SUSTAINABILITY ANALYSIS OF MICROHYDRO POWER PLANTS IN JAYAPURA REGENCY, PAPUA

Pius Adhitia[1], Muhammad Sulaiman[2], Rachmawan Budiarto[3]

[1] Master in System Engineering, Gajah Mada University
[2]Department of Civil Engineering, Vocational College, Gadjah Mada University
[3]Departement of Nuclear Engineering and Engineering Physics, Gadjah Mada University
*Corresspondence : piusadhitia@ugm.mail.ac.id

Abstract

The need for energy and electricity in a number of regions currently tends to increase every year. The fast pace of modernization and increasing economic activity in various parts of Indonesia are the main factors triggering the increase in energy demand. The data analysis technique in this study was using quantitative correlation methods with questionnaires and data from field observations. Data in the form of questionnaires and data from observations are primary data in this study. The purpose of this survey is to measure the performance of Micro hydro Power Plants (MHPP) at each site using KPIs related to the sustainability of the site. In addition to verifying objects that are connected and not connected to the MHPP, this survey also covers topics related to the sustainability of the MHPP site which includes operational status, finances, checking of physical components and the results obtained. Based on a survey conducted on the five MHPP sites, there are 325 houses stairs, 24 social institutions, and 28 PUE, Non-functioning buildings are the main reason, Damage to components and the presence of new generators are the main reasons behind MHPP not operating, There is a correlation between MHPP performance and customer satisfaction, Tariff system applied by all MHPP sites is a fixed rate with a cost of Rp. 20,000.00 to Rp. 30,000.00, All MHPP sites, Damage to generator and ELC components, Deforestation occurs in all MHPP sites, and Based on physical checks on MHPP.

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1. Introduction

The need for energy and electricity in a number of regions currently tends to increase every year. The fast pace of modernization and increasing economic activity in various parts of Indonesia are the main factors triggering the increase in energy demand. In 2018, Indonesia recorded a total number of primary energy production consisting of oil, natural gas, coal and renewable energy reaching 411.6 MTOE (*Million Tons of Oil Equivalent*). 64% or 261.4 MTOE of the total production was exported mainly coal and LNG (Den, 2019). In addition, Indonesia also imports energy, especially crude oil and fuel products of 43.2 MTOE as well as a small amount of high-calorie coal which is needed to meet the needs of the industrial sector. The results of a study from the National Energy Council (DEN), National final energy demand for *Business as Usual* (BaU), Sustainable Development (PB), and Low Carbon (RK) scenarios, energy demand will increase every year with an average annual growth of each 5.0%, 4.7% and 4.3% respectively. Thus, it is projected that energy demand in 2050 will reach 548.8 MTOE, 481.1 MTOE and 424.2 MTOE, respectively.

However, if the need for energy and electricity is still met through a *business as usual* (BaU) energy supply approach, it will have the potential to further reduce the quality of the environment considering that the use of fossil energy for electricity generation in Indonesia is currently still very dominant (RPJMN, 2020) and its raw materials also become one of the largest export commodities. In Indonesia, the use of renewable energy is regulated in Presidential Regulation (PP) Number 79 of 2014 concerning National Energy Policy (KEN), the target for the new and renewable energy mix in 2025 is at least 23% and 31% in 2050.

Based on data obtained from the Directorate General of EBTKE, in 2018 Indonesia has renewable energy potential equivalent to 442 GW which can be used for electricity generation. Hydropower has a potential of 94.3 GW which can be utilized as a renewable energy source for hydroelectric power plants for household, commercial and industrial purposes. The existence of renewable energy, such as micro-hydro electricity, is included in the category of "other renewable energy" which as a whole is targeted to be able to contribute 5% of national energy needs by 2025 (Lipi, 2017). The development of mini-hydro and micro-hydro power for electric power is projected at 3 GW in 2025 and 7 GW in 2050 or 37% of the mini-hydro and micro-hydro potential of 19 GW. Papua, as a province with contours in the form of hills and mountains, has mini-hydro and micro-hydro potentials that are quite large. Based on a study obtained from RUEN, the potential for mini-hydro and micro-hydro in Papua has a potential of 615 MW.

Of the 139 villages, there are seven villages that have MHPP as a source of electrical energy. A number of MHPPs in Jayapura Regency are managed independently by the local villagers. Of the seven villages that have MHPPs, several MHPPs in Jayapura Regency have been damaged, either heavily or lightly. The causes vary. Some are damaged due to natural factors (disasters), some are damaged due to human factors (operational errors, lack of *maintenance,* and so on). For villages where the MHPP was damaged, the condition of the village was back to how it used to be, namely being a village without a source of electrical energy.

The sustainability of a MHPP until the end of its useful life is largely determined by the ability of the user community to manage, finance operational activities, and carry out repairs and maintenance independently.

Therefore, to maintain the sustainability of the MHPP which is managed independently by the local community, it is necessary to evaluate and identify the actual condition of the MHPP. Evaluation and identification activities include identification of institutional problems, technical conditions (civil, electrical, mechanical), social, economic, natural factors, and a number of other indicators. By knowing how the actual condition of the MHPP is, it is hoped that problems will occur during its operational process. The problems in this research can be formulated to conduct a Sustainability Analysis of Micro-hydro Power Plants (MHPP) in Jayapura Regency, Papua. This research focuses on identifying the problems of MHPP which is operated by the local community independently, on the research of Micro-hydro Power Plant Sustainability Analysis (MHPP) in Jayapura Regency with the aim of knowing the problems that occur in MHPP and evaluating and finding solutions to these problems.

2. Methodology

The implementation of this research uses the Key Performance Indicator (KPI) survey method which involves several processes which will be discussed in detail in this section. The following is the flow of the survey implementation.

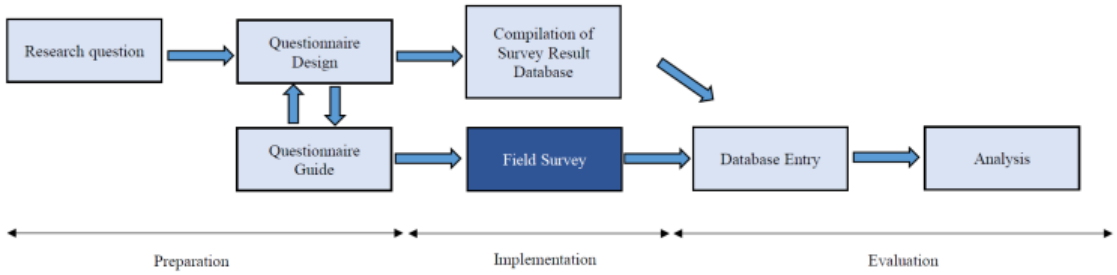

Figure 1. KPI Survey Method Flow

A. Research Question Formulation: there are main research questions that must be answered. These questions have a very broad scope and contain many complex aspects. Therefore, more specific questions were formulated to facilitate the design of the questionnaire and were referred to as derived questions.

B. Questionnaire Design: Word choice should be simple and understandable to unskilled surveyors, and understandable by villagers when asked. Questions should be structured in a logical order and workflow so that the unskilled surveyor can communicate naturally with the interviewee, and be able to complete all questions smoothly. Checkboxes are widely used because they have several advantages, including: being able to minimize narrative answers by defining several previous answers, the occurrence and frequency of predefined answers can be easily measured (while unexpected reasons are categorized as “other” options), and make it easier to deal with conditional questions effectively. The structure of the questions accommodates verification of the consistency of the surveyed data and Anticipates the most common and typical situations in the village area that can interfere with the survey process and data integrity.

