Micro-Hydro-Power in Rural Areas of Indonesia

Practical Training Seloliman, Indonesia
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Celia Moreno Chiunti
Elisa Rodríguez Sánchez
Postgraduate Programme Renewable Energy (PPRE)
Carl von Ossietzky University Oldenburg

Unggul Budi Prasojo
Firman Dayu Rizkianto
Institut Teknologi Sepuluh Nopember

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LIST OF ABBREVIATIONS

IDR	Indonesian Rupiah Currency
PLN	PT Perusahaan Listrik Negara (Persero) – State Electricity Enterprise
GMN	Gerbang Multindo Nusantara
PPLH	Pusat Pendidikan Lingkungan Hidup – Environmental Education Center
MHP	Micro hydro plant
PKM	Paguyuban Kalimaron – Cooperative in charge of Seloliman and Wotlemah MHP
FPR	Forum Perjuangan Rakyat – Organization in charge of Sendi plant management

1. Project Expectations

The aim of this project was to conclude if three mhp plants installed in Seloliman area are working appropriately, find out if there are any problems or opportunity areas, and give possible solutions. And also analyze the impact on the communities, which we expect to be positive, increasing job opportunities and improving their life conditions.

On the other hand, we will show the advantage and disadvantages of the micro hydro power plants compared to other energy sources.

2. Introduction

Seloliman and Sendi villages lie in the Eastern part of Java Island in Indonesia, surrounded by Mountains and a dense tropical forest. It is house of a wide variety of wild life and plant species. The climate is hot and humid during the day and cools down at night. There are two main seasons; Rainy and Dry (the first one from September-March, the second one from April-August).

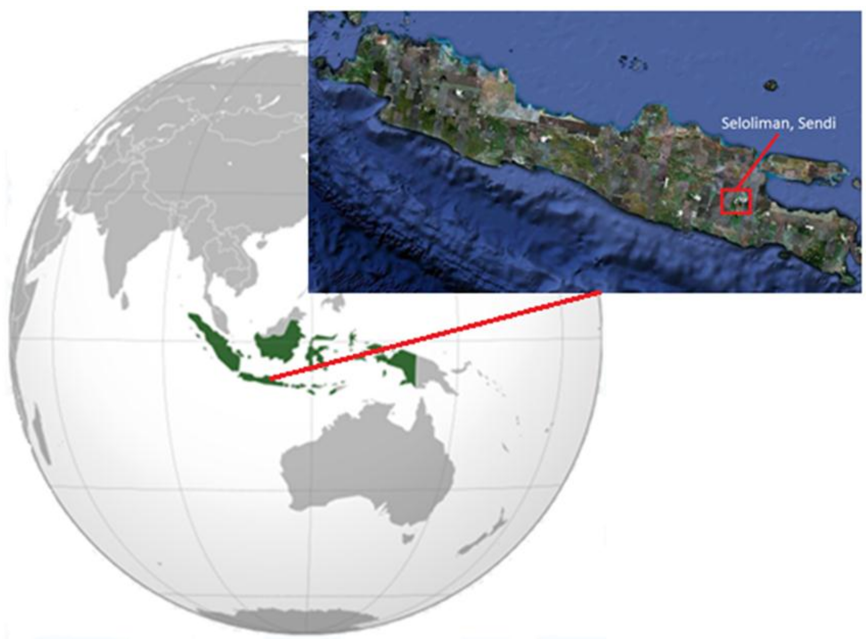


Image 2.1. Location of Indonesia and specially Seloliman Zone and Sendi Village.

This area has a privileged location, just beside a mountain, therefore the rivers catch great amounts of water, and are rarely dry, which not only benefits the MHP's but It's also the reason why many rice fields are located in this area.

Image 2.2. View of the terrain around Seloliman village.

Despite the great hydropower potential of the zone, only about 60kW have been harnessed so far.

During the 90's the Environmental Education Center (Pusat Pendidikan Lingkungan Hidup, PPLH) located in Seloliman decided to encourage the generation of power through Small Hydropower Sources of energy. The first Micro Hydro plant of the region (Seloliman Plant, 1996) was built by GTZ, but so far 3 hydro-electric projects are already producing electricity in this region.

In this work the three Small Micro Hydro power projects have been evaluated for their performances as part of an internship program for PT. Gerbang Multindo Nusantara (GMN), a national private company that specializes in energetic, mechanic and electric systems, particularly those related to alternative energy systems and renewables.

Suggestions for suitable remedies for improving the performance of these Mini Hydropower Projects are also discussed.

3. MHP Description

For the technical description of the plants several tasks were performed:

1. Visit to each of the plants.
2. Analysis of the data on the log book of one of the plants (Seloliman).
3. 24 hour data record for each plant.

A general description of the components of the plants is included, as well as technical information such as capacity factor, availability factor and plant efficiency.

Capacity factor is the ratio of the actual output of a power plant over a period of time and its output if it had operated at full nameplate capacity the entire time. To calculate the capacity factor, the total energy the plant produced during a period of time was divided by the energy the plant would have produced at full capacity.

$$CF\ [\%] = \frac{Energy\ generated\ during\ a\ period\ of\ time\ [kWh/period]}{Energy\ produced\ at\ full\ capacity\ during\ a\ period\ of\ time\ [kWh/period]} * 100\%$$

The energy generated per year was approximated with the data in the log book for the case of Seloliman plant, for the other 2 plants an approximation was made with the data collected in the 24 hour data record.

The *availability factor*, is the amount of time that the plant is able to produce electricity over a certain period, divided by the amount of the time in the period.

$$AF\ [\%] = \frac{Time\ power\ plant\ produces\ electricity\ in\ a\ period\ of\ time\ [h/period]}{Time\ in\ the\ period\ [h/period]} * 100\%$$

For Seloliman plant the availability factor could be calculated per year with the data in the log book, for the other two plants this was calculated using the hour meter reading in the ELC panel, and calculating the time that has elapsed since the power plants started operating. Also, due to the lack of written information regarding shut downs on Wot Lemah and Sendi plants, this was approximated considering the comments the plant operators made regarding the time the plant has shut down for maintenance or problems in general.

Finally the efficiency of the plants was calculated as follows:

$$\eta_{plant} = \eta_{penstock} * \eta_{turbine} * \eta_{generator}$$

Or,

$$\eta_{plant} = \frac{Power\ generated\ by\ the\ plant\ [kWh]}{Power\ of\ water\ before\ entering\ the\ system\ [kWh]}$$

The power of the flowing water was calculated as follows:

$$P_{water} = Q\rho gH$$

Where

Q=Water flow [m^3/s]

ρ= density of water [1000kg/m^3]

g= gravity [9.81m/s^2]

H= Head [m]

4. SELOLIMAN MICRO HYDRO PLANT

Seloliman Hydro-power plant is sited on the Kalimaron River in the east coast of Java Island in Indonesia; the project started in 1996 by hands of PPLH and GTZ, and was commissioned to PAGUYUBAN "PLTM" KALIMARON (PKM), Seloliman in 2003. Seloliman has a net head of 14m. Water from Kalimaron river is fed into an open channel of 150m long, and then to the intake, furthermore there is a 70m pipe which feds the water to the forebay tank. The penstock is an exposed steel pipe, 38cm diameter and 45m long. The turbine house is situated 15 m below and adjacent to the river, is a closed structure (4x3 m^2) with a window for ventilation. It houses the Cross Flow T14 turbine rated at 30kW. The generator is connected to the main district grid and to Janjing and Sempur villages as well as PPLH and some other businesses.

Table 4.1 Seloliman Micro-Hydro Plant Characteristics

Plant Characteristics	
Power	30kW
Head	15m
Net Head	14m
Design Flow	305l/s
Intake Type	Off take from Kalimaron River
Sand Trap	2X6x2.5m
Headrace	Open channel made from stone and concrete 150m, and 70m steel pipe
Spillway	Integrated with sand trap
Penstock	Steel pipe, 45m long and diameter of 38cm
Penstock Efficiency	93.3% *
Power House	4X3m^2 with window for ventilation

*The efficiency of the penstock was calculated considering the 1m head loss.

Table 4.2 Components of the Seloliman Micro-Hydro Plant

Mechanical and Electrical Components of the Plant	
Turbine	Cross Flow T14
Runner Diameter (Blade Turbine)	30cm
Max RPM of the Turbine	573/750 RPM
Efficiency of Turbine	80%
Driver/Converter	Flat Belt
Generator Type	Synchronous
Generator Capacity	40kVA
RPM of the Generator	1500 RPM
Generator Efficiency	90%

Image 4.1 Crossflow turbine T14 on Seloliman Micro-Hydro Plant

4.1. Plant Performance

For the performance evaluation of this plant we counted with two log-books of the plant. One had the plants records from October 2003 - November 2005, the second one goes from June 2007 till today, both of them are missing data for some days (especially holidays). The log-book with the data for December 2005, 2006 and the four first months of 2007 was lost in a flood.

