

# A Comparative Study: Micro-Hydro Power Management Model in Rural and Isolated Area

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**Abstract.** Micro-Hydro Power (MHP) is a solution to the need for renewable energy in the era of the industrial revolution 4.0. Its environmentally friendly effect has become a consideration for many people to consider implementing it in their respective places. One of the critical points to realize this is a sustainable MHP management model. This paper discusses the assessment of the MHP management model for electrification in rural areas in Indonesia. There are two objects in this research: Kunci Putih MHP in Jatirunggo Village, Semarang Regency, and the Mbakuhau MHP in Kamanggih Village, East Sumba Regency. This research aims to assess the management model of the Kunci Putih MHP and Mbakuhau MHP from the social-managerial, economic, and technical aspects. This study uses descriptive qualitative methods with gap analysis techniques. The results show that the two locations have different challenges based on three aspects that have been recognizing in international standards. The private sector manages Kunci Putih MHP with a National scale installation operated by the company directly. In contrast, Mbakuhau MHP manages by a credit union collaboration with National Electricity East Sumba. Kunci Putih MHP is driven by the private sector through auction and is responsible for maintenance, project engineering, repair, and equipment maintenance. Mbakuhau MHP can be successful in community-based management because IBEKA (Pro-Poor Public-Private Partnership) gave the community training during construction. The community provides technical training in leadership because Mbakuhau MHP is an electrification solution for isolated villages so that management is better carried out by the community. Therefore, the two cases cannot significantly be compared because they are different in power and scale.

## 1. Introduction

The 2015 Paris Agreement on Climate Change marked the agreement between countries to combat the earth's temperature changes' adverse effects, which increased by 1,5 degrees Celsius in the 21<sup>st</sup> century. One of the efforts is by focusing on the development of Renewable Energy (NRE). The demand for energy in Indonesia, particularly electrical energy, is still dominated by fossil fuels and coal. This energy supply can enable numerous activities such as housing, industries, agriculture, and many others. The environmental impact of these activities' fulfillment is the increase in pollution and the destruction of productive land on a large scale. According to the World Resource Institute (WRI), Indonesia is the 6th highest emitter of CO<sub>2</sub> globally. It is necessary to develop new and renewable energy that is environmentally friendly as an alternative source of electrical energy for communities. The Micro-Hydro Power (MHP) provides many benefits for communities. In addition to being environmentally friendly, the power plant also produces neither pollution nor waste. Most rural areas, close to water sources, such as rivers, can utilize the MHP as an alternative. Micro-Hydro is a small-scale power plant



that uses hydropower from sources such as rivers, waterfalls, and irrigation channels to generate power while monitoring the water discharge. The construction of MHP in rural areas can support rural development by improving rural communities' socio-economic welfare [1]. Increased living standards from the community have felt in communities, households in Nepal, and increased health, education, environment, and agriculture are significant local benefits from the MHP project in rural households [2].

Micro-Hydro is commonly used in electricity-generating installations of up to 100 kW [3] or on a small-scale using water flow as an energy source. This power comes from a river or lake with a suitable discharge to drive a turbine connected to an electric generator. The higher the waterfall, the more potential energy can be converted from water flow into electrical power [4]. MHP projects can be alternative electricity solutions for isolated communities [5], usually rural areas rich in water resources. As the research's initial framework, these criteria and sub-criteria formulate according to the study's scope, namely economic risk, economic take-up, environmental effects, cultural acceptance, resource efficiency, and social stability [6]. However, in this study, the focus is to assess three components: social, managerial, financial, and technical. This Micro-Hydro project is also community-based. It requires concrete business management, emphasizing job training, creating a household budget to start its success. In this case, women should participate in decision-making because they are most often affected by the project [7]. A project manager is also essential for the success of the project, as expected. Policymakers do not have an excellent critical understanding of cultural practices [8]. In evaluating a project, things must consider determining whether the project is running effectively or not. The approach to assessing from various sources becomes one of the benchmarks in evaluation activities. There are five criteria in the program evaluation process, namely (1) needs assessment, (2) program theory assessment, (3) program process assessment, (4) impact assessment, (5) efficiency assessment. Each study must identify criteria before collecting data and analysing data [9].