C. Preparation of the Questionnaire Guide: The manual questionnaire aims to provide an illustrative guide to each question. This questionnaire is designed to assist field surveyors by: Providing step-by-step instructions on required survey equipment, time allocation, and recommended survey workflows. Give an example of how to answer the questions in the questionnaire correctly. Provide an explanation of where data can be obtained, alternative data sources, and resource persons and Provide an explanation of the terms used in the survey. Provide guidance on the interpretation of unclear answers from uncertain/unpredictable conditions in the village area. Give examples of the types of words that can be used. This was done to train field surveyors. The field surveyors selected are field operators who have experience.

D. Survey Result Data: The survey results that have been obtained will be compiled in database to facilitate analysis, and ensure that the data is in accordance with the analysis format. database used consisted of excel data entry and spreadsheet evaluation.

E. Field Survey: Field survey will be conducted in May 2021 at five MHPP sites located in Jayapura Regency. Make an appointment to meet with MHPP management team at each location to be surveyed. Take a trip to the survey site. Visiting and checking the physical condition of the building structure, power house, and customer network at the MHPP site. Visit the MHPP management team and conduct interviews based on the questionnaire that has been created, as well as check the MHPP site records and Conduct interviews with the most respected people in the village such as village heads or community leaders.

F. Data Analysis: The data pre-processing stage is required in processing raw data related to households, social institutions, and is required in processing financial data. In general, the data processing process involves a screening for the survey results. The process of correcting the data can be carried out, but if the data is inconclusive, unavailable or unreasonable, then the data is not

considered in the calculations. Data inconsistency, households, social institutions, PUE, financial data.

3. Results & Discussion

A. Survei Key Performance Indicator (KPI)

Survey was conducted on five MHPP sites in Jayapura Regency. The sites surveyed consisted of Ormu Wari, Yongsu Spari, Necheibe, Wambena 1, and Wambena 2.

Table 1. Detail of the MHPP Sites Survey

No.	Location	Village	Coordinate	Capacity		Developer Agency	Operator Agency	Funding Agency
				Installed (kW)	Generator (kW)			
1	Ormu Wari	Ormu Wari	2°27.608' 140°32.579'	17	32	Village Government	Operator PLTMH	PNPM Mandiri-Respek
2	Yongsu Spari	Yongsu Spari	2°26.247' 140°27.622'	10	16	Contractor	Ketua RW 3 & RW 1	Dinas Pertambangan & Energi Irian Jaya, Pemerintah Kampung
3	Necheibe	Necheibe	2°27.269' 140°35.114'	10	16	Village Government	Operator PLTMH	PNPM Mandiri-Respek
4	Wamena 1	Wamena	2°24.889' 140°24.574'	10	16	Wahana Visi Indonesia	Bumkam Sauman	Wahana Visi Indonesia
5	Wamena 2	Wamena	2°24.808' 140°24.728'	75	50	Contractor	Bumkam Sauman	Dinas ESDM Provinsi Papua

The number of households, social institutions, and Productive Use of Energy (PUE) connected to the MHPP is essential. In the survey conducted, there were five MHPP sites with details in the following table. Based on the following table, it can be seen that the MHPP has been connected to 325 households, 24 social institutions, and 28 PUE.

Table 2. MHPP Electrified and Non-Electrified Buildings

Indicators		Connected to MHPP	Non-Electrified
Household		325	8
Social Institutions	Schools	7	1
	Health Center	5	1
	Community Center	6	2
	Place of Worship	6	0
Total Social Institutions		24	4
Productive Use of Energy		28	0

- Households

Based on the survey conducted, as many as 97.6% of household have been connected to MHPP while the other 2.4% are not electrified from any power source. Details of data from the survey conducted in this section are presented in the following table.

Table 2. Households connected and not connected to MHPP.

No.	MHPP Site	Household	
		Connect to MHPP	No Electricity
1	Ormu Wari	78	0
2	Yongsu Spari	98	8
3	Necheibe	45	0
4	Wambena 1	52	0
5	Wambena 2	52	0
TOTAL		325	8

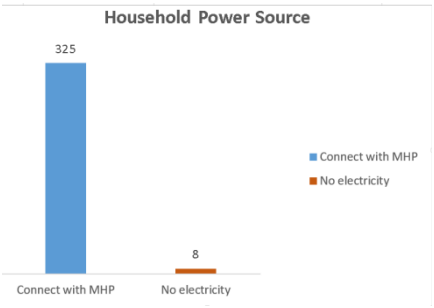

Figure 2. Source of household electricity

- Social Institutions

A total of 28 social institutions were included in the survey, of which 29% were used as schools, 25% as places of worship, 25% as community centers, and 21% as health centres. Of all these institutions, there are still 4 institutions that are not connected to a power source. As many as 25% of the four institutions are not connected to electricity because the equipment is operated manually, 50% because it is not permitted by the MHPP management, and 25% for other reasons (the building is no longer in use).

Table 3. Social Institutions Connected and Not Connected to MHPP.

No.	Sites MHPP	Social Institution	
		Connect to MHPP	No Electricity
1	Ormu Wari	6	1
2	Yongsu Spari	4	2
3	Necheibe	4	1
4	Wambena 1	5	0
5	Wambena 2	5	0
TOTAL		**24**	**4**

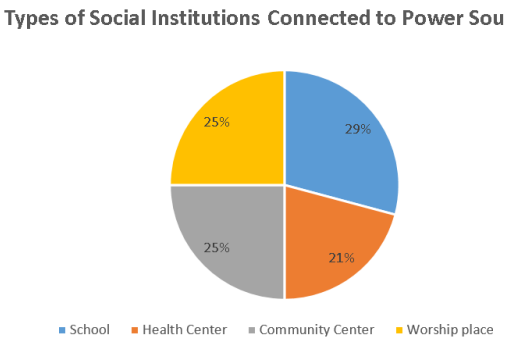

Figure 3. Types of Social Institutions Connected to Power Sources

- Use of Productive Energy

There are 31 PUEs covered in this survey, all of which are connected to electricity sourced from MHPP. Of the total PUE, 90% of them are small shop and 10% are other small business. In addition, the survey also includes the future prospects of PUE connection levels. As many as 40% indicate that in the future, there will be more PUE without electricity which will be connected to a power source in the form of MHPP as much as 60% of the other data cannot be obtained.

Table 4. PUE connected and not connected to MHPP.

No.	Sites MHPP	Small shop	
		Connect to MHPP	No Electricity
1	Ormu Wari	6	0
2	Yongsu Spari	8	0
3	Necheibe	4	0
4	Wambena 1	5	0
5	Wambena 2	5	0
TOTAL		**28**	**0**

Table 5. Types of PUE connected to MHPP.

No.	Sites MHPP	Type PUE Connected to MHPP	
		Small shop	Others
1	Ormu Wari	6	0
2	Yongsu Spari	8	1
3	Necheibe	4	0
4	Wambena 1	5	1
5	Wambena 2	5	1
TOTAL		**28**	**3**

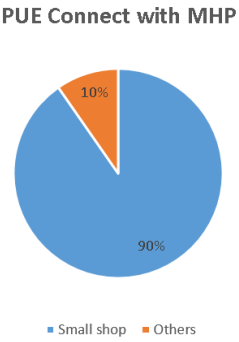

Figure 4. PUE Connected to MHPP

- General Energy Supply

This section includes a survey of hour meter and kWh meter installations. Based on the survey conducted, it can be seen that 60% of the hour meters have been installed, while the other 40% have not been installed. Unlike the case with the installation of a kWh meter where the percentage of installation is only 20%, while the other 80% has not been installed.