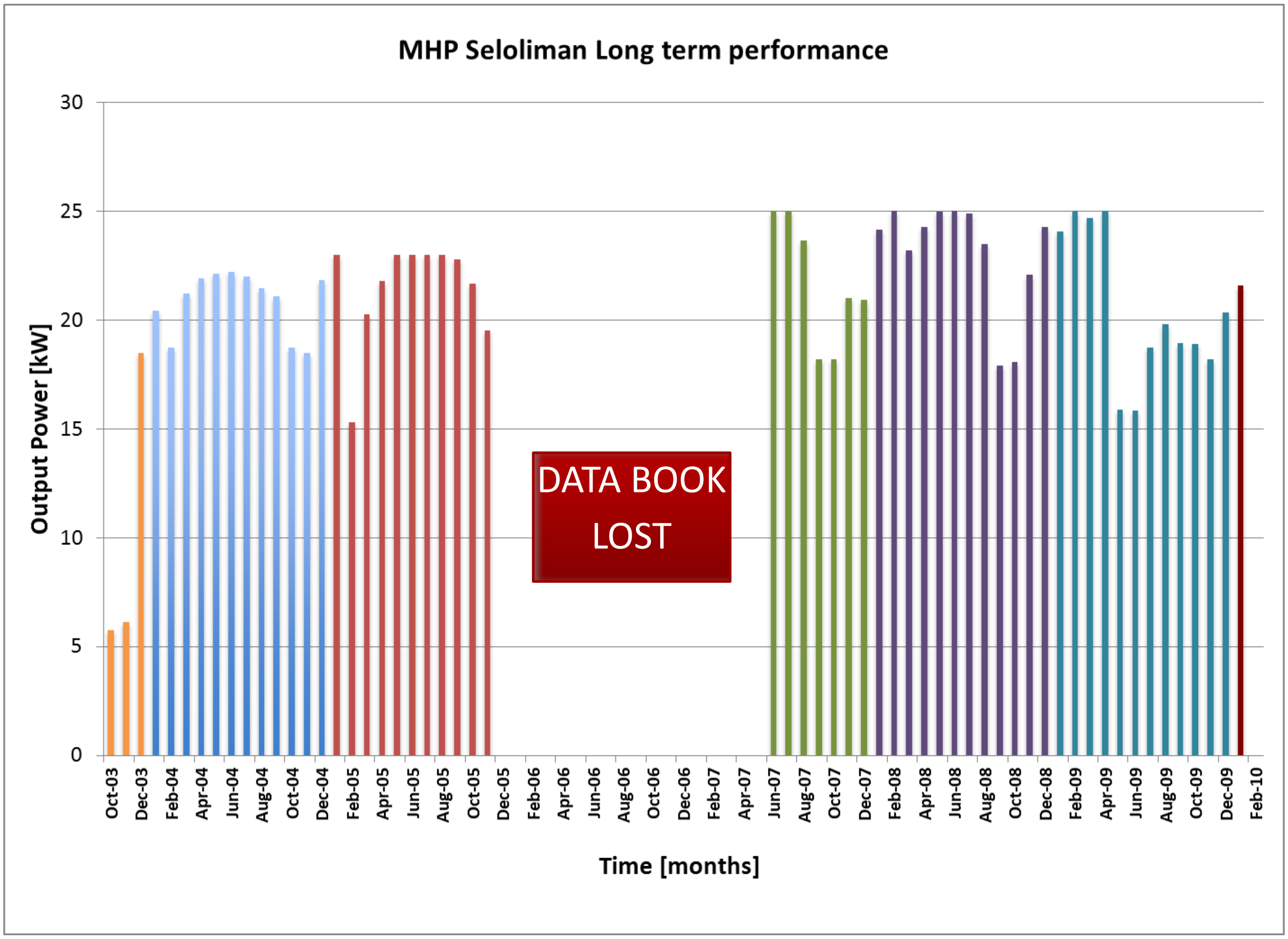
The information provided by the log-book was:

- Hours the plant has operated since October 2003 till now (54,011 hours)
- Frequency (50Hz)
- Voltage (220V)
- Power production of the plant per day [kW]
- Power to the grid and the village at day and at night [kW]

According to the available data a long term (2004-2008) performance graph was made for Seloliman Micro Hydro Plant.

We noticed there is an increasing output power tendency since 2003 till now. In average, the power production of the plant has increased 0.6 kW per year since 2004, with an average (whole lifetime) power output production of 20.6kW.

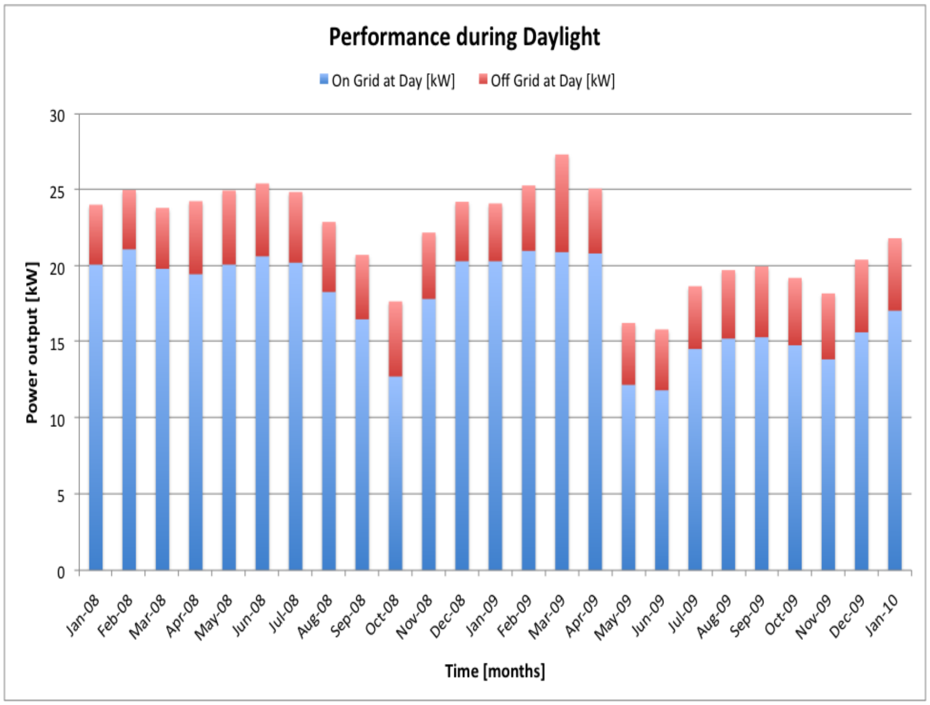
Despite what we might think, that in rainy season there is more water and thus the power production increases, the plant's power output actually increases in dry season, and during December and January in rainy season. During dry season the flow is steadier and less plant shut downs occur, as opposed to rainy season, where flow is unsteady and huge amounts of trash are carried by the river and into the system, interrupting the well-functioning of the plant.



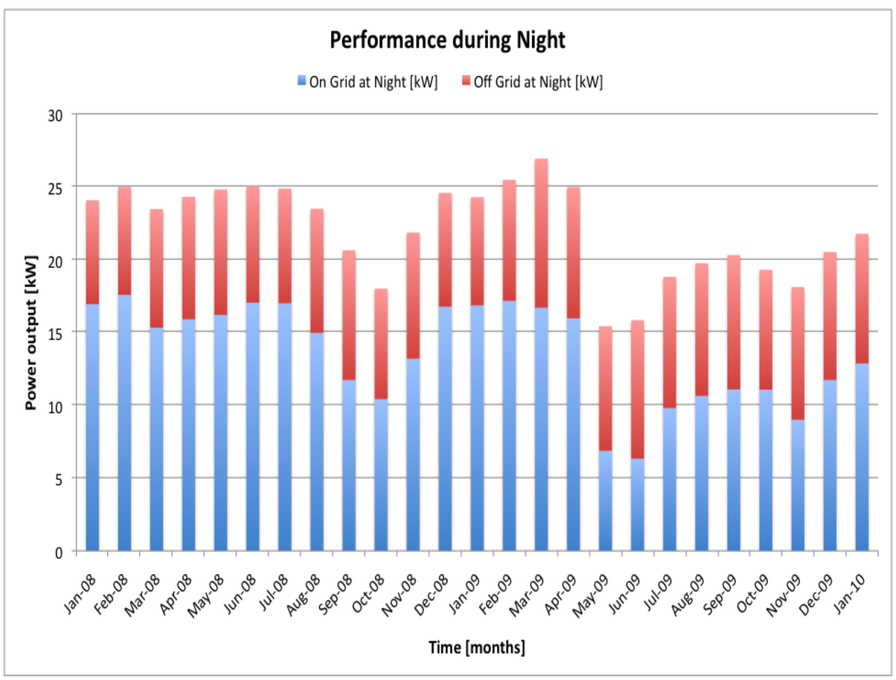
Graph 4.1. Seloliman Micro Hydro Plant long term performance. The output power values shown in the graph are an average of the monthly power output of the plant.