Semarang Regency is an area enriched with water sources, with an average rainfall of 2.427 mm. According to data from the Bina Marga Office, Water Resources, and Energy Mineral Resources of Semarang Regency in 2018, the Semarang Regency has 17 locations with the potential to produce renewable electrical energy which comes from the river. MHP offers a cost-effective and low-impact power plant solution with the potential for rural electrification [10]. MHP can produce electricity of up to 100 kW and is popular among developing countries throughout the last four decades [11]. In 2018, One of the MHP projects located in Jatirunggo Village, Semarang Regency, has been legally managed by a private company; namely, Kunci Putih MHP cooperates with State Electricity Enterprise.

The effort to meet energy demands also undertaken in Kamanggih Village, Kahaungu Eti District, East Sumba, East Nusa Tenggara. The MHP constructed in the village is the first on Sumba Island, and the construction is based on the fact that there have been no lighting or electricity and telephone signals in Kamanggih Village for decades. In 2004, Kamanggih Village received aid in water pump machines and solar panels from the government, one of the international donors in 1999. Sumba Island residents did not lack water to meet their daily needs, but the water was not well-distributed because it is in a foothill. In contrast, most residents live in the higher mountain areas. In the 2000s, IBEKA researched in order to construct a power plant project. Upon approval, the MHP was finally constructed and utilized in 2011 while being managed by the Peduli Kasih Credit Union. This construction has given many benefits to the rural community since the MHP has supported its economy. Members of the community can run small businesses and sustain themselves with other livelihoods with the power plant's help.

## 2. Data and Model

This study conducted using the qualitative method. Moeloeng said that the qualitative method aims to holistically understand the phenomenon of what is experienced by the research subject, such as behavior, perception, motivation, action, and others using written description, regarding a specific natural context that uses numerous natural methods [12]. The qualitative approach method is to extract in-depth information from relevant stakeholders to be used as information on project management [13]. This study also used two types of data, namely primary data and secondary data. Primary data collection

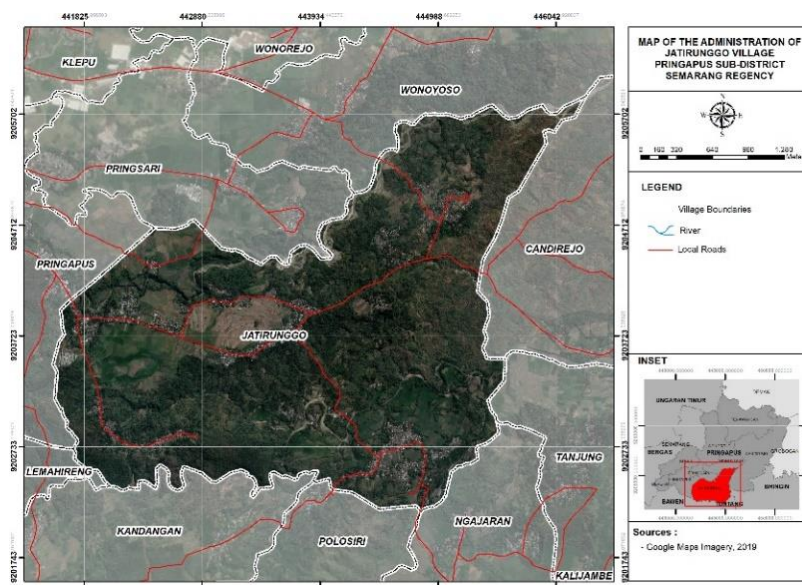
techniques are interview and observation, while secondary data collection technique is a literature review. Data obtained from interviews and observation were analyzed using descriptive qualitative analysis to explain findings such as gaps.

Gap analysis is to compare both study areas. Gap analysis is an analytical method commonly used to help organizations understand where they are now and where they want to be or their current state and desired state [14]. Gap analysis's main objective is to assess a strategic plan project's performance to achieve long-term goals [15]. Therefore, this study's gap analysis looks at the gaps between the two projects in Jatirunggo Village and Kamanggih Village.