Table 7. Installation Status Hour Meter and kWH Meter.

No.	Sites MHPP	Hour Meter		kWh Meter	
		Installed	No	Installed	No
1	Ormu Wari		✓		✓
2	Yongsu Spari	✓			✓
3	Necheibe	✓			✓
4	Wambena 1		✓		✓
5	Wambena 2	✓		✓	

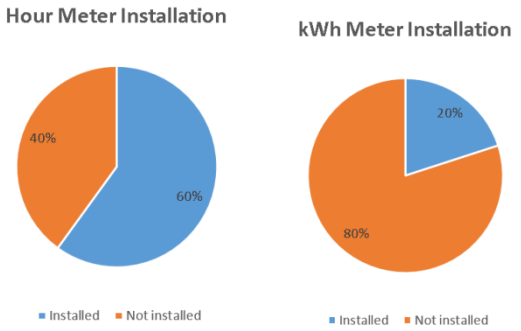

Figure 5. Installation Status of Hour Meter and kWH Meter

- Technical Problems at the MHPP Site

The survey results show that 40% of MHPPs are operating well, while 20% of MHPPs are operating with problems. In addition, there are 40% of MHPPs that are not operating due to new generators and there are MHPPs that stop operating due to component damage.

Table 8. Current Operational Status to MHPP

No.	Site MHPP	Status MHPP		
		Operated	Operated, there is a problem	Not Operating
1	Ormu Wari	✓		
2	Yongsu Spari	✓		
3	Necheibe		✓	
4	Wambena 1			✓
5	Wambena 2			✓

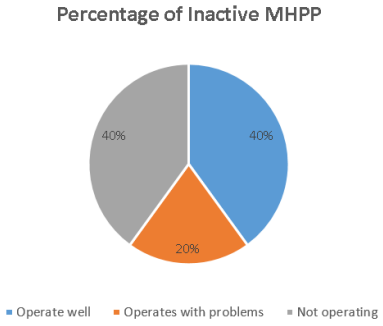

Figure 6. Percentage of Inactive MHPP

Of all the MHPPs covered in the survey, damage to the generator was the main reason for the MHPP not to operate. The damage has a percentage of 40%. In addition, there is damage to the controller, damage to the ELC, and other reasons in the form of a new generator with a percentage of 20%.

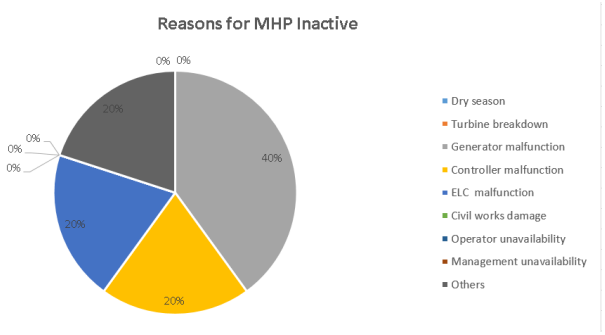

Figure 7. The Reason the MHPP is Not Active

- Correlation between technical indicators and subjective perceptions of the quality of electrical energy

The quality of the electrical energy produced depends on the voltage and frequency of the electrical energy supply. Therefore, analysis of the quality of electrical energy produced by MHPP requires data loggers that function to record daily fluctuations in the supply of electrical energy. However, data loggers are not yet available on the MHPP sites surveyed, so the analysis is carried out through identification of disturbances such as flashing lights and the occurrence of black outs.

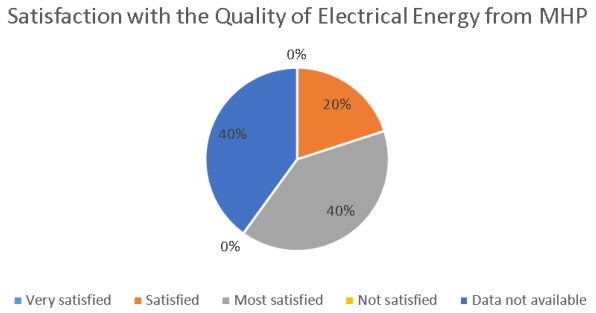

Figure 8. Satisfaction with the Quality of Electrical Energy from MHPP

The survey also includes disturbances that occur, namely the frequency of flashing lights and the frequency of black outs. As many as 40% of respondents stated that the lights blink frequently, 20% stated that the lights rarely blinked, while data from the other 40% could not be obtained. For disturbances in the form of black outs, 40% of respondents stated that black outs occurred frequently, 20% stated that black outs were rare, and data from the other 40% could not be obtained.

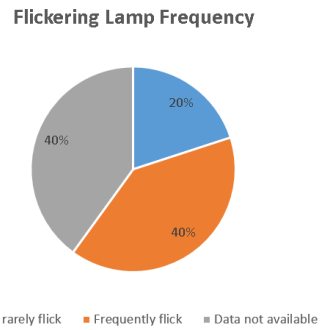

Figure 9. Frequency of Flickering Lights

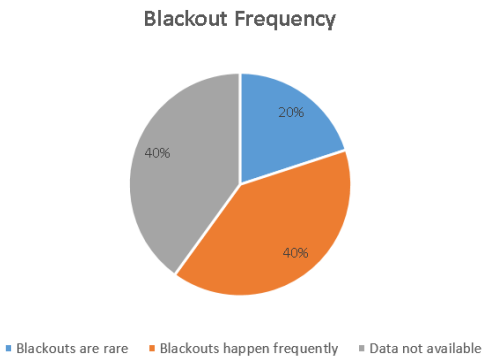

Figure 10. Frequency of Blackouts.

The survey results regarding the frequency of equipment breakdowns showed that 40% of respondents stated that the equipment was damaged due to inadequate energy quality, 20% stated that the equipment was not damaged even though the energy quality was inadequate, while data from the other 40% could not be obtained. Detailed data from the survey.

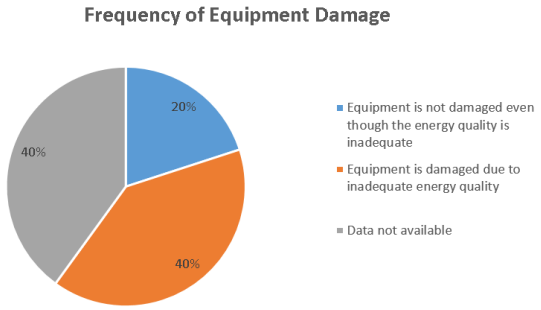

Figure 11. Frequency of Equipment Damage

- Commercial Indicators (Administration and Management)

Commercial indicators highlight the managerial aspects of the MHPP management team. Management that is accountable and transparent can create a sustainable MHPP management system. The indicator used to measure the commercial performance of MHPP in this survey is the tariff collected from customers. There are two aspects surveyed in order to determine the sustainability of the MHPP management, namely the financial condition and tariff arrangements.

The survey results show that the size of the management team is dominated by six people with a percentage reaching 40%. There is also a management team consisting of two (20%), three (20%), and four (20%). Furthermore, it can be seen that all MHPPs surveyed have Operator 1 and Operator 2, but only some have other management functions such as Operator 3 (60%), Operator 4 (20%), Secretary (60%), Accountant (40%) , and Manager (40%).

Table 13. Size of the Management Team at MHPP.