Despite the fact that power output measurements are only recorded once a day, measurements for the plant's on grid power output are taken twice a day by part of the plant's operators, once during the morning, approximately at 7:30am and another measurement in the afternoon, at approximately 5:30pm.

During the day approximately 80% of the power produced by the plant goes directly to the grid, and the rest goes to the villages. In the afternoon-night these percentages change to 60% on grid power supply and 40% to the villages. During the morning most of the villagers work out of their houses, most of them in farms, children attend school, so it's mostly housewives and small children who stay at home, decreasing electricity consumption considerably during this time. The electricity consumption for the villages doubles its value in the afternoon, when the workers and children return to their homes and watch TV, listen to the radio, necessarily turn on the lights, etc.

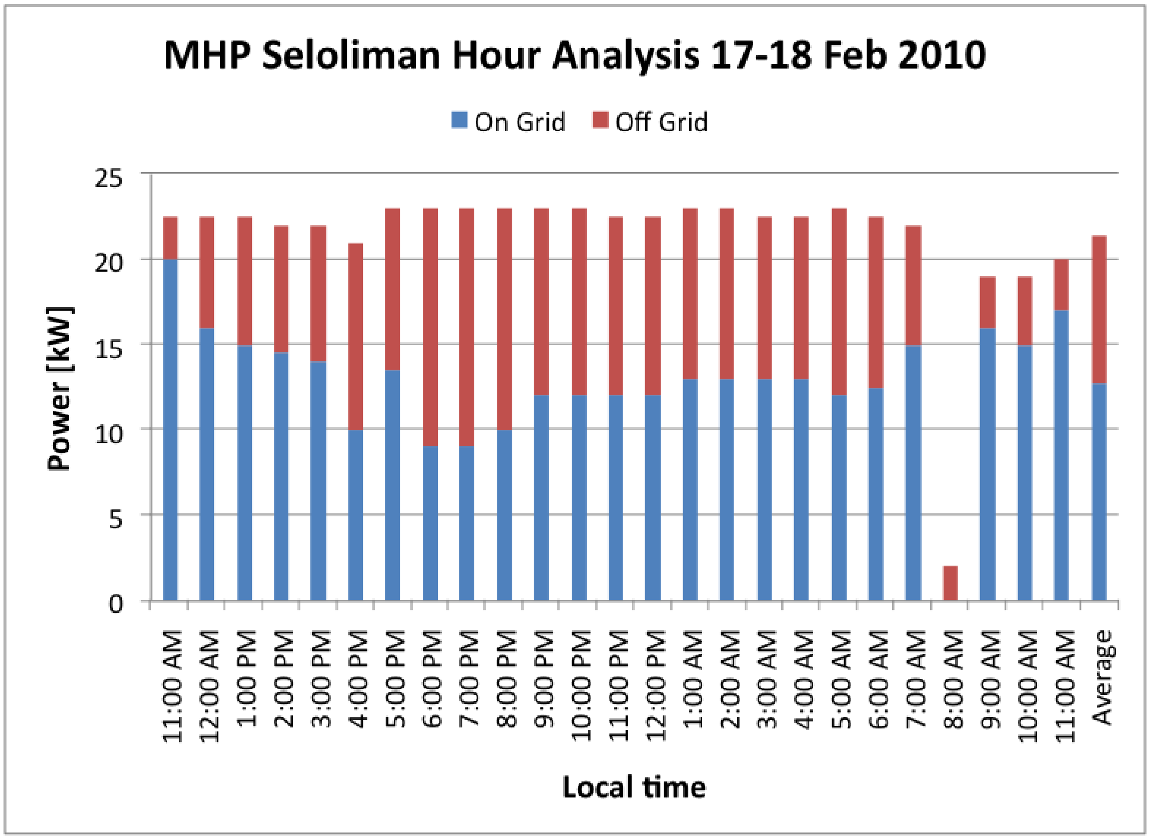


Graph 4.2. Performance of the plant during the day.



Graph 4.3. Performance during the night.

A 24 hour data analysis was performed to obtain more accurate information on the hour to hour power output of the plant. The power output to the grid varies from almost 90% of the total power output of the plant at 11am and starts decreasing to values as low as 40% at 6 and 7pm, afterwards the power output to the grid increases again. From the graph it can be said that villagers wake up around 5am, when it is still dark outside, and therefore have the necessity to turn on the lights, that's why we see an increase in Off grid power output at this time, which starts decreasing throughout the morning, and increases again after 11am, when family members start arriving home, this tendency continues till 7pm, after this the off grid power output decreases, which can indicate that the villagers go to sleep around this time, finally we see that the off grid power output stays stable during the night and rises again early in the morning. Also, at 8 am we notice an extraordinary low power output, this is because the plant shuts down every day at about 7:30am – 8:00am for maintenance (cleaning intake and filter).

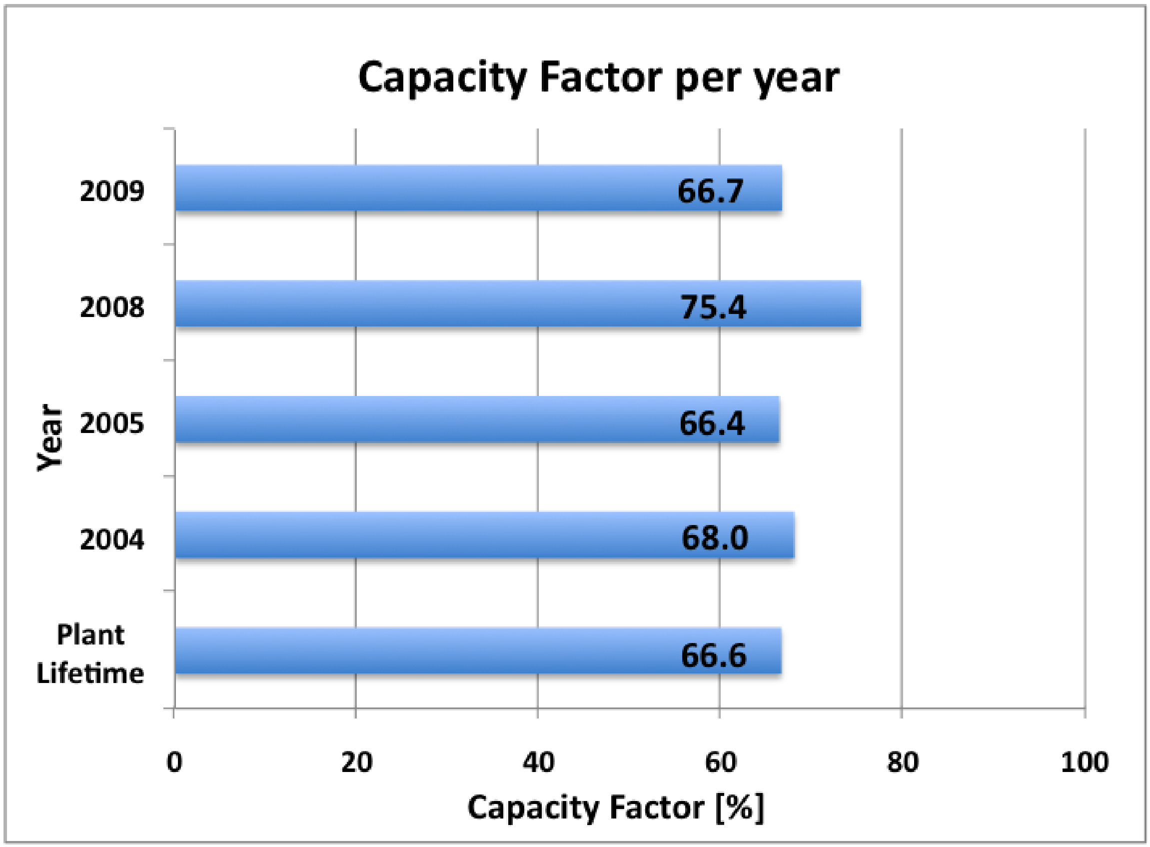


Graph 4.4. 24 hour power output analysis for Seloliman plant.

It is well known that electricity supply is an important factor when talking of economic and social growth of a region. Seloliman plant plays an important role in the growth of Janjing, Sempur and Bitting villages, as well as PPLH, and for that it should have an optimal performance. Every year the plant generates in average 21kW and operates for approximately 8528 hours. If we compare this to the 30kW capacity of the plant and the 8760 hours there are in a year, we can find the capacity factor for this plant.

$$CF[\%] = \frac{21[kW] * 8528[h/y]}{30[kW] * 8760[h/y]} * 100\% = 66.6\%$$

With a standard deviation of 4.2%.

