results of the interviews and observations conducted at the site of Kedungrong MHP are described in this section. The interviews were given to all the local residents of Kedungrong Hamlet with a total of 43 houses with 46 families.

The existing conditions of Kedungrong MHP are presented in Table 2 below.

Table 2. Review, Evaluation & Recommendation Kedungrong MHP

	Review	Evaluation	Recommendation
Technical and Environmental Aspects			
Civilian components	Relatively good	Waste was found on the intake that may disrupt the flow of water into the carrying channel.	▪ Periodic maintenance is necessary for the civilian component. ▪ Waste should be cleaned at any time.
Mechanical & Electrical Components	▪ Operating and still in a good condition. ▪ Turbines were operated interchangeably as the power output cannot be used optimally.	▪ Electricity had not been used optimally. ▪ Electricity was used for lighting, carpentry, and overhauls.	▪ Development of productive economic activities. ▪ Addition of stabilizing power of two generators that produce electricity.
Economic Aspects			
Funding	▪ Maintenance and operational costs were obtained from regular dues. The amount of the dues : Rp 1.000,00 for street lighting → 45 "KK". Rp 5.000,00 for domestic needs → 29 "KK".	An increase in the goods needed for the maintenance and operation of the MHP occurred so that the maintenance and operational costs increased.	It is recommended to increase the amount of the dues given because of the increasing operational costs of the MHP.
Social Aspects			
Social	The community were involved in the maintenance of the MHP.	▪ The significant contribution of the community determines the sustainability of the MHP. ▪ A few productive economic activities	▪ Few productive economic activities utilize by the MHP. It is advisable to apply for assistance to the relevant agencies for the development of productive activities. ▪ Organizing training for the community concerning the development of the productive economy.
Management and Institution	The management of the MHP has been formed	▪ This MHP management cannot be developed. ▪ This is because the MHP management's understanding has not improved.	▪ The organization that has been formed should be made into a legal entity such as a cooperative. ▪ Organizing training for the MHP management to increase their competence.

The present study also made a partial comparative study of the MHPs that did not operate or "stalled". The partial comparative study was made at Minggir MHP.

The partial comparative study was intended to compare Kedungrong MHP with other MHPs with almost similar characteristics to predict the sustainability off this MHP. Minggir MHP was selected to be included in the comparative study because:

- It is a tributary of Progo River.
- The channel that is used for the MHP is irrigation.
- It is built using the regional budget of Yogyakarta Province.
- What makes them different is that Kedungrong Micro Hydropower Plant currently still operates while Minggir Micro Hydropower Plant does not.

3. Result and Discussion

From the results of research in Kedungrong MHP, the formulation of a sustainable MHP management model can be described in Table 3.

Table 3. The Formulation of a Sustainable MHP Management Model

	Model Formulation	Information
Technical and Environmental Aspects	*Civilian component* a) Planning MHP Location - There is a flow of water in rivers and channels with sufficient supply of water flows throughout the year. - The flows of water are relatively stable with minor differences in discharge. - The flows of water do not affect changes in river flows. - Even if a flood once occurred, it does not potentially damage MHP buildings. - The location must consider topography and geology. - The location has easy road access to reach. - MHPs must be located in the center of the load. - The MHP location does not damage the environment or situated in the location of a conservation area that is prohibited. Civilian Building - The design of those civilian buildings should pay attention to the characteristics of the land.. - Those civilian buildings are at a basic channel slope of 1: 1000-1: 1500. - The minimum age of the construction design is 20 years. - The type of the selected construction considers the conditions of the topography and the geological location. - The building materials used have a good quality. b) Development Civilian Building - Supervision at the construction stage of the MHP must be performed by an expert in micro hydropower plants. c) Operation and Maintenance Hydrology - The flows of river water and or channels must have continuous water supply throughout the year. - An effort of environmental monitoring is made to minimize the risk of environmental changes caused by physical changes in the environment during the operation of the MHP.	- Sufficient supply of water flow can calculate with dependable flow analysis. - The location should be close to the power receiver/user of electricity generated MHP. - Material Standards Book issued by each region. - Improper supervision will result buildings that are not appropriate and will lead to cost overruns. - Continuity of flow rates can be done by preserving the watershed, due to discharge into the primary source for MHP.