No.	MHPP Site	Management Team Size
1	Ormu Wari	3
2	Yongsu Spari	2
3	Necheibe	4
4	Wambena 1	6
5	Wambena 2	6

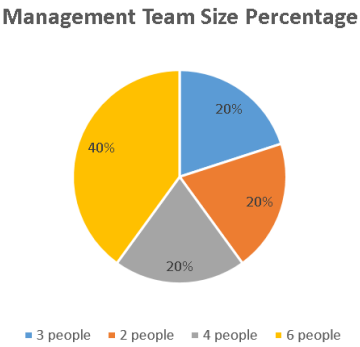

Figure 12. Management Team Size Percentage

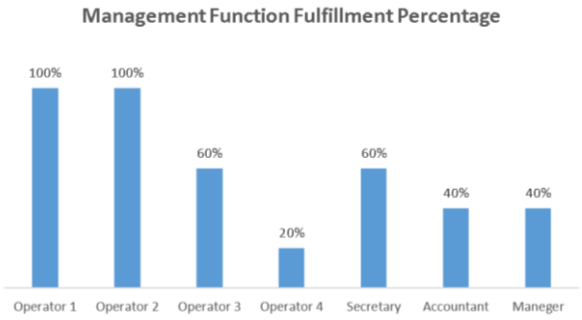

Figure 13. Percentage of Management Team Size

The amount of salary given is one indicator that can be used to determine the appreciation of the duties of each management function. Based on the survey results, each management function has a different average salary. Operators have the highest average salary compared to other positions, while Accountants and Managers are at the lowest positions because they are voluntary. The operator's role in each MHPP is very important because it has a big responsibility.

Table 6. Average Salary for Each Management Function.

Function	Average
Operator 1	Rp1.280.000,00.
Operator 2	Rp1.280.000,00.
Operator 3	Rp1.466.666,00.
Operator 4	Rp2.000.000,00.
Secretary	Rp1.000.000,00.
Accountant	0
Manager	0

The survey also includes the quality of administrative performance which can be identified through the condition of the management book. Good administration is reflected in well-structured and well-maintained documentation, including data on collected tariffs, financing and customers, as well as records of technical indicators and damage suffered. The results obtained indicate that there are only two MHPP sites that use the customer data book well, while other administrative books in the form of *logbooks,* tariff books, and budget books are mostly not available on the MHPP site.

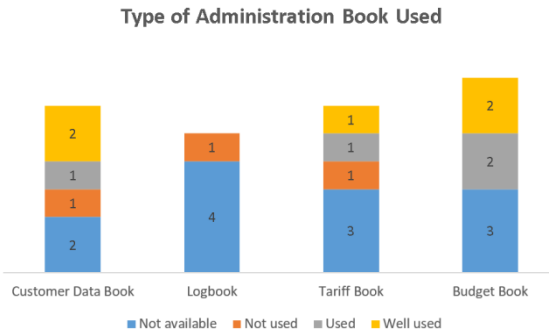

Figure 14. Types of Administrative Books Used

Surveys were also conducted on activities related to the organization of the MHPP management team, including regular meetings held, routine selection of administrators, training providers, knowledge sharing or exchange of experiences. The implementation of these activities can increase the insight of the MHPP management so that they are able to provide good operational performance.

Based on the results obtained, it can be seen that as many as 60% of MHPP do not hold regular meetings and only 40% do. Meanwhile, routine elections for management or reorganization were never held by all MHPP surveyed because the MHPP administrators were old staff. Furthermore, as many as 40% of MHPP do not provide training and another 40% conduct training with old staff as training providers. However, as many as 80% of MHPP administrators conducted knowledge sharing with other MHPP administrators.

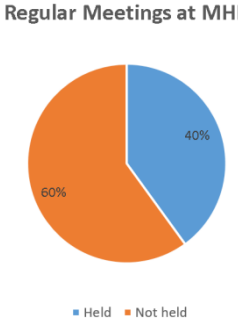

Figure 15. Routine Meetings at MHPP

Figure 16. Reorganization

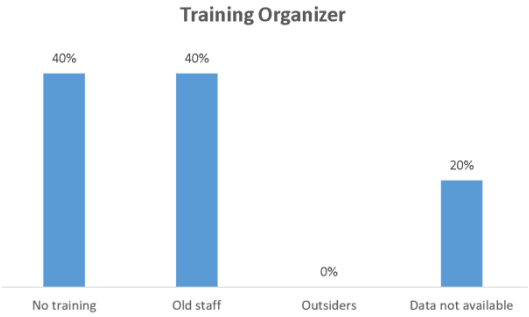

Figure 17. Training Organisers

Table 18. Implementation Knowledge Sharing.

No.	MHPP	Knowledge Sharing	
		Held	Not Held
1	Ormu Wari		✓
2	Yongsu Spari	✓	
3	Necheibe	✓	
4	Wambena 1	✓	
5	Wambena 2	✓	

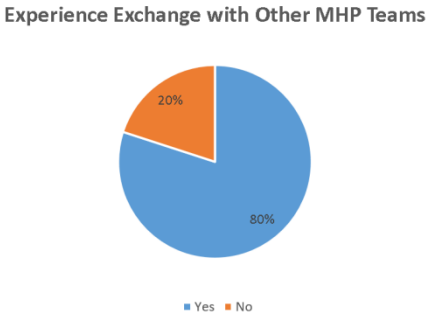

Figure 18. Excange Experience with another MHPP Teams

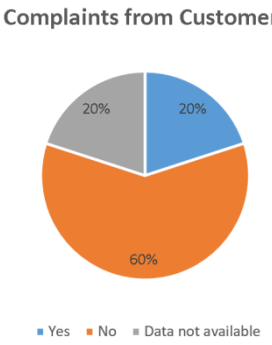

Figure 25. Complaints from Customers.

- Financial Indicators

In order for the MHPP to operate sustainably, the management needs stable finances to be able to meet the MHPP maintenance costs and the salaries of the management. The MHPP income is obtained from electricity payment rates collected from customers. The tariff application system can be an indicator of community participation as well as a form of appreciation and sense of belonging to the MHPP. Therefore, a survey was conducted on the application of tariffs at each MHPP. Based on the results obtained, it can be seen that 80% of the tariff system applied is a fixed rate, while the other 20% data cannot be obtained.

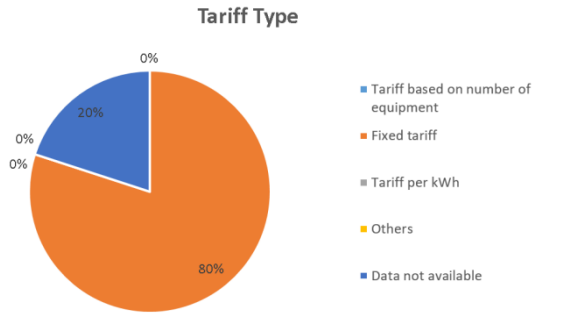

Figure 26. Type of Tariff Provided to Customers.

The provision of special rates is also included in this survey. The survey in this section aims to determine the specific allocation given by the MHPP to underprivileged households, social institutions, and PUE. In addition, a survey was conducted to find out if there were any changes in the rates applied by the MHPP. Based on the results obtained, there are MHPP that provide special rates to underprivileged households and social institutions, but none of them provide special rates to PUEs and there are also no MHPP that raise rates regularly.