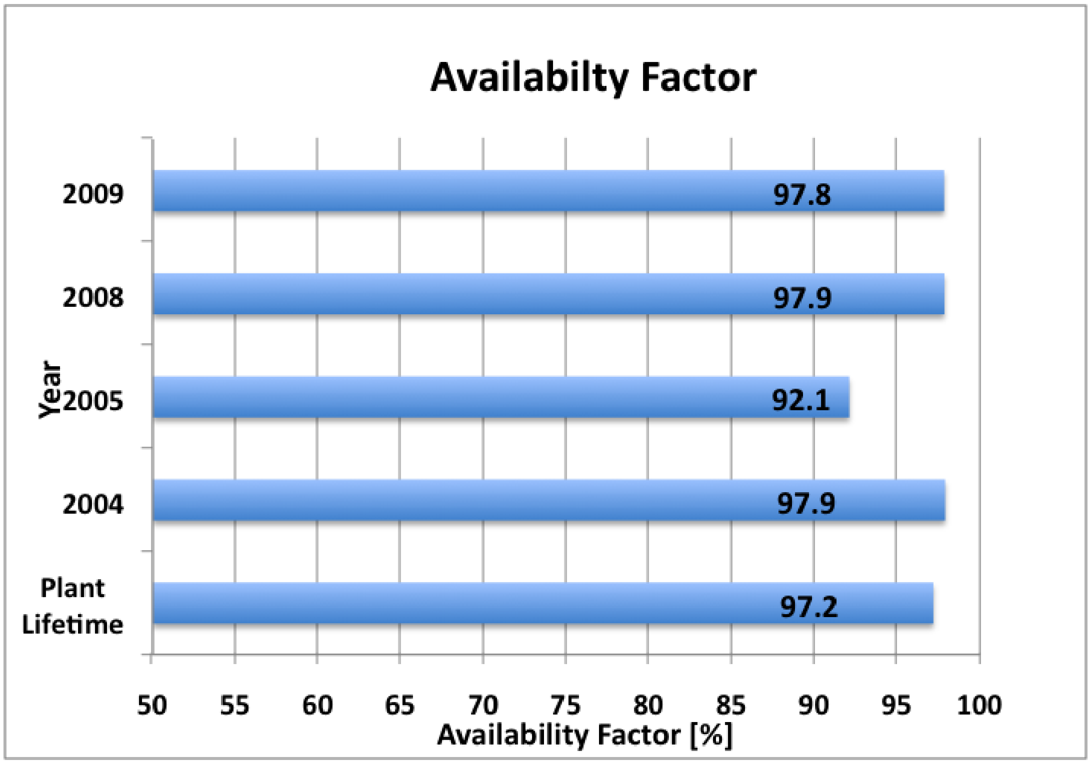


*Graph 4.5. Capacity factor for Seloliman Plant. *For the year 2005 an approximation of CF was made, since information for December 2005 was missing, we averaged the number of hours the plant worked per month in 2005, and assigned that value to December, the same was done for the power output. ** The plant lifetime is since October 2003-today.*

Electricity consumers of places which are fed from the grid can expect to have electricity almost 100% of the time, but villages or remote access areas with off grid connections can't expect this, especially if they rely on a single plant. All power generating plants need to shut down now or then due to maintenance, or situations in general. Micro hydro plants need special maintenance as well in order to function properly, and Seloliman MHP is no exception, therefore the plant shuts down every day, several minutes, for maintenance purposes and also when unexpected problems appear. This is the reason why the plant operates in average 8528 hours per year, instead of the complete 8760 hours in a year, thus the availability factor of Seloliman plant is

$$AF\ [\%] = \frac{8528\ [h]}{8760\ [h]} * 100\% = 97\%$$

With a standard deviation of 2.9%, thus indicating that the beneficiaries of Seloliman Plant count with electricity approximately 97% of the time, which makes the plant reliable.



*Graph 4.6. Availability Factor for Seloliman Plant. *Check graph 5 for information on 2005 and Plant Lifetime data.*

Both CF and the AF depend on the amount of time the plant is shut down, which is also dependent on the different issues that affect the plant each year.

Every energy transformation system is always accompanied by losses, and Micro Hydro Plants are no exception. In this case the potential energy of a reservoir or flowing water is transformed into kinetic energy which later on is transformed to electricity. In these types of plants there are always losses in the penstock, turbine and generator. According to the datasheet of Seloliman plant, the total efficiency of the plant is

$$Efficiency\,[\%] = (0.933)(0.80)(0.90) * 100\% = 67\%$$

The maximum power output of the plant (30kW) can only be achieved when the water flow is equivalent to 0.305m^3/s, in this case the efficiency (which agrees with the previous calculated value) is

$$Efficiency = \frac{30{,}000[W]}{1000[k/m^3] * 9.81[m/s^2] * 15[m] * 0.305[m^3/s]} * 100\% = 67\%$$

5. Wot Lemah Micro Hydro Plant

Wot Lemah Hydro-power plant is also sited on the Kalimaron river; The project started in march 2009 iniciated by PPLH, GMN and ITS, and was commissioned to PAGUYUBAN "PLTM" KALIMARON (PKM), Seloliman in 2009. Water from Kalimaron river is fed into an open channel of 300m long, and then to the intake and forebay tank. The penstock is an exposed steel pipe, 40cm diameter and 35m long. It has a net head of 12m. The turbine house situated 14 m below and adjacent to the river, is a closed structure (6x3 m^2) with windows for ventilation. It houses the Cross Flow T14 turbine rated at 20kW. The generator is connected to the main district grid and to Bitting and Balekambang villages.

Table 5.1 Wot Lemah Micro-Hydro Plant Characteristics.

Plant Characteristics	
Power	20kW
Head	14m
Net Head	12m
Design Flow	250l/s
Intake Type	Off-take from the split of Kalimaron River
Sand Trap	5m long, 2m wide and 2.7m deep
Headrace	Open channel made from stone and concrete 300m
Spillway	Integrated with sand trap and filter
Penstock	Steel pipe, 35m long and diameter of 40cm
Penstock Efficiency	85.7%
Power House	6X3m2

Table 5.2 Components of the Wot Lemah Micro-Hydro Plant.

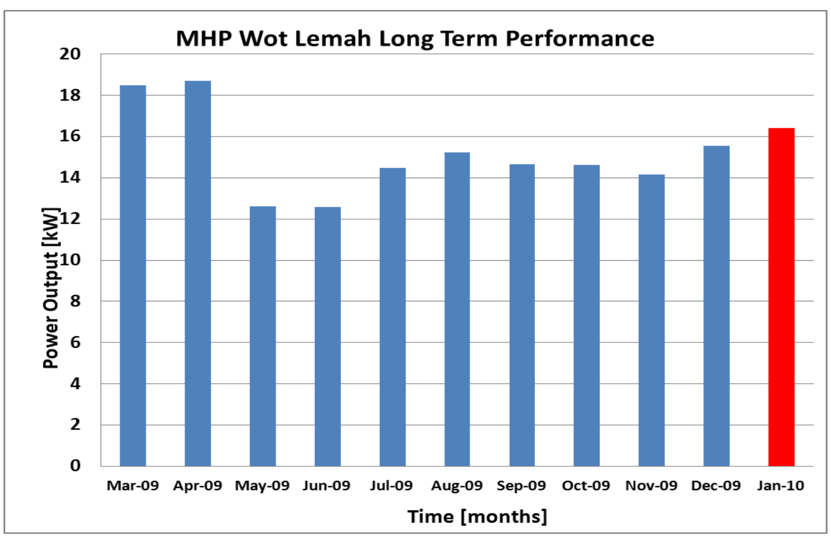
Mechanical and Electrical Components of the Plant	
Turbine	Cross Flow T14
Runner Diameter (Blade Turbine)	30cm
Max RPM of the Turbine	573/750 RPM
Efficiency of Turbine	80%
Driver/Converter	Flat Belt
Generator Type	Synchronous
Generator Capacity	25kVA
RPM of the Generator	1500 RPM
Generator Efficiency	90%

Image 5.1 Wot Lemah Micro-Hydro Plant.