### 3. Result and Discussion

#### 3.1. The History of MHP

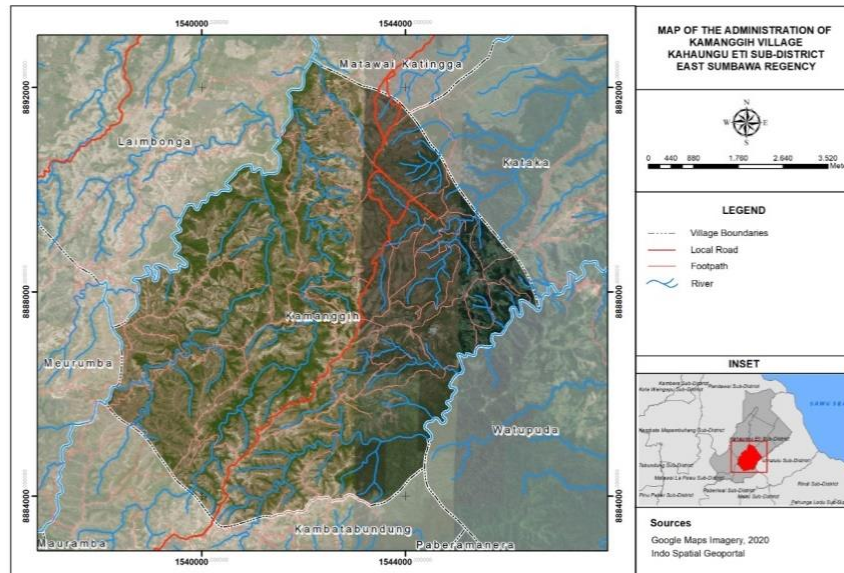
The research area is Jatirunggo Village, Semarang Regency, namely Kunci Putih MHP. This village consists of 11 sub-villages. The difficulty of access to the electricity network has hindered the community from carrying out many daily activities. Therefore, the Kunci Putih MHP supports community activities. In 2009 its initial phase consisted of location selection, land search, land acquisition, building construction, and licensing from both business and resident's permission. This process extended into 2013. Residents issued a notice that the MHP should not ignore agricultural irrigation and damage the environment. In 2013, Kunci Putih MHP started to operate in Jatirunggo Village, Pringapus District, Semarang Regency.



**Figure 1.** Map of Jatirunggo Village, Pringapus District, Semarang Regency

This Kunci Putih MHP was initially managed by Adi Banuwa Company, a Surabaya-based company that independently funded the project. The company's control over the project only lasted until 2016 due to cost constraints or hampered investment flow, so that the Kunci Putih MHP project stalled for two years until 2018. Afterward, the management is given to Kunci Hidro Energi Company, based in Jakarta. This company also funded the project independently and cooperated with PLN Jatingaleh and PLN Kota Salatiga. The MHP still operates to this day to supply the national electricity demand. This project's primary energy source is the Tuntang River flow, which discharges in Rawa Pening Lake. The comparative study areas are in Kamanggih Village, Kahaungu Eti District, East Sumba Regency, East Nusa Tenggara Province. The Kamanggih Village area covers 57,80 km<sup>2</sup> and has a river flow that connects villages and sub-districts. Kamanggih's village consists of 7 sub-villages, with each

sub-village composed of 2 neighborhoods and each community is composed of 2 hamlets. Kamanggih village brings up to a total of 7 sub-villages, 14 neighborhoods, and 28 hamlets.



**Figure 2.** Map of Kamanggih Village, Kahaungu Eti District, East Sumba, East Nusa Tenggara

A resident initiated the Mbakuhau MHP in Kamanggih Village with Umbu Hingu Panjanji, who sent a project proposal to HIVOS, an international NGO, in 2010. HIVOS is an institution based in the Netherlands which initiated a project titled “Sumba Iconic Island” that highlighted 4 model districts in Sumba Island. Examples of renewable energy that were utilizing include solar, biogas, wind, and water power. Initially launched in January 2011. The Micro-Hydro Power (MHP) with 37 kWh was socialization for relevant communities on the power plant’s operational aspects. Throughout the project’s length, residents established the Peduli Kasih Credit Union to manage the electrical network in Kamanggih Village. Mbakuhau MHP initially served 100 houses, and then in 2013, it was managed by National Electricity East Sumba Regency for operations and maintenance. The electricity network houses were around 350 houses and several surrounding villages. Apart from the village community’s homes, the electricity network also runs through internet provider companies, small industries, business areas, and social institutions. The electric voltage includes 450 kWh, 900 kWh, 1300 kWh, 1600 kWh, and 6600 kWh.