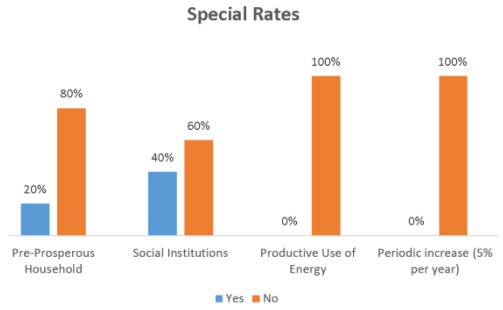

Figure 27. Provision of Special Rates

In addition to conducting a survey on tariffs, a survey on MCB was also conducted. A survey on the size of the MCB used by each MHPP showed variations in the size used. The most widely used size by MHPP is 2A with a percentage reaching 100%, while MCB sizes 3A and 5A are not used at all MHPP sites MHPP.

Table 22. The Size of the MCB Used

No.	Sites MHPP	Size MCB					
		1A	2A	3A	4A	5A	6A
1	Ormu Wari	✓	✓				✓
2	Yongsu Spari		✓		✓		
3	Necheibe	✓	✓				
4	Wambena 1		✓		✓		
5	Wambena 2		✓		✓		

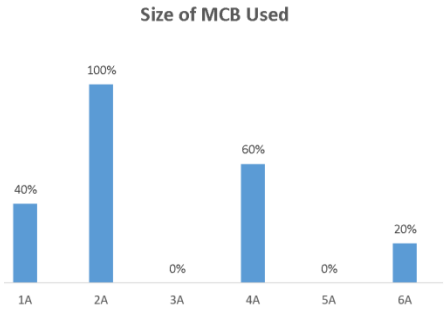

Figure 2. Size of MCB used

A survey of household use of MCB shows that most households use MCB of different sizes. The percentage of households that use MCB in this way reaches 80%. However, there were no houses that used MCB collectively.

Table 7. Use of MCB.

No.	MHPP Site	Use of MCB	
		Different MCB Sized	MCB Used with
1	Ormu Wari	✓	
2	Yongsu Spari	✓	

No.	MHPP Site	Use of MCB	
		Different MCB Sized	MCB Used with
3	Necheibe		
4	Wambena 1	✓	
5	Wambena 2	✓	

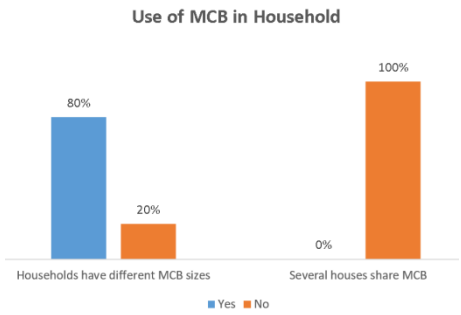

Figure 29.Use of MCB in Households

The connection fee charged by MHPP to the customer needs to be known to quantify the tariff given. Connection fee is the fee charged to connect the electricity generated by the MHPP to the customer's house. Based on the survey conducted, no customer is required to pay a connection fee. However, the connection fee is also not included in the household installation.

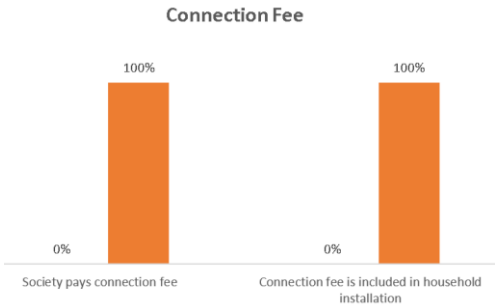

Figure 30. Connection Fee

To find out the differences in the applied tariff system, a comparison is made against the average tariff per household. The data displayed is based on information on the rate per month paid by each household. The maximum tariff charged to customers is Rp. 30,000.00 per month, while the lowest rate is Rp. 20,000.00. Meanwhile, the average rate paid by each household per month is Rp. 22,000.00.

Table 8. Total Tarif Per month

No.	MHPP Site	Total Tarif per month
1	Ormu Wari	Rp30.000,00.
2	Yongsu Spari	Rp20.000,00.
3	Necheibe	Rp20.000,00.
4	Wambena 1	Rp20.000,00.
5	Wambena 2	Rp20.000,00.

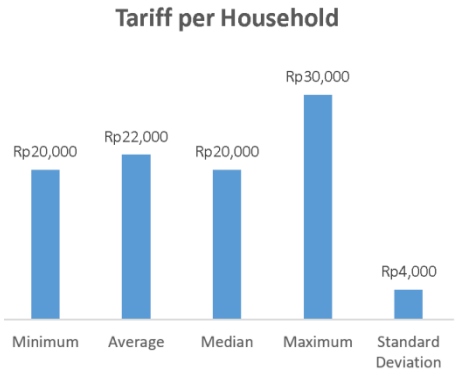

Figure 31. Rates per Household.

A survey was also conducted on the total monthly rates obtained by all MHPP. Based on the results, it can be seen that the maximum income earned is Rp.2,340.000,00 while the minimum income is Rp.900,000.00. Meanwhile, the average total monthly tariff collected is Rp. 1,488.000,00. The higher the total monthly tariff, the higher the number of customers. This is related to the amount of tariffs that are almost the same for each MHPP.

Table 9. Total Monthly rates

No.	MHPP Site	Total Monthly Tariff
1	Ormu Wari	Rp2.340.000,00.
2	Yongsu Spari	Rp1.920.000,00.
3	Necheibe	Rp900.000,00.
4	Wambena 1	Rp1.140.000,00.
5	Wambena 2	Rp1.140.000,00.

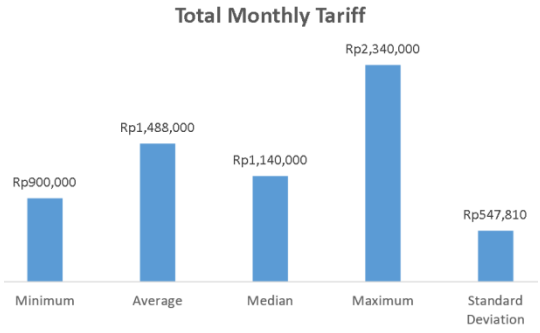

Figure 32. Total Monthly Rates.

A survey of the tariff collection mechanism was carried out for all involved MHPPs. Based on the results, it can be seen that 100% of fare collection is carried out by MHPP staff by walking to each customer's house. There is no MHPP that has determined a special location as a place for paying tariffs by customers. This shows that the established tariff collection mechanism still

requires further development, so that it is more effective and efficient.

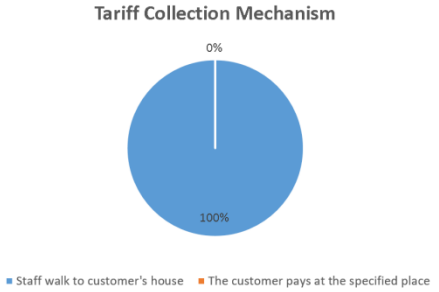

Figure 33. Tariff Collection Mechanism

The quality of financial operational indicators can also be identified through the imposition of sanctions for customers who do not pay the specified tariff. The imposition of sanctions can provide a deterrent effect to customers so as to increase discipline in making tariff payments. Based on the results obtained, it can be seen that all MHPP do not impose sanctions on customers who do not pay, and have never applied any sanctions.

Figure 34. Sanctions for Not Paying

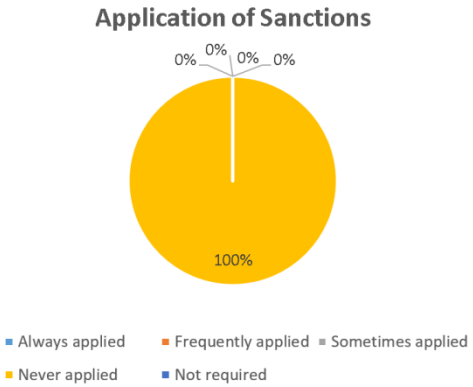

Figure 35. Application of Sactions

Of all MHPP surveyed, as many as 40% of them kept the funds obtained with the treasurer, another 40% kept the funds obtained with the operators, while the other 20% of the data could not be obtained. The results show that there is no MHPP that utilizes banks and cooperative savings in their financial management.