5.1 Plant Performance

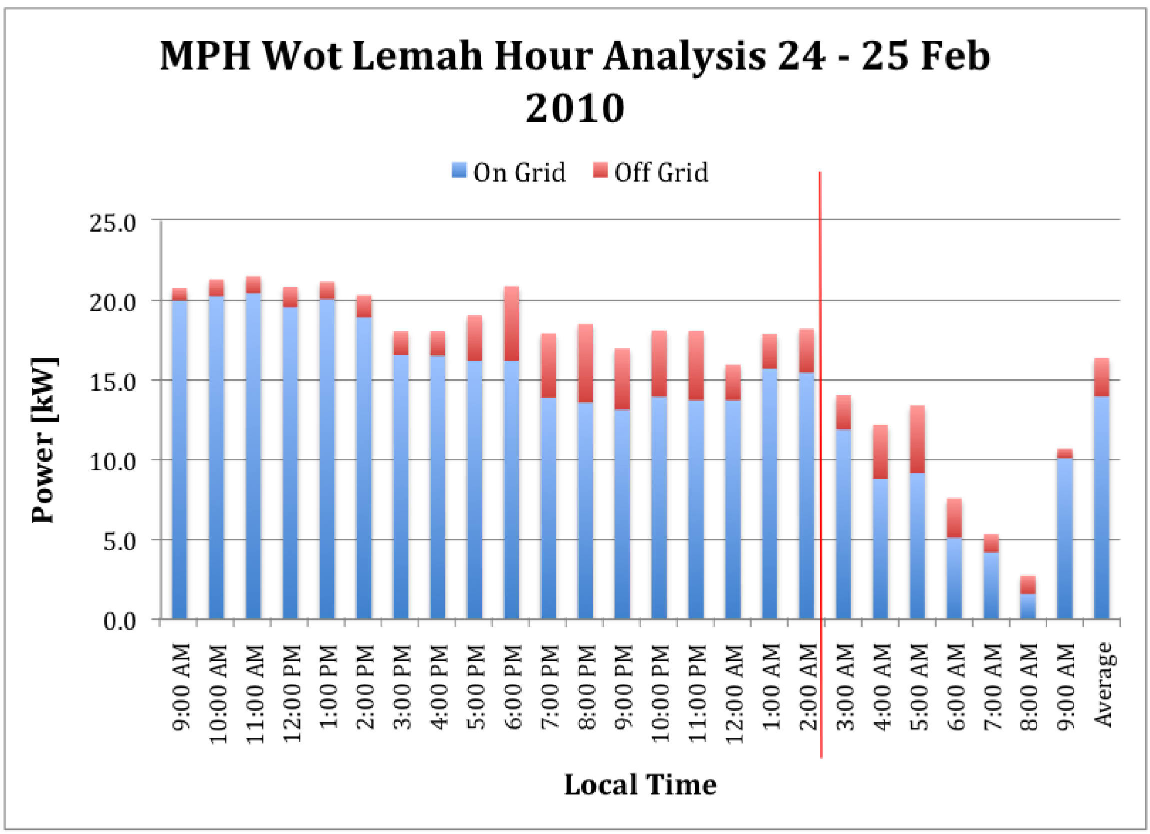
The log-book for the evaluation of this plant was lost in a flood, for this reason long term performance analysis of this plant was not possible.

We can assume that the long term performance of Seloliman and Wot Lemah Plant's follow a proportional growth pattern, this assuming that both of them have the same type of problems, considering their location and the similarity of their components, the fact that the management staff is the same for both plants, and the similar necessities between the villages they supply.



*Graph 5.1. Assumed long performance of Wot Lemah Plant. *For January 2010 an average power output of 16.2kW was considered, from there the percentage of power output per month was equaled to Seloliman power output percentage per month.*

A 24 hour data analysis was performed to obtain information on the hour to hour power output of the plant. For Wot Lemah the power output to the grid varies from almost 96% of the total power output of the plant at 9am and starts decreasing to values of 73% at 8pm, afterwards the power output to the grid increases again. It stays stable from 10 to 12pm, and then again from 1 to 2am. It can be said that most of the villagers are not at home during the morning-afternoon (9am-4pm), after 4pm they arrive home and start utilizing more electricity, until 8pm, when they go to bed and again on grid power output increases. We can't infer anything from 2am till 9am, during the 24 hour measurements a problem of trash surged, and consequently the water flow decreased and power output as well. Plant operators realized about the problem when they arrived to the plant early in the morning and solved the problem at approximately 8am, after this the power output started increasing. Another important observation was that the power output from 9am till 2pm was greater than 20kW, this is because the operator did not close the valve of water entering the turbine, of course this could have been damaged the plant equipment (generator).



Graph 5.2. 24 hour power output analysis for Wot Lemah plant.

Bitting and Balekambang villages have been growing both economically and socially since electricity was supplied to them and Wot Lemah Plant happens to be their main power supplier, so in order to keep the village growing it is important that Wot Lemah operates accordingly. The 24 hour analysis of plant showed that it generated in average 16kW. Again, since both plants are located within the same river, only 300m apart from each other and maintenance shut downs are the same for both, we can assume that Wot Lemah also operates 8528 hours per year. If we compare this to the 20kW capacity of the plant and the 8760 hours there are in a year, we can find the capacity factor for this plant.

$$CF[\%] = \frac{16[kW] * 8528[h/y]}{20[kW] * 8760[h/y]} * 100\% = 78\%$$

With the considerations mentioned above the Avalability Factor for Wot Lemah is the same as for Seloliman

$$AF\ [\%] = \frac{8528\ [h]}{8760\ [h]} * 100\% = 97\%$$

Which also makes the plant reliable.

Efficiency calculations were performed for Wot Lemah Plant, with the following results

$$Efficiency\ [\%] = (0.857)(0.80)(0.90) * 100\% = 62\%$$

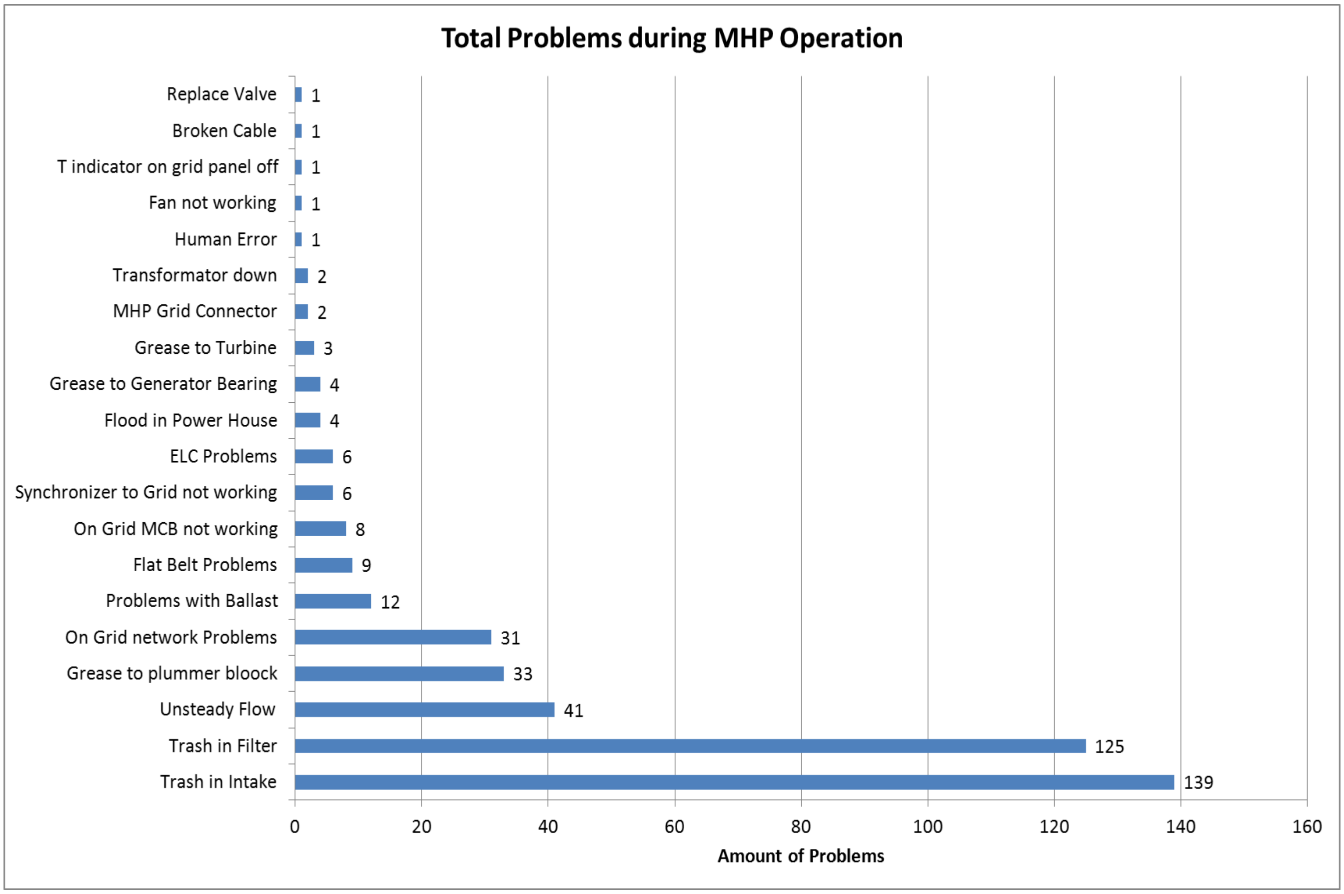
This according to the datasheet of Wot Lemah plant. On the other hand, flow measurements were performed for Wot Lemah Plant, as well as power output record. When the power output records were 18kW, the approximate water flow was 210l/s, with this

$$Efficiency = \frac{18{,}000[W]}{1000[k/m^3] * 9.81[m/s^2] * 15[m] * 0.25[m^3/s]} * 100\% = 62\%$$

As we can see, Wot Lemah is less efficient than Seloliman, and it’s because of the energy losses (friction) in the penstock. This result shows us how important the penstock is in the system, even though a 5% difference doesn’t seem as much, in other renewable energy systems, such as PV (at most 20% efficiency), having a 5% increase in efficiency is an important issue.