### 3.2. GAP Analysis on the MHP Project Management

The conducted study determined that the GAP exists between 2 study areas: Kunci Putih MHP in Jatirunggo Village and Mbakuhau MHP in Kamanggih Village. The difference between the two lies in the project management’s socio-managerial, financial, and technical components. The following is the table of GAP analysis based on those three components.

**Table 1.** GAP Analysis of the Project's Social and Managerial Components

No.	Existing		GAP
	Kunci Putih MHP	Mbakuhaus MHP	
1.	Kunci Putih MHP was initially constructed and managed by Adi Banuwa Company.	The Mbakuhaus MHP is funded by a Dutch international institution, namely HIVOS, in collaboration with IBEKA Company for the construction process.	There is an apparent difference in development. Kunci Putih MHP was initially a company using independent funding, whereas an international institution built Mbakuhaus MHP.
2.	This management only lasted until 2016 due to funding issues or hindrance in investment flows. Therefore, the power plant had stopped operating for two years.	From 2011 until 2013, Mbakuhaus MHP was managed by Peduli Kasih credit union in Desa Kamanggih.	Kunci Putih MHP was managed by a company, whereas Mbakuhaus MHP was managed by Peduli Kasih credit union in Desa Kamanggih.
3.	In 2018, the project took over by Kunci Hidro Energi Company, based in Jakarta.	In 2013, the company decided to collaborate with the National Electricity Company to manage MHP operation and generator maintenance.	The electrical energy generated by these two MHP is sold to the National Electricity Company and then distributed to the public.
4.	Both companies established cooperation with National Electricity Region Salatiga.		Meanwhile, for maintenance responsibilities, Kunci Putih MHP is managed by the Kunci Hidro Energi Company, and the community manages Mbakuhaus MHP at minimal costs.
5.	Currently, Kunci Putih MHP is fully managed by the company, particularly in maintenance and repair.	Peduli Kasih Credit union with the community is responsible for monitoring and on-field inspection of the generator located near the Mbakuhaus River.	In terms of maintenance, Kunci Putih MHP is fully managed by the company. In contrast, Mbakuhaus MHP is partly managed by Peduli Kasih Credit Union, particularly in terms of generator monitoring and on-field inspection.
6.	The technicians and spare parts for Kunci Putih MHP are imported from out of the city.	The technicians from the Credit Union, IBEKA, and PLN were deemed competent enough as several members of the credit union company have had prior technical training.	Kunci Putih MHP still sources their operators or technicians from Bandung, whereas Mbakuhaus MHP utilizes local resources and credit union members in Kamanggih village for operators and technicians.

No.	Existing		GAP
	Kunci Putih MHP	Mbakuhaus MHP	
7.	Kunci Putih MHP does not provide work opportunities for the local community, aside from security officer positions.	Kunci Putih MHP provides work opportunities for the local community through the technical training provided by IBEKA.	Kunci Putih MHP does not provide work opportunities, whereas Mbakuhaus MHP can provide work opportunities for the power plant technicians.
8.	Participation of the local community in Kunci Putih MHP only revolves around permit or licensing and land acquisition for project construction.	The participation of Kamanggih Village residents in Mbakuhaus MHP deems excellent, albeit not every community component is a credit union member. However, during the construction, many community members went to provide support by bringing cement, turbine engine, iron, and woodblocks. Almost all of the project construction was from the hard work of Kamanggih Village residents.	The participation of Jatirunggo Village residents in terms of the maintenance of Kunci Putih MHP is relatively low as the company is entirely responsible for all aspects of the project. Meanwhile, Kamanggih Village residents' participation is deemed excellent, both in terms of construction and maintenance.

**Table 2.** GAP Analysis on the Project Finances of Kunci Putih MHP and Mbakuhaus MHP

No.	Existing		GAP
	Kunci Putih MHP	Mbakuhaus MHP	
1.	The funding for Kunci Putih MHP construction is a source from independent funds owned by Adi Banuwa Company and Kunci Hidro Energi Company.	Mbakuhaus MHP construction funding is a source from HIVOS with 2.5 billion rupiahs and Kamanggih Village residents' independent fund amounting to hundreds of millions of rupiahs.	The funding for Kunci Putih MHP construction was sourced from the company, whereas Mbakuhaus MHP is a source from HIVOS and the community's independent fund.
2.	Upon completion of construction, the payment for electricity was made directly to PLN and by household users.	From 2011 to 2013, there was a fixed electricity fee of 20 thousand rupiahs/house/month. From 2013 until now, electricity payment is managed by PLN, and residents are pay according to each user.	In Jatirunggo Village, electricity payment is made directly to the National Electricity Region Salatiga city. However, in Kamanggih Village, from 2011 to 2013, there was a fixed electricity fee. Currently, Kamanggih Village residents also pay directly to