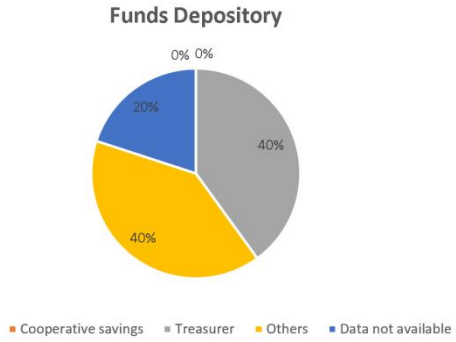

Figure 3. Depository Place

Survey also includes significant expenditures related to operational activities. Based on the information obtained, it can be seen that as much as 80% of significant expenditures come from component repair activities such as generators, ELC, and repair of broken pipes.

Table 31. Significant Expenses

No.	MHPP site	Component	Data not available
1	Ormu Wari	✓	
2	Yongsu Spari	✓	
3	Necheibe		✓
4	Wambena 1	✓	
5	Wambena 2	✓	

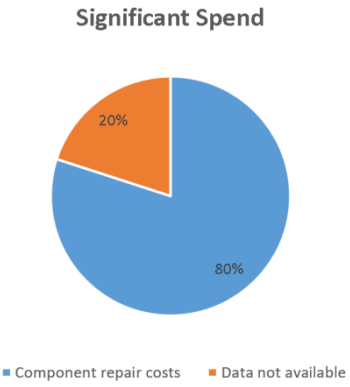

Figure 4. Significant expenses

- Operation and Maintenance MHPP

To determine the quality of MHPP operation and maintenance activities, a survey related to this was conducted, including regarding water use in other sectors that could affect MHPP performance. The results showed that 80% stated that the use of water in other sectors affected the performance of the MHPP and only 20% stated that they did not. Among the MHPP which state that there is water use, there is 40% of water use that is used for water pumps, while the other 60% is used for other functions.

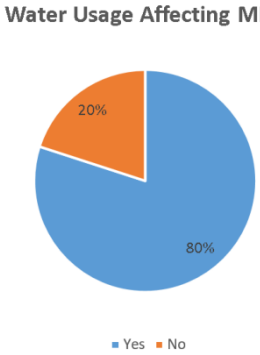

Figure 38. Water Use Affecting the Performance of MHPP.

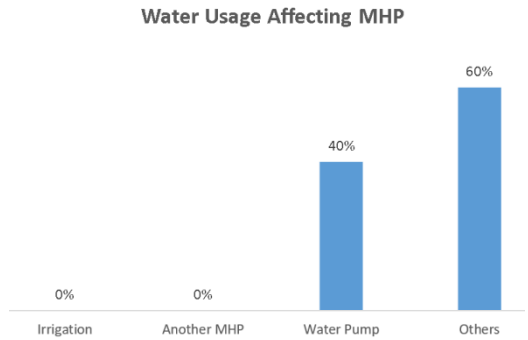

Figure 5. Types of water use that affect to MHPP.

A survey of operating hours shows that all MHPP operate for 24 hours, namely in the morning, afternoon, evening and night. This shows the need for a survey regarding component damage that has occurred in all MHPP.

Table 10. Operational time of MHPP.

No.	Site MHPP	Morning	Afternoon	Evening	Night
1	Ormu Wari	✓	✓	✓	✓
2	Yongsu Spari	✓	✓	✓	✓
3	Necheibe	✓	✓	✓	✓
4	Wambena 1	✓	✓	✓	✓
5	Wambena 2	✓	✓	✓	✓

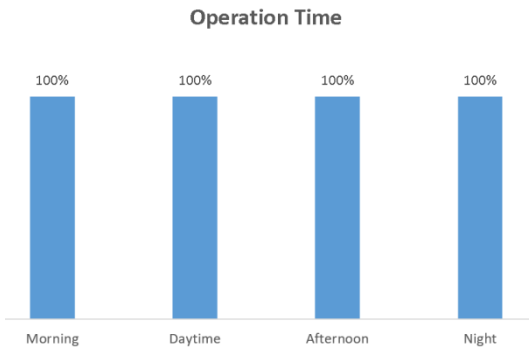

Figure 6. Operational time MHPP

- **Damage to components that have occured**

Table 11. Damage that has occured

Componet	Damaged		
	Yes	No	Data Not available
Turbine	40%	60%	0%
Generator	100%	0%	0%
Sluice	0%	20%	80%
ELC	100%	0%	0%
Controller	0%	0%	100%
Distribution cable	0%	60%	40%
Cable (power house)	20%	40%	40%
Dam	20%	40%	40%
Duct	20%	40%	40%
Forebay	40%	20%	40%
Penstock	80%	20%	0%
Inlet	0%	60%	40%
Belt	40%	20%	40%
Trash rack	0%	40%	60%
Others	0%	0%	0%

Damage to components was experienced by all MHPP sites surveyed. At the Ormu Wari MHPP site, damage has occurred to components such as generator, ELC, channel, forebay, penstock, and belt. Most of the damage occurred in 2013 with 365 days of interruption to the operation of the MHPP. Improvements have been made to the generator and ELC components through funds provided by the Regency ESDM.

At the Necheibe MHPP site, damage has occurred to components such as turbines, generators, ELCs, power houses, and penstocks. Most of the damage occurred in 2021 caused by a burnt cable. The damage caused an interruption to the operation of the MHPP for 30 days. Improvements have been made to the turbine and generator components through the Village Fund.

The MHPP Wambena 1 site is currently no longer operating due to a new power plant. Therefore, the survey data is represented by the MHPP Wambena 2 site. At this site, damage has occurred to components such as generator, ELC, and penstock. The damage occurred in 2021 caused by a short circuit and improper component installation. The damage caused an interruption to the operation of the MHPP for 180 days.

In addition to surveys regarding component damage, surveys related to abuse by customers were also

conducted. As many as 60% stated that there was no abuse by customers, while 40% said there was abuse by customers. Abuse by customers is dominated by 40% of customers ignoring MCB and inappropriate connections from the network to the customer's home. As many as 20% more abuse by making connections that are illegal.

Table 12. Misuse by Customers

No.	MHPP Site	There is abuse by customers	There is no abuse by customers
1	Ormu Wari		✓
2	Yongsu Spari	✓	
3	Necheibe	✓	
4	Wambena 1		✓
5	Wambena 2		✓

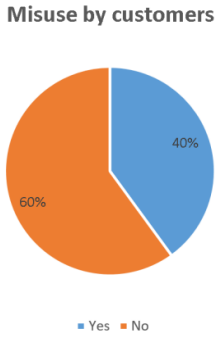

Figure 41. Misuse by Customers.

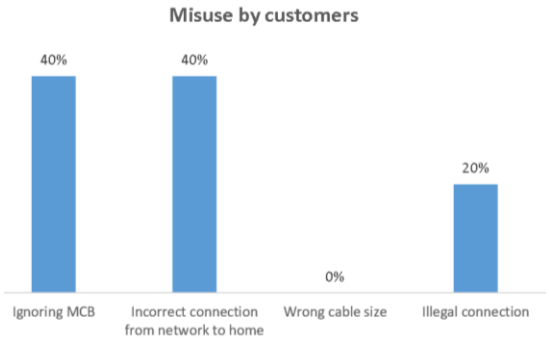

Figure 7. Types of Abuse by Customers.