6. Causes of failure

When talking about power plants it is common to mention some types of problems that cause breakdowns of the systems, especially when these power plants involve renewables. In order to acquire more confidence and reliability in renewables it is of major importance to reduce these breakdowns, and have the power plants functioning as stable as possible. It is important to mention that not all causes of breakdowns can be controlled, but most of them can, or at least they can be predicted and worked on before breakdowns occur. Next is a list of problems faced by Seloliman Hydropower Plant since 2003 to 2010, it is important to mention that not all of them where causes of breakdown of the system, but had some relevance in its performance.

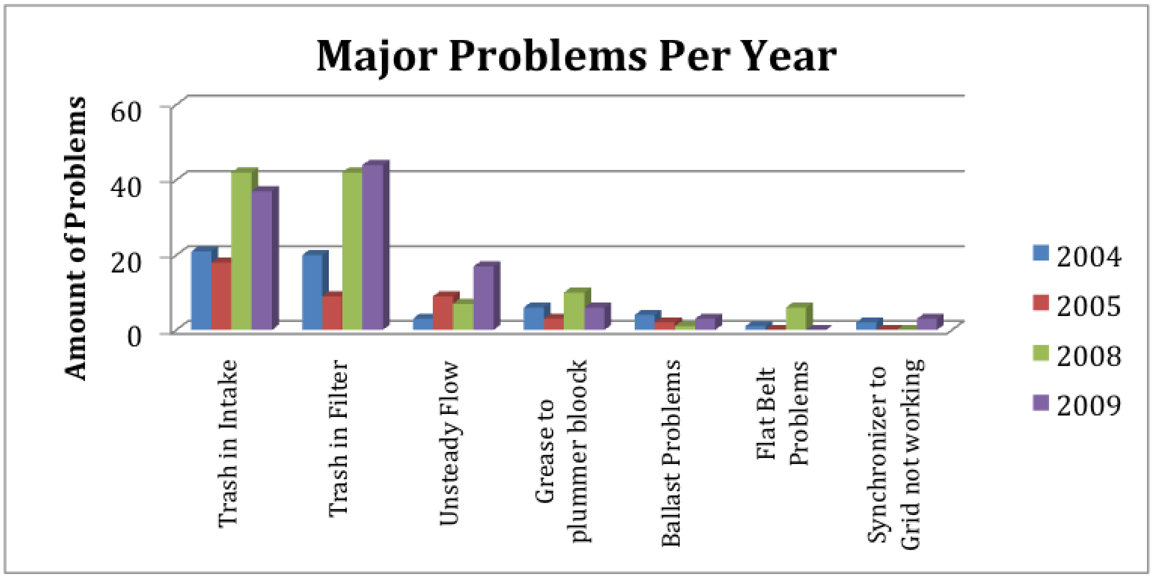


Graph 6.1. Total Problems of Seloliman MHP since 2003 till now.

The major problems and causes of breakdowns are caused by trash carried by the river and open channel, to the intake and filter, as well as unsteady flow, grease to some parts of the system, ballast and flat belt problems, etc. Some of the problems are correlated with each other, for example floods in power house affect also on grid MCB, ELC, etc. As mentioned before some of these problems could be prevented, with no need of shutting down the plant in not planned hours.

Every morning the plant is shut down for less than an hour with cleaning purposes (intake, filter, etc.), during this time maintenance to other parts of the system could be done (grease to some parts, etc.) in order to reduce the number of breakdowns.

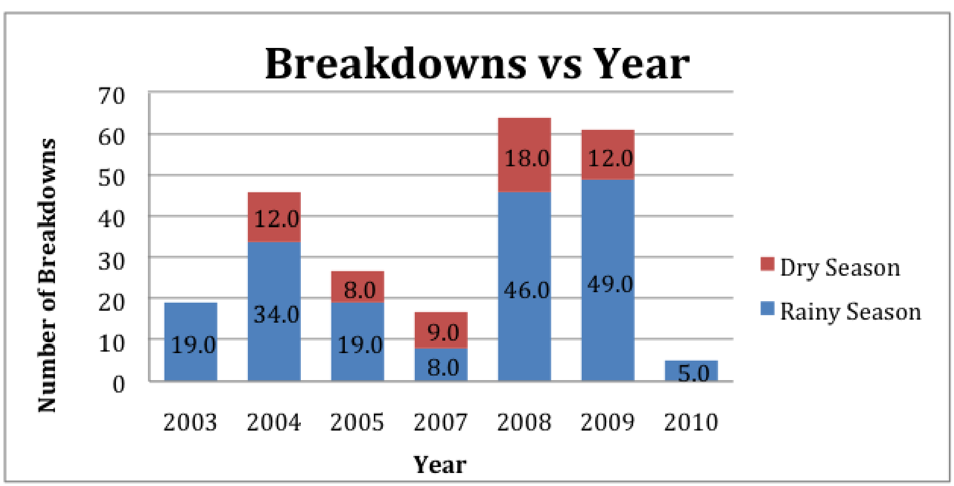
In the next graph we see the major problems of the plant per year.



Graph 6.2. Major Problems of Seloliman MHP per year.

Trash has been a major problem throughout the years. We can observe how trash in intake and filter have risen over the years, this is mainly because the catchment area has been deforested, and now more trash and sand reach the river and channel, augmenting the trash in intake and filter.

In Seloliman Plant several breakdowns per year occur, minimizing them would increase the plants capacity and availability factors.

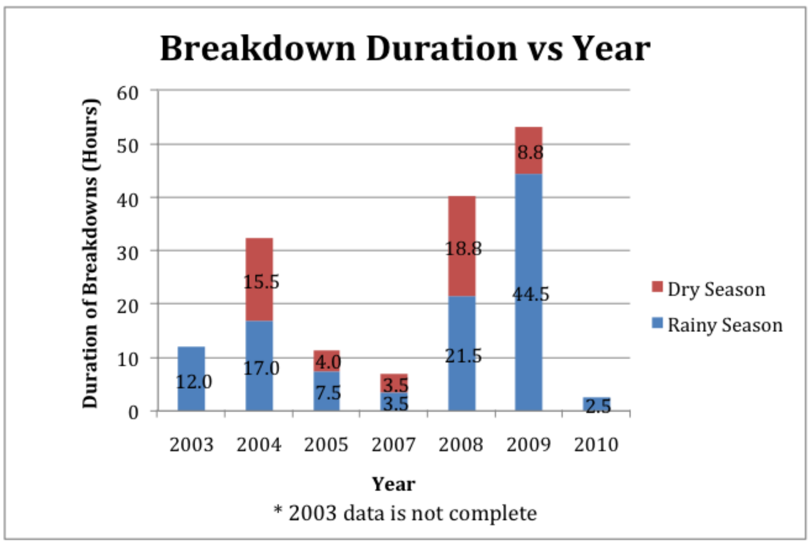


*Graph 6.3. Number of Breakdowns of Seloliman MHP per year. * 2003 data is not complete.*

In Graph 6.3, we can observe that in 2007 the majority of problems are in dry season, this is because the data for rainy season 2007 is not complete.

In all cases the majority of system breakdowns occur in rainy season. As mentioned before, trash is a major cause of breakdown, in rainy season the amount of trash carried by the river is greater, thus breakdowns rise. Also unsteady flow increases in this season, and with that, floods and other causes of breakdown in the plant.

The duration of each breakdown varies according to the cause, trash problems in the intake, filter, etc. can be fixed in relatively short periods of time, aprox. 30 min, but other problems involving grid network problems, or cleaning of the river can take up to 10 hours.