No.	Existing		GAP
	Kunci Putih MHP	Mbakuhaus MHP	
3	The National Electricity Region East Sumba. The company bears the maintenance fee without collecting fees from the residents.	For maintenance purposes, the Peduli Kasih Credit Union collects fees from its members. Net income is generating from community contributions minus the turbine maintenance costs (400-500 thousand rupiahs) and annual building maintenance (1-2 million rupiahs).	The company bears the maintenance fee for Kunci Putih MHP. In contrast, the maintenance cost for Mbakuhaus MHP is still covering by fees collected from the Peduli Kasih Credit Union members.

**Table 3.** GAP Analysis on the Technical Aspects of the MHP Projects

No	Existing		GAP
	Kunci Putih MHP	Mbakuhaus MHP	
1.	Kunci Putih MHP does not supply electricity only for Jatirunggo Village but also for the national network.	Mbakuhaus MHP is building to supply electricity across all villages in Kahaungu Eti. For the national network, the power plant only generates electricity to the downtown area, more than 60 km from Kamanggih Village.	Kunci Putih MHP generates electricity for the national supply, whereas Mbakuhaus MHP only generates electricity to Kamanggih Village and other nearby villages and downtown areas.
2.	The power plant can supply electricity to Salatiga.	Initially, the power plant only supplies electricity to 100 houses but is later upgraded to supply 350 houses, including nearby villages.	Kunci Putih MHP can supply electricity to Salatiga city, whereas Mbakuhaus MHP can supply 350 houses, including nearby villages.
3.	The electricity voltage of the Kunci Putih MHP is 1,200 Megawatt (MW) because it includes in the national network. In contrast, for the community in Jatirunggo Village, the voltage is around 8,500 watts.	The power supply voltage for Mbakuhaus MHP ranges from 450 kWh to 1300 kWh. However, most power plants have around 900 kWh.	The electricity voltage of Kunci Putih MHP is greater than the electricity voltage of Mbakuhaus MHP.
4.	A repair has done four times a year, consisting of replacing the turbine machine delivered from Bandung city and the monthly maintenance such as cleaning ducts and turbine engines.	A repair has usually done once or twice a year. Building maintenance has been complete once a year; lubricant replacement is done every week, and machine clean-up has been complete once a month.	Maintenance and repairs are more regular in Kunci Putih MHP than Mbakuhaus MHP due to the broader electricity network.

### 3.3. Cooperation Model for MHP Management

The cooperation in the management of Kunci Putih MHP in Jatirunggo Village and Mbakuhau MHP in Kamanggih Village has significant differences. The form of cooperation that exists in the Kunci Putih MHP is PPP (Public-Private Partnership), involving the private sector and the government. In addition, the Mbakuhau MHP form of cooperation which involves multiple actors, is usually referred to as PPCP (Public-Private-Community Partnership). These components are as important as one another; the private sector is essential, considering the need for funding support. The government is a vital component that grants licensing for MHP construction, whereas the community is the user of electricity and management support. Further explanation about PPP and PPCP in the development of MHP can found in **table 4** and **table 5**.

**Table 4.** The Concept of PPP Cooperation in Kunci Putih MHP Management

MANAGEMENT CONCEPT		DEVELOPMENT TYPE	
		MHP	
Cooperation Type		PPP	
Cooperation Form		PPP	
Parties Involved		Government, Private Sector	
Asset	Initial	Land owned by residents.	
	Final	MHP construction is fund by the private sector and managed by the government.	
Management Patterns		In constructing both Kunci Putih MHP, the funding is a private-sector source. In contrast, the government granted the licenses as the initial landowner and electricity user.	
<i>Capital Investment</i>	Local Government	Grant construction permit and electric management network.	
	Private Sector	Build, fund, and manage the MHP project.	
<i>Operational management</i>	Local Government	They are monitoring the performance of the MHP project.	
	Private Sector	Fully responsible for MHP construction and management.	
<i>Commercial Risk</i>	Economic Risk		
	Construction Risk	Low maintenance can damage the construction and the resistance or robustness of the MHP.	
	Social Risk	Noise pollution from MHP machinery can cause discomfort for residents.	
	Environmental Risk	-	
Duration	Project	3-4 years.	
	Cooperation		
Justification		PPP is a form of cooperation involving the government and the private sector. The land, initially owned by residents, was then used to build the MHP with the government's permit. The power plant was then constructed by the private sector as the primary funding source,	