The survey in this section also includes periodic checks and the availability of supporting equipment at all MHPP sites involved. The components surveyed include the availability of toolboxes, the availability of manuals, the availability of spare parts vendors, the organization of workshops, filling of logbooks the periodic The results show that only 20% of MHPP sites have toolbox availability—namely the Necheibe MHPP site, while the other 80% do not. This unavailability also includes manuals, where 100% of the MHPP sites stated that they did not have manuals. In addition, 80% of MHPP sites do not logbook periodically This is different from spare parts vendors and workshops, where 100% of the MHPP sites have availability for this.

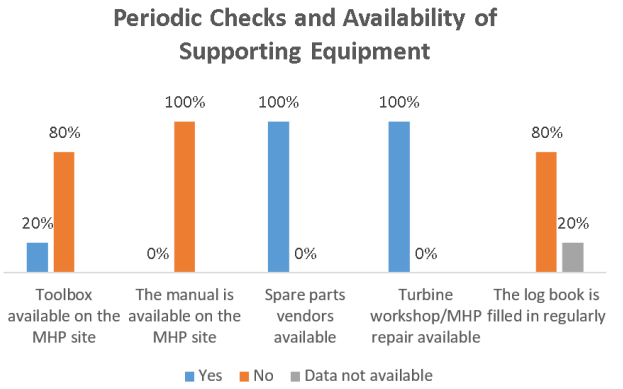

Figure 43. Periodic Checks and Availability of Supporting Equipment

Maintenance and repair efforts carried out by the MHPP management are also included in the survey. This section covers lubrication, *belt repair,* civil construction, and cleaning of MHP components. The results show that there are several repairs and maintenance that have not been carried out, including the provision of lubricants with a percentage of 20%, namely at the Yongsu Spari MHPP site;repair *belt* with a percentage of 60% at the MHPP Ormu Wari, Wambena 1, and Wambena 2 sites; civil construction with a percentage of 60%, namely at the MHPP Ormu Wari, Wambena 1, and Wambena 2 sites; and cleaning of 40% at the Wambena 1 and Wambena 2 MHPP sites.

There are also periodic repairs and maintenance. Repairs and maintenance carried out every six months include *belt* with a percentage of 40% at the Yongsu Spari and Necheiba MHPP sites. Meanwhile, there are also repairs and maintenance carried out once a month including the provision of lubricants with a percentage of 80%, namely at the MHPP Ormu Wari, Necheibe, Wambena 1, and Wambena 2 sites; civil construction with a percentage of 20%, namely at the MHPP Necheibe site; and cleaning with a percentage of 40% at the Yongsu Spari and Necheibe MHPP sites.

- Catchment area

The survey covers the condition of the catchment area of the involved MHPP. The quality of water catchment management can affect the performance of the MHP. Therefore, all MHPP pay attention to the relationship between water catchment area management and MHPP performance.

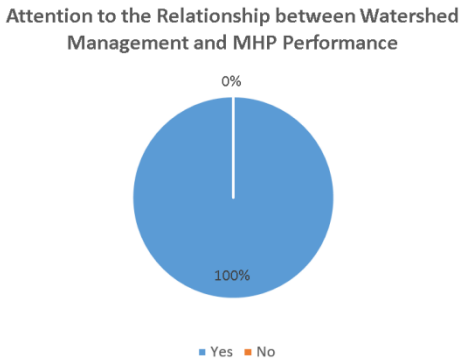

Figure 8. Attention to the relationship between catchment area management and MHPP performance

There are various factors in the catchment area that can affect the performance of the MHP, either directly or indirectly. Deforestation is one of the common factors that has a major influence on the performance of MHPP. Based on the results obtained, all PTLMH stated that there was deforestation in the catchment area. The deforestation that occurs is caused by human activities. 60% of deforestation is caused by population activities, while the other 40% is caused by the influx of migrants

Table 39. Deforestation in Catchment Area

No.	MHPP site	Deforestation in catchment areas	
		Yes	No
1	Ormu Wari	✓	
2	Yongsu Spari	✓	
3	Necheibe	✓	
4	Wambena 1	✓	
5	Wambena 2	✓	

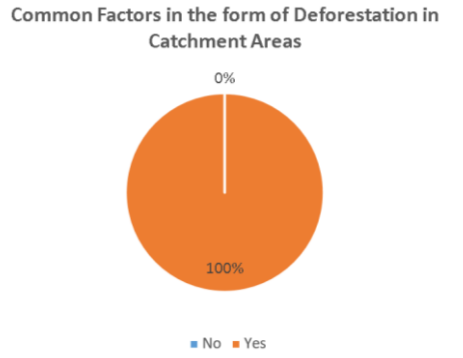

Figure 46. Deforestation in Catchment Areas

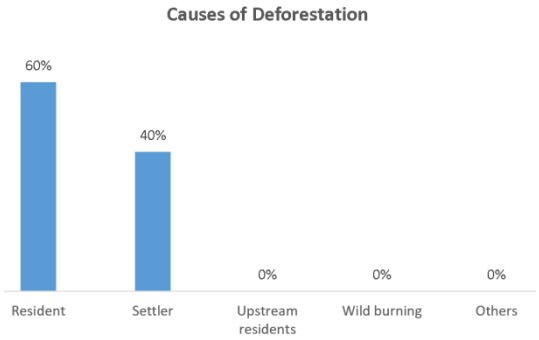

Figure 47. Causes of Deforestation

The occurrence of deforestation is influenced by various community interests. Based on the survey conducted, it can be seen that the use of wood contributes 20% to deforestation. In addition, there is also a conversion of forest land to plantations found in all MHP sites. Utilization for other purposes also contributed 40%.

Table 13. Product of deforestation

No.	MHPP Site	Result of product deforestation			
		Timber	Firewood	Plantation (Palm, Oil, Rice)	Others
1	Ormu Wari			✓	
2	Yongsu Spari			✓	
3	Necheibe	✓		✓	
4	Wambena 1			✓	✓
5	Wambena 2			✓	✓

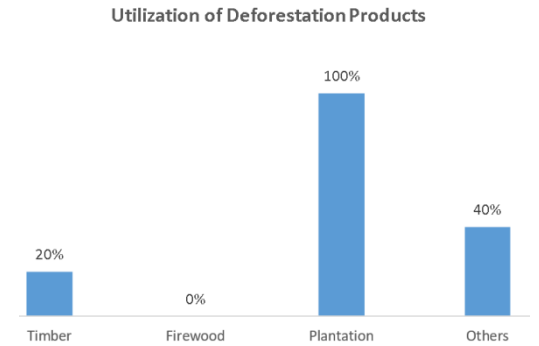

Figure 9. Utilization of Products from Deforestation

Apart from deforestation on forest land, there are various other factors that have been included in this survey. The results indicate that there is deforestation on the slopes in the catchment area with a percentage of 80%, namely at the Yongsu Spari, Necheibe, Wambena 1, and Wambena 2 MHP sites. Also found a factor in the form of landslides with a percentage of 40% at the Ormu Wari MHP site and Yongsu Spari. Apart from that, there are other factors covered in this

survey consisting of erosion in ditches, drought of wetlands, diversion of water for irrigation, flooding, disturbances to water flow, infertile soils, loss of supporting vegetation, overgrazing, soil hardening due to animals, livestock, and other factors.