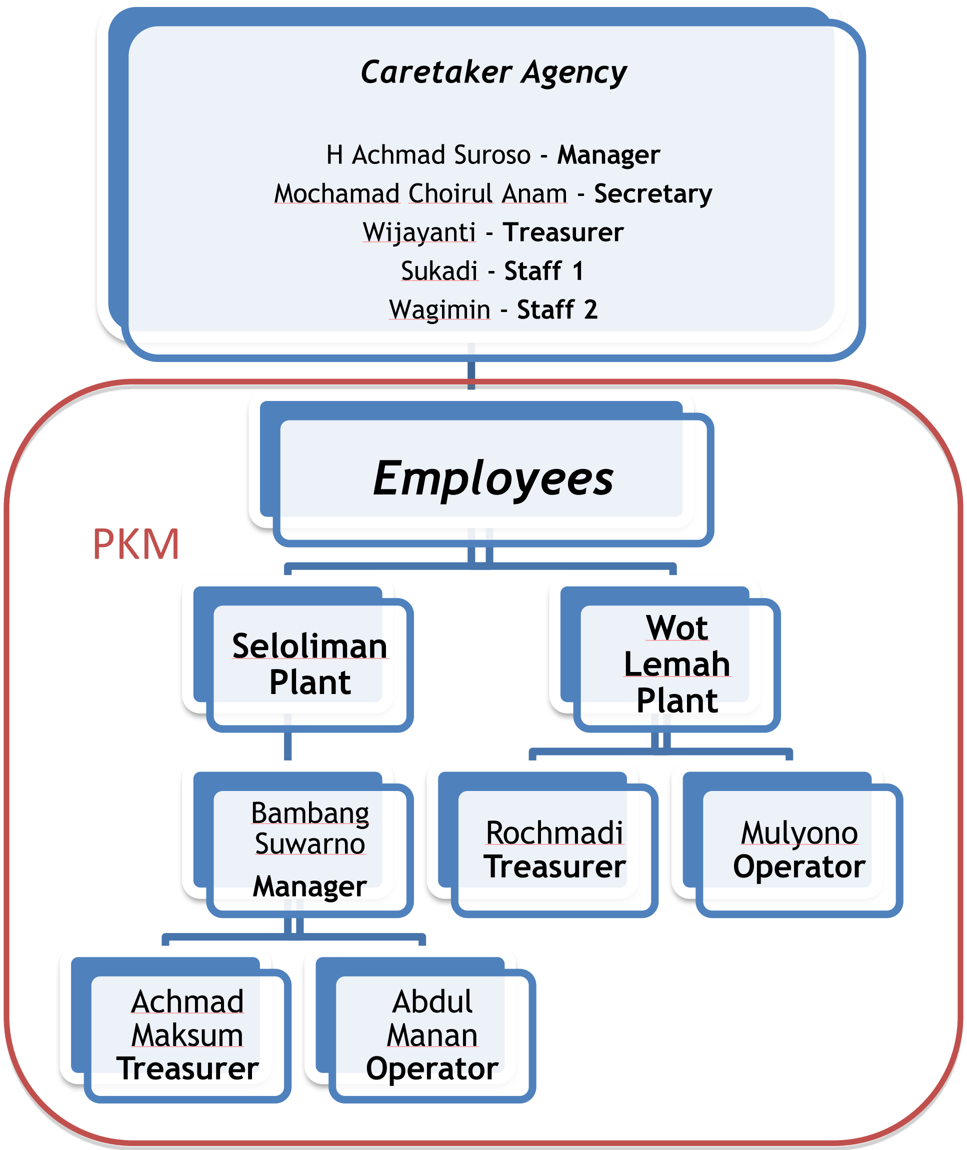


Graph 6.4. Duration of Breakdown per year for Seloliman MHP.

The duration of the break downs is not entirely dependant on the number of break downs, as we can observe for 2008 and 2009, in 2008 there were more brakdowns than in 2009, but the problems in 2009 took more time to fix than those of 2008.

7. Plant Management

PKM "Paguyuban Kalimaron" is the cooperative responsible of the management of Seloliman and Wotlemah micro-hydro plants and is organized as follows:



On the top of the organization chart is a Care-taking Agency, which gives support to PKM and checks that everything works properly in Seloliman and Wotlemah micro hydro plants, this support is costless for PKM organization.

The responsibilities of PKM members are:

Manager – Staff leader, who is responsible of the coordination of employees and the correct management of Seloliman Plant.

Main activities:

- Organize activities,
- Public relations,
- Negotiations,
- Meeting leader,
- Admonitions,
- Document authorizer,
- Responsible of anything that happens to the organization.

Treasurer – Responsible of the correct and transparent administration of the micro hydro plant's incomes and outcomes.

Main activities:

- Keep the organization's money safe,
- Monthly record the incomes from the different sources, off and on grid,
- Manage the loan and savings,
- Report the accountancy of the plant, monthly and annual.

Operator – Responsible of the manual operation of the plant.

Main activities:

- Run and operate the plant
- Record in the Data book every unusual activity and report them at the meetings.
- Check the network connection.
- Hand in a monthly report.
- Give maintenance to the plant and also keep it secured.
- Consider the plant as his first priority.

Each PKM member receives a monthly salary according to the positions mentioned before, which is mentioned further on this report.

8. Costs and Economics

MHP Tariffs

As mentioned before, Seloliman and Wotlemah MHP are managed by PKM "Paguyuban Kalimaron" (the micro-hydro cooperative), which has established the following tariffs for each plant.

Regarding Seloliman MHP, the tariff for the Off Grid customers is classified depending on the load and also on the electricity consumption in kWh, where there are several subclasses:

Table 8.1. Seloliman's tariffs classification

Classification for MHP	Administration Fee	Energy kWh	Price 2010 IDR per kWh
R1 [200Watt]	3,300	1 - 20	203
		21-80	248
		>80	270
R2 [450Watt]	5,500	1-20	203
		21-80	248
		>80	270
U1 [900 Watt]	8,800	1-30	180
		31-90	203
		91-300	225
		>300	248
U2 [1350 Watt]	11,200	1-40	180
		41-100	203
		101-400	225
		>400	248
U3 [2500 Watt]	13,200	1-40	180
		41-100	203
		101-400	225
		>400	248
U4 [3300 Watt]	24,200	1-40	180
		41-100	203
		101-400	225
		>400	248

The taxes for Seloliman plant are fixed to IDR 500.00.

Finally, the calculation for obtaining the price for the customer is done as follows,

Class R1 and R2:

$$\text{Total Price} = (P_{1\text{-}20} \times \text{Price}_{1\text{-}20}) + (P_{21\text{-}80} \times \text{Price}_{21\text{-}80}) + (P_{>80} \times \text{Price}_{>80}) + \text{Administration Fee} + \text{Taxes}$$

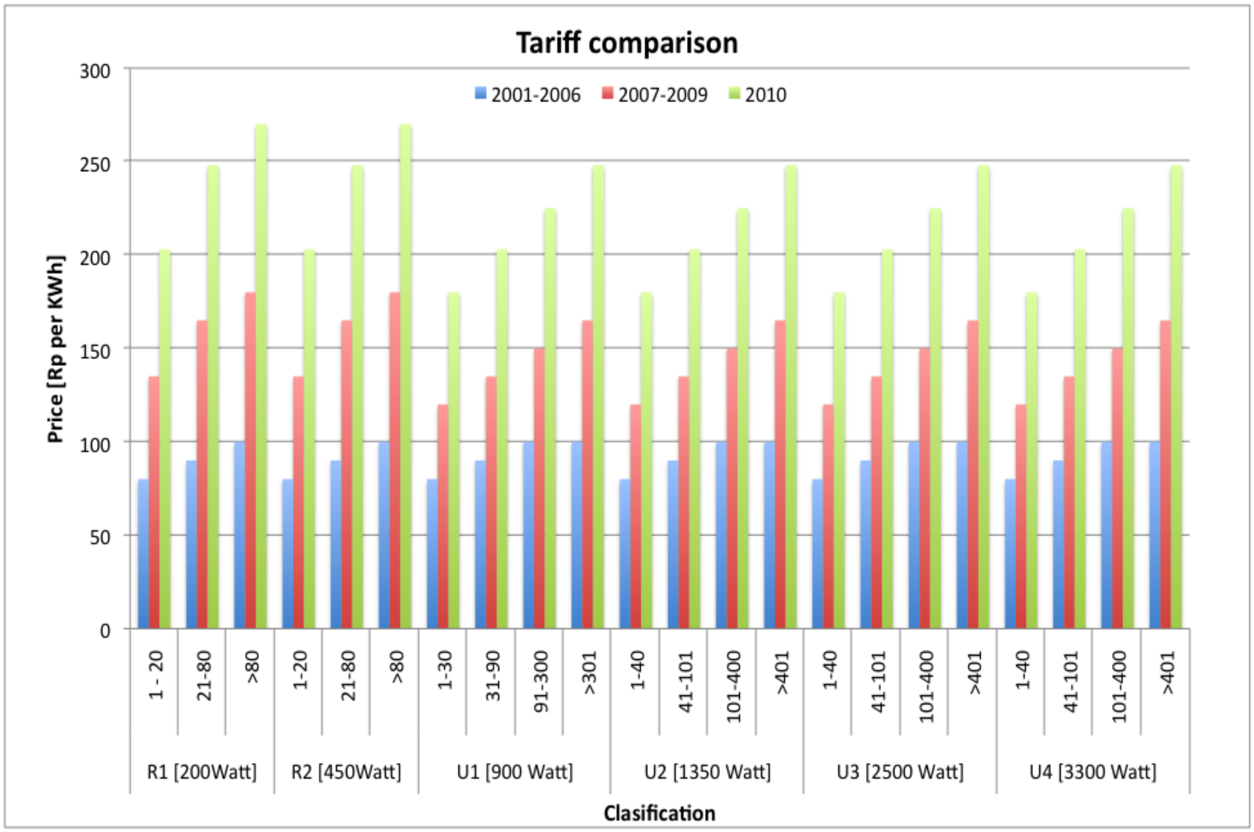
Class U1:

$$\text{Total Price} = (P_{1\text{-}30} \times \text{Price}_{1\text{-}30}) + (P_{31\text{-}90} \times \text{Price}_{31\text{-}90}) + (P_{91\text{-}300} \times \text{Price}_{91\text{-}300}) + (P_{>300} \times \text{Price}_{>300}) + \text{Administration Fee} + \text{Taxes}$$