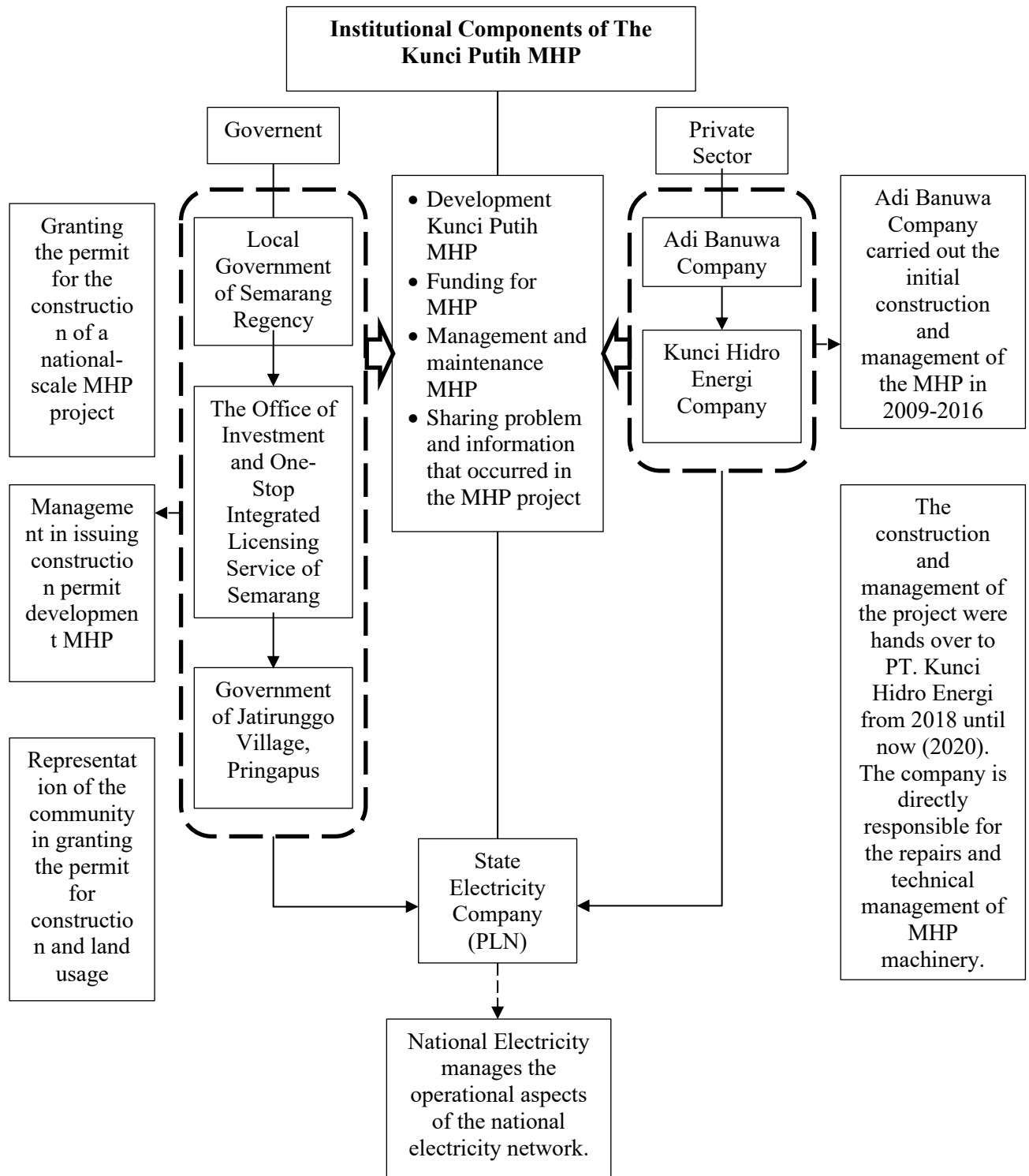
MANAGEMENT CONCEPT	DEVELOPMENT TYPE
	MHP
	hence making cooperation with the private sector imperative.