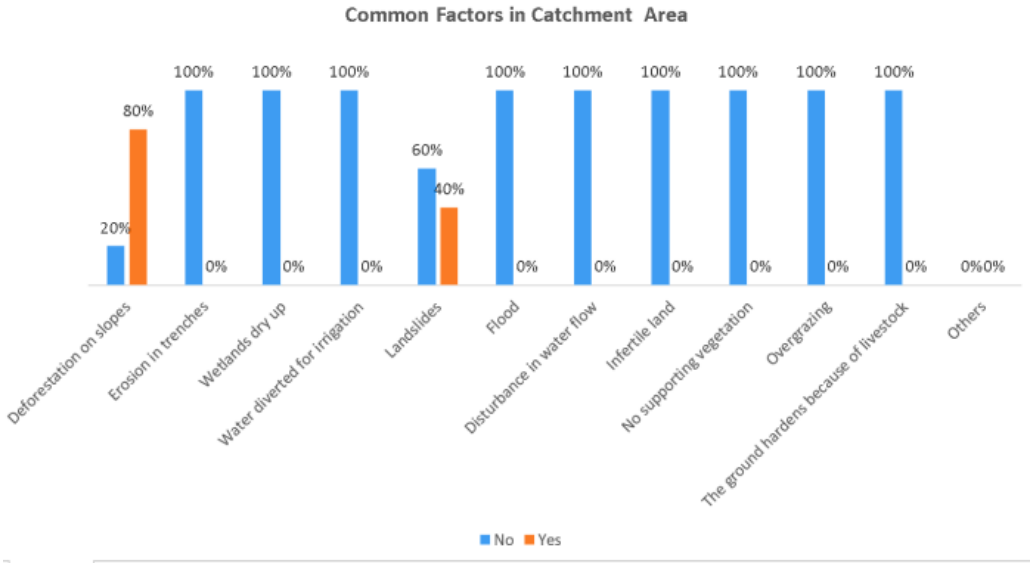

Figure 49. Common Factors Observed in the Catchment Area

Based on the general factors observed in the catchment area, landslide is one of the observed factors. Based on the results obtained, there is a MHP site which states that landslides with an intensity of more than 5 times occur every year. The percentage of the intensity more than 5 times reached 20%, no landslide occurred 60% while 20% data not available.

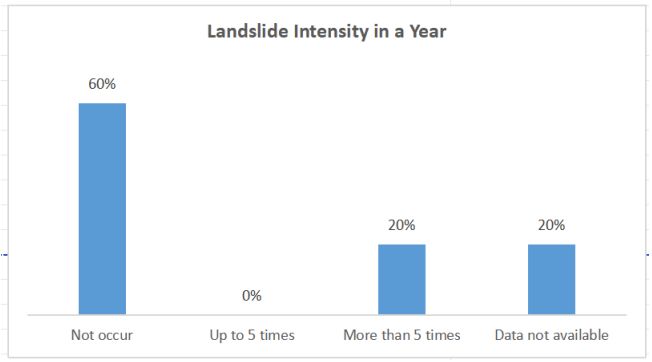

Figure 50. Landslide Intensity in a Year

Efforts to protect water catchment areas can be pursued by MHPP to improve the performance of the MHP. However, based on the results obtained, as many as 60% of MHP have not made any efforts to protect water catchment areas, namely the MHPP Necheibe, Wambena 1, and Wambena 2 sites. Only 20% of MHP have made efforts to protect water catchment areas by protecting water sources and land. Namely the Ormu Wari MHPP site, while data from the other 20% could not be obtained.

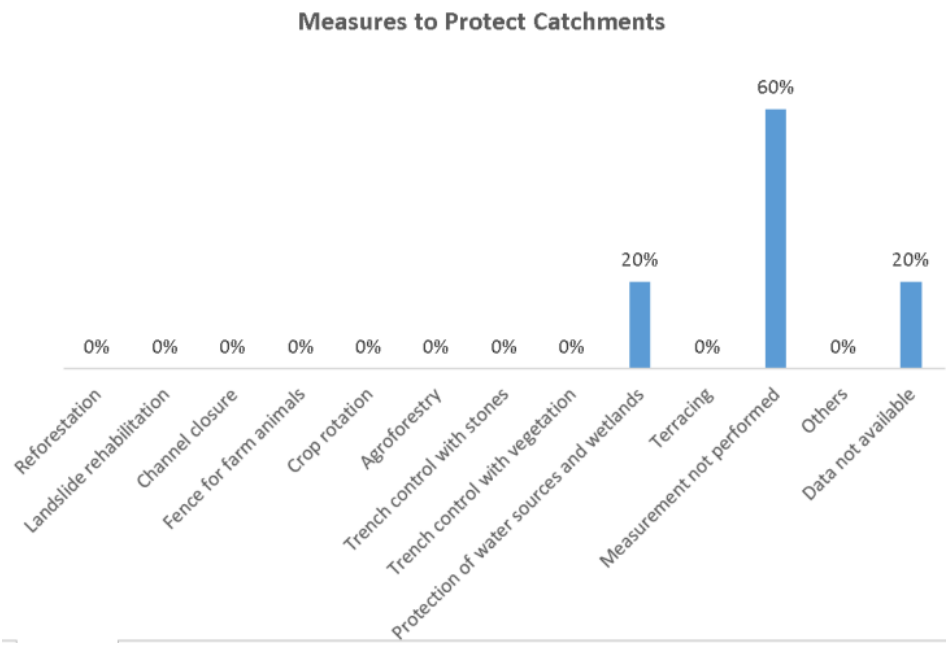

Figure 51. Measures to Protect Catchments

Efforts to protect water catchment areas are carried out through support from fund providers. 20% of the support was given by an NGO, namely the World Wide Fund, 20% was given by the government, while the other 20% came from other parties.

4. Conclusion

This KPI survey was conducted in May 2021 involving five MHPP sites in Jayapura Regency consisting of Ormu Wari, Yongsu Spari, Necheibe, Wambena 1, and Wambena 2. The purpose of this survey is to measure the performance of MHPP at each site using KPIs related to the sustainability of the site. In addition to verifying objects that are connected and not connected to the MHP, this survey also covers topics related to the sustainability of the MHPP site. The following are related topics covered in this survey:

a. Operational status: The reliability of the operation of the MHP and the challenges faced
b. Financial status: Administrative accountability and financial aspects of the management to ensure the sustainability of the MHPP.
c. Physical component checking: Checking the current condition of MHPP.
d. More efforts need to be made to manage the environment in the area around MHPP to preserve water as a source of electricity.
e. MHPPs that still have the potential to continue operations are Ormu Wari, Yongsu Spari, Necheibe and Wambena 2 because these villages still have protected rain catchment areas.

The results obtained through this survey show that each MHPP site has different performances. The following is a summary of the results obtained:

a. Based on a survey conducted on the five MHPP sites, there are 325 households, 24 social institutions, and 28 PUEs that have been connected to MHPP.
b. Buildings that are not functioning are the main reason for objects that are not connected to the MHPP or other power sources.
c. Damage to components and the presence of new generators are the main reasons behind the non-operational MHPP. Therefore, it is important to carry out regular checks on the MHPP components.
d. There is a correlation between MHPP performance and customer satisfaction. MHPP that is able to operate properly will get a satisfactory assessment from the community, and vice versa.
e. The tariff system applied by all MHPP sites is a fixed rate with a cost of Rp. 20,000.00 to Rp. 30,000.00. The mechanism for collecting tariffs is still done manually by all MHP sites. In addition, all MHPP sites do not impose any sanctions on customers who do not pay tariffs.
f. Suggestions for further studies on how to build KPIs that can be used to assess the sustainability of an MHP

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