Table 3. (continued)

	Model Formulation	Information
Technical and Environmental Aspects	Civilian Building - Care and maintenance of civilian buildings must be done continuously. - Any damage should be repaired immediately. - Blocking waste by installing trashracks on the intake and regularly checking these trashracks at least once a day and more frequently when there heavy rain falls and flooding occurs. *Mechanical and Electrical Components* a) Planning Equipment Used - The type of turbine used considers the head and the design discharge. - Generator selection is based on the characteristics of the turbine used. - The age of the equipment design minimally is 10 years, and at least 3 years for the moving parts. Transmission Line - The transmission line for electrical distribution should consider the ease of access and maintenance, strong and stable soil conditions for installing power pylons and avoiding potential landslides, - For the transmission line, the shortest line of distribution is selected. b) Development Equipment Used The equipment is manufactured by a turbine manufacturer which provides mechanical electrical components that consist of turbines, mechanical transmission, generators, controls, and so on with the following provisions: - The efficiency of the turbine is not less than 60%. - The manufacturer must be able to guarantee that minimally during the first year of operations there will be no replacement of spare parts. - The manufacturer must provide the schedule for predictive maintenance and projection of spare part replacement. - The manufacturer guarantees to provide non-standard components that can be provided only by the manufacturer. The non-standard components include runner, guide vane, and other turbine components. - Operation and Maintenance Equipment Used - Care and maintenance must be done continuously and in accordance with the Standard Operation and Maintenance documents of the MHP.	- Generator selection consider adjusting the turbine speed with the speed of the generator. - The manufacturer must be able to guarantee at least the first year. - The spare parts include water seal, bearing, runner, belt, generator, controller, ballast load, and the like. - The non-standard components include runner, guide vane, and other turbine components.

Table 3. (continued)

	Model Formulation	Information
Technical and Environmental Aspects	c) Operation and Maintenance Equipment Used - Care and maintenance must be done continuously and in accordance with the Standard Operation and Maintenance documents of the MHP. - MHP management must be trained and have the competency to operate and maintain the installations of the MHP based on the Standard Operating of the MHP. - Waste can damage the turbine therefore regular checks need to be performed of at least once a day and more frequently when heavy rain falls and flooding occurs. - Cleaning the equipment at least once a month so that the equipment can operate and work well. - Checking the completeness of the equipment and the spare parts regularly at least after doing the routine maintenance.	- Operation and Maintenance Standards Document of MHP prepared by the management of MHP and MHP must be implemented by the operator.
Economic Aspects	*Invesment* a) Sources of Funding - Government, whether it is local or central government. - The government provide their supports by allocating some budget/ funding to develop the energy that continues to increase since 2005 till now. - Public sectors (Investors). - Investors are interested in making investment in micro hydropower plants with big capacity, of about 500 kW so thy can enter into PLN's networks (*on-grid*). - Public Organization. b) Form of Funding - Direct funding in the form of grants, loans or investment. - Procurement of physical equipment. *Operation and Maintenance* a) Sources of Funding - The amount of the dues paid considers the maintenance and operation costs of micro hydropower plants for the purpose of future supply of electricity.	- The maintenance and operation costs of micro hydropower plants include: the operators' salary, regular maintenance and monthly operation, preparation for annual maintenance, preparation for long-term renovation, and preparation for investment in the establishment of new micro hydropower plants.

Table 3. (continued)

	Model Formulation	Information
Economic Aspects	- The maintenance costs about 1-3 % of the investment cost. Micro hydropower plants situated in the environment with huge social capital are not necessary to spend some money on the aspects that have been maintained. However, if there is no huge social capital, maintenance costs should be allocated at the planning stage. - The selling price of electricity should be accommodated by the calculation of the economic analysis based on the estimated life time. If the generated power can be connected to the network of PLN (with certain conditions) then the electricity can be sold to ensure market/ user availability. - The economic analysis is made by calculating the values of NPV and BCR Transparency and accountability in capital management. b) Form of Funding - Assistance - Improvement in the capacity of human resources	- The amount of funding : 1- 3% of the funding from the government, a maximum of 2 years; 3% of the financing from the private sectors. - Acuan pembelian tenaga listrik dari PLTA (termasuk PLTMH) oleh PLN sesuai Permen ESDM No. 14 Tahun 2014. - Reference the purchase of electricity from hydropower (including MHP) by PLN according Minister Regulation of Energy and Mineral Resources No. 14/ 2014.
Social Aspects	*Planning* - The society has to have a good response towards the micro hydropower plant establishment plan. - Distributing information to raise community participation in the micro hydropower plant establishment plan. *Implementation* - The community participate in the process of micro hydropower plant establishment. *Operation and Maintenance* - The community should have significant participation in the management. - Assistance must be given to the community through a facilitator for at least 3 years and knowledge must be transferred to the community. - There must be an improvement in the educational capacity of the management, operators, and community. - There must be an improvement in community's welfare through productive economic activities that use electricity generated from the micro hydropower plant such as: small-scale industries, handicraft industries, overhauls, sewing, and so forth.	- If the micro hydropower plant uses irrigation, the maximum discharge is 50 % because it has to share with other usage, especially for rice field watering/irrigation. - They participate in the attempt to look after and maintain the micro hydropower plant (voluntary work). - The community should participate since the planning of the micro hydropower plant. This will guarantee the success and continuity of the micro hydropower plant.