**Table 5.** The Concept of PPCP Cooperation in Mbakuhau MHP Management

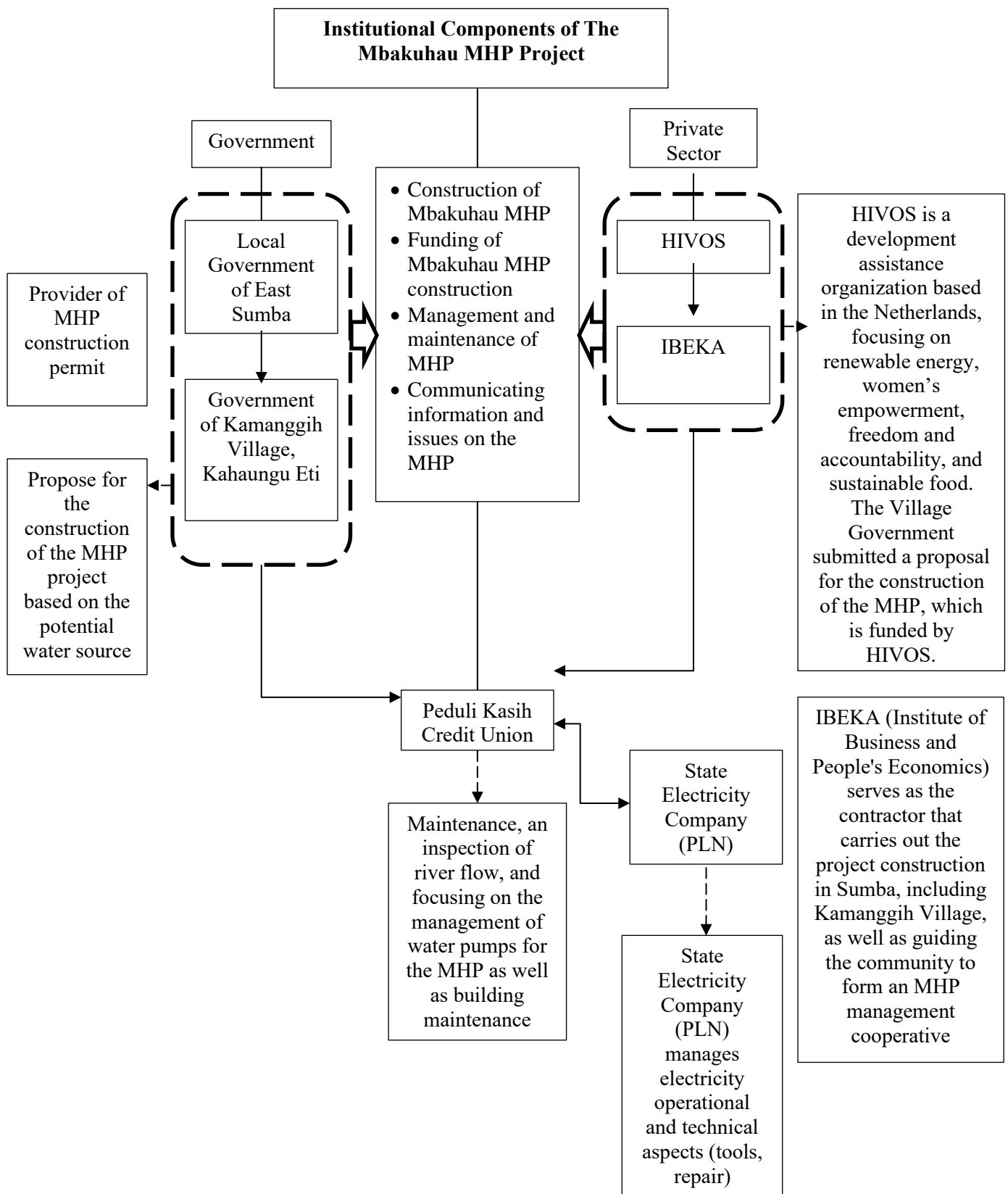
MANAGEMENT CONCEPT	DEVELOPMENT TYPE	
	MHP	
Cooperation Type	PPP	
Cooperation Form	PPCP	
Parties Involved	Government, Private Sector, Community	
Asset	Initial	Land owned by residents.
	Final	MHP construction is fund by the private sector and managed by the community.
Management Patterns	In constructing Mbakuhau MHP, the funding is a private-sector source. In contrast, the government and the community granted the licenses as the initial landowner and electricity user.	
<i>Capital Investment</i>	Local	Grant construction permit.
	Government	Build and fund the MHP project. It is providing land for MHP construction.
	Private Sector	
Community		
<i>Operational management</i>	Local	They are monitoring the performance of the MHP project.
	Government	Fully responsible for MHP construction.
	Private Sector	
Community	Responsible for maintaining and management, as well as keeping the environment clean.	
<i>Commercial Risk</i>	Economic Risk	Low maintenance can damage the construction and the resistance or robustness of the MHP. Noise pollution from MHP machinery can cause discomfort for residents.
	Construction Risk	
	Social Risk	
	Environmental Risk	
Duration	Project	3-4 years.
	Cooperation	
Justification	PPCP is a form of cooperation involving the government, the private sector, and the community. The land, initially owned by residents, was then used to build the MHP with the government's permit. The power plant was then constructed by the private sector as the primary funding source, hence	

MANAGEMENT CONCEPT	DEVELOPMENT TYPE
	<p style="text-align: center;"><b>MHP</b></p> <p>making cooperation with the private sector imperative.</p>

Based on **figure 3** and **figure 4**. There are differences in management between Kunci Putih MHP and Mbakuhau MHP. The significant difference is that in the funding sector, Kunci Putih MHP was originally held by a private company, namely Adi Banuwa Corporate, due to obstructed funds was later taken over by Kunci Hidro Energi Corporate. Meanwhile, Mbakuhau MHP is funded by HIVOS. Then for the management of Kunci Putih, MHP is managed directly for energy distribution by State Electricity Company and for equipment maintenance and repairs managed by the company Kunci Hidro Energi Corporate. For the management of Mbakuhau MHP, energy distribution and electricity operations, equipment, and repair technicians are managed by State Electricity Company. However, in terms of maintenance, checking river flow and focusing on water pump management for MHP and building maintenance is the Peduli Kasih Credit Union which is directly held by the people of Kamanggih Village.



**Figure 3.** Chart of the Institutional Components of the Kunci Putih MHP Project



**Figure 4.** Chart of the Institutional Components of the Mbakuhau MHP Project

#### 4. Conclusion

MHP is one of the solutions to meet the demands for renewable energy in the era of industrial revolution 4.0. The MHP utilizes either irrigation or river flow as the energy source for the power plant. This MHP is an innovation in environmentally friendly new and renewable energy (NRE) that does not produce pollution nor waste that can damage the ecosystem. This study observed MHP project construction in Jatirunggo Village, Pringapus, Semarang, and Kamanggih Village, Kahaungu Eti, East Sumba. The results of this study indicate that there exists a GAP between Kunci Putih MHP and Mbakuhau MHP. The GAP is observing several researched indicators that include socio-managerial, financial, and technical aspects. This study also observed and compared Kunci Putih MHP in Jatirunggo Village, Semarang, and Mbakuhau MHP in Kamanggih Village, East Sumba. The results indicate that there is a significant difference in terms of project funding. Initially, the Kunci Putih MHP project was handle by Adi Banuwa Company, a private company. However, due to financial issues, the project was taken over by Kunci Hidro Energi Company. Meanwhile, the Mbakuhau MHP project was fund by HIVOS, an international organization based in the Netherlands that focuses on renewable energy, women's empowerment, freedom and accountability, and sustainable food. Furthermore, in management, the Kunci Putih MHP project is directly managed by National Electricity for energy supply and Kunci Hidro Energi Company for maintenance and repairs. On the other hand, National Electricity managed Mbakuhau MHP for energy supply, electricity operational, and technical aspects as well as repairs. However, the river flow inspection, water pump management, and building maintenance of the MHP are handled by the Peduli Kasih Credit Union, which is directly run by the people of Kamanggih Village. Therefore, the two cases cannot significantly be compared because they are different in terms of power and scale.

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