Table 3. (continued)

	Model Formulation	Information
Social Aspects	Management and Institution *Operation and Maintenance* - The management of the micro hydropower plant is an organization or management formed based on the results of deliberation among the community and it has a legal basis just like: cooperatives, village-owned enterprises, and groups which utilize micro hydropower. - There is an institution that can solve the conflicts within or between the communities around it. - Concerned stakeholders need to provide support and supervision.	- Cooperative formed for the purpose as a container for managing the MHP or part of a business cooperative (MHP become part of one of the co-operative effort). - BUMDes in the management of MHP are in control of the village government. - Group/user community micro hydro is the most widely used in the management of MHP in Indonesia.

From the description of the model formulation, the sustainable management of MHP can be described relationship management model is shown in Figure 2.

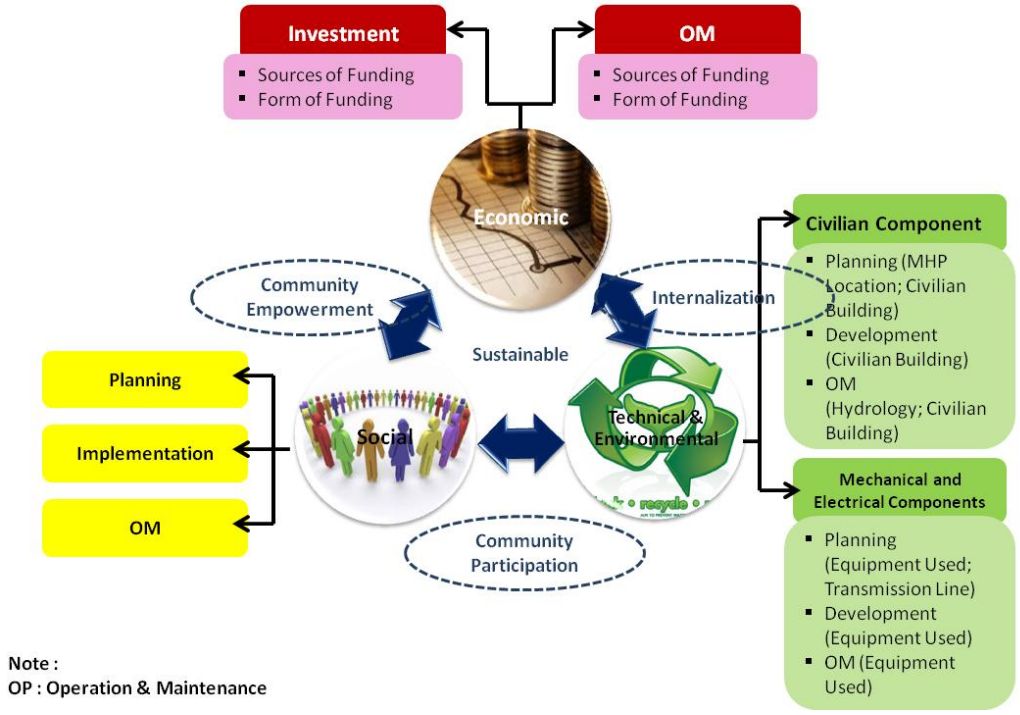

Figure 2. The Formulation of a Sustainable MHP Management Model

The formulation for a sustainable MHP management model is influenced by technical and environmental aspects, economic aspects and social aspects. The three aspects are related to each other. The relationship between the technical and environmental aspects with the economic aspects sustainable, internalization and valuation can be carried out. To make the relationship between the technical and environmental aspects with the social aspects sustainable, the community should contribute their significant participation. And to make the relationship between the social aspects with the economic aspects sustainable, community empowerment is necessary.

4. Conclusion

Based on the research findings, the following can be conclused:

1. The system management of Kedungrong MHP generally has been fairly good because until now it still operates and generates electricity for the needs of the local residents of Kedungrong Hamlet. Seen from the technical and environmental aspects, the civilian and mechanical & electrical components are still in a good condition and operate properly. In addition, the social and economic aspects also significantly support the management of Kedungrong Micro Hydropower Plant. These social aspects are influenced by significant public

participation in maintaining the MHP, for an example through voluntary work. Moreover, the management have a great sense of responsibility to develop the MHP. While the economic aspects are supported by the ability of the residents to pay dues with the amount that has been determined in accordance. The existence of productive economic activities that utilize electricity generated by MHPs such as carpentry, overhauls and sewing to improve the community's economy also plays a role. This managemet is still ongoing today. The success of an MHP cannot be separated from appropriate management. For that reason, a sense of possessing this MHP should always be maintained.

2. The formulation for a sustainable MHP management model is influenced by technical and environmental aspects, economic aspects and social aspects. The three aspects are related to each other.

   The technical aspects are seen from the civilian, mechanical and electrical components that have been done at the stages of planning and developing up to the stages of operation and maintenance. While the environmental aspects have something to do with the sustainability of water resources. The social aspects have been implemented since the stages of planning and developing up to the stages of operation and maintenance. The role of the community in active participation through economic activities can increase their incomes. While the economic aspects are seen from the investment stage and the operation stage and the maintenance stage. In these two stages, sources and forms of funding are discussed.

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