Class U2, U3 and U4:

$$\text{Total Price} = (P_{1\text{-}40} \times \text{Price}_{1\text{-}40}) + (P_{41\text{-}100} \times \text{Price}_{41\text{-}100}) + (P_{101\text{-}400} \times \text{Price}_{101\text{-}400}) + (P_{>400} \times \text{Price}_{>400}) + \text{Administration Fee} + \text{Taxes}$$

The tariff for the electricity produced by Seloliman Plant has been modified three times in the past 10 years, with increments of approximately 50%.



Graph 8.1. Seloliman's tariffs comparison in time

For Wotlemah plant the Off Grid tariff calculation is different, this is due to the short period of time the plant has been working. As a promotion for the plant, the first 3 months of electricity service for the villages were for free. By June 2009, only one class was established, and the prices of this one depend on the Energy consumption level only.

Table 8.2. Wotlemah's tariff classification.

Classification	Taxes	Administration Fee	Energy	Price 2010
	IDR		kWh	IDR per kWh
Single Class	250	7500	1 - 30	450
			30-70	500
			>70	600

The same procedure showed for the tariff calculation in Seloliman is applied for Wot Lemah.

PLN tariff

The electricity company also establishes different classes for the electricity tariff depending on the use (households, business, industry, etc), the connected power and power consumption.

The tariff calculation is similar to the ones explained before, but instead of an administration fee, there is a fix power cost, which has to be pay by the customer depending on each class. Table 7.3 shows the current electricity tariff from the PLN, we will focus in the tariff related to households.

Table 8.3. Baseline Electricity Tariff (TDL)

TARIFF GROUP	CONNECTED POWER	POWER COST (IDR./kVA/mo	Energy Cost (Rp./kWh)
Social			
S-1/TR	220 VA	-	Lumpsum/month IDR = 14.800
S-2/TR	450 VA	10,000	Block-I : 0 - 30 kWh = 123. Block II : above 30-60 kWh = 265. Block III: above 60 kWh = 360
S-2/TR	900 VA	15,000	Block-I : 0 - 20 kWh = 200. Block II : above 20-60 kWh = 295. Block III: above 60 kWh = 360
S-2/TR	1.300 VA	25,000	Block-I : 0 - 20 kWh = 250. Block II : above 20-60 kWh = 335. Block III: above 60 kWh = 405
S-2/TR	2.200 VA	27,000	Block-I : 0 - 20 kWh = 250. Block II : above 20-60 kWh = 370. Block III: above 60 kWh = 420
S-2/TR	above 2.200 VA - 200 kVA	30,500	Block-I : 0 - 60 active hours = 380. Block II : above 60 next active hours = 430
S-3/TM	above 200 kVA	29,500	Block WBP = K x P x 325. Block LWBP = P x 325
Residential			
R-1/TR	up-to 450 VA	11,000	Block-I : 0 - 30 kWh = 169. Block II : above 30-60 kWh = 360. Block III: above 60 kWh = 495
R-1/TR	900 VA	20,000	Block-I : 0 - 20 kWh = 275. Block II : above 20-60 kWh = 445. Block III: above 60 kWh = 495
R-1/TR	1.300 VA	30,100	Block-I : 0 - 20 kWh = 385. Block II : above 20-60 kWh = 445. Block III: above 60 kWh = 495
R-1/TR	2.200 VA	30,200	Block-I : 0 - 20 kWh = 390. Block II : above 20-60 kWh = 445. Block III: above 60 kWh = 495
R-2/TR	above 2.200 VA - 6.600kVA	30,400	560
R-3/TR	above 6.600 VA	34,260	621
Business			
B-1/TR	up-to 450 VA	23,500	Block-I : 0 - 30 kWh = 254. Block II : above 30 kWh = 420
B-1/TR	900 VA	26,500	Block-I : 0 - 108 kWh = 420. Block II : above 108 kWh = 465
B-1/TR	1.300 VA	28,200	Block-I : 0 - 146 kWh = 470. Block II : above 146 kWh = 473
B-1/TR	2.200 VA	29,200	Block-I : 0 - 264 kWh = 480. Block II : above 264 kWh = 518
B-2/TR	above 2.200 VA - 200 kVA	30,000	Block-I : 0 - 100 active hours = 520. Blok II : above 100 next active hours = 545
B-3/TR	above 200 kVA	28,400	Block WBP = K x 452. Block LWBP = 452
Industry			
I-1/TR	up-to 450 VA	26,000	Block-I : 0 - 30 kWh = 160. Block II : above 30 kWh = 395
I-1/TR	900 VA	31,500	Block-I : 0 - 72 kWh = 315. Block II : above 72 kWh = 405
I-1/TR	1.300 VA	31,800	Block-I : 0 - 104 kWh = 450. Block II : above 104 kWh = 460
I-1/TR	2.200 VA	32,000	Block-I : 0 - 196 kWh = 455. Block II : above 196 kWh = 460
I-1/TR	above 2.200 VA - 14 kVA	32,200	Block-I : 0 - 80 active hours = 455. Block II : above 80 next active hours = 460
I-2/TR	above 14 kVA - 200 kVA	32,500	Block WBP = K x 440. Block LWBP = 440
I-3/TR	above 200 kVA	29,500	0 - 350 active hours, Block WBP = K x 439. above 350 active hours Block WBP = 439. Block LWBP = 439
I-4/TR	30.000 kVA and above	27,000	434
Government Offices and Street Light			
P-1/TR	up-to 450 VA	20,000	575
P-1/TR	900 VA	24,600	600
P-1/TR	1.300 VA	24,600	600
P-1/TR	2.200 VA	24,600	600
P-1/TR	above 2.200 VA - 200 kVA	24,600	600
P-2/TR	above 200 kVA	23,800	Block WBP = K x 379. Block LWBP = 379
P-3/TR	-	-	635
Traction			
T/TM	above 200 kVA	23.000 **)	Block WBP = K x 360. Block LWBP = 360
Bulk			
C/TM	above 200 kVA	26,500	Block WBP = K x 390. Block LWBP = 390
Multipurpose			
M/TR/TM/TT	-	-	1.380 **)

P	=	Multiplication Factor for S3 Group; P = 1 for purely social, P=1.17 for mixed social and commercial
K	=	Ratio between WBP and LWBP in accordance to typical local load profile
WBP	=	Peak-load Time
LWBP	=	Off-peak Load Time
Active hours	=	the monthly kWh of electricity consumed divided by power connected

In order to compare the PLN tariff with the MHP tariff, the same consumption and class was analyzed for the three plants

Seloliman:

Customer Class U2 (1350 Watts) who consumes 138kWh in one month will pay:

Total Price = (40 x 180) + (60 x 203) + (38 x 225) + (0 x 248) + 11,200 + 500

Total Price = IDR 39,630

Wotlemah:

The same customer (there is just one class) who consumes 138kWh in one month will pay:

Total Price = (30 x 450) + (40 x 500) + (68 x 600) + 7,500 + 250

Total Price = IDR 82,050

We notice that the prices for Wotlemah are much higher than those for Seloliman, this is because PKM organization realized the prices in Seloliman were extremely low and the people was not making good use of the electricity, therefore they looked for a fair price when building Wotlemah plant, which they plan to keep unchanged for some time, while prices for Seloliman are being increased to reach a fair tariff. With these changes the communities are expected to become more responsible with the use of electricity.

PLN:

A similar customer (household R1)

Total Price = Power Cost + Block I + Block 2 + Block 3 + Service Fee

Total Price = Power Cost + $(P_{1\text{-}30} \times Price_{1\text{-}30}) + (P_{31\text{-}60} \times Price_{31\text{-}60}) + (P_{>60} \times Price_{>60})$ + Service Fee

Total Price = 30,200 + (20 x 390) + (40 x 445) + (58 x 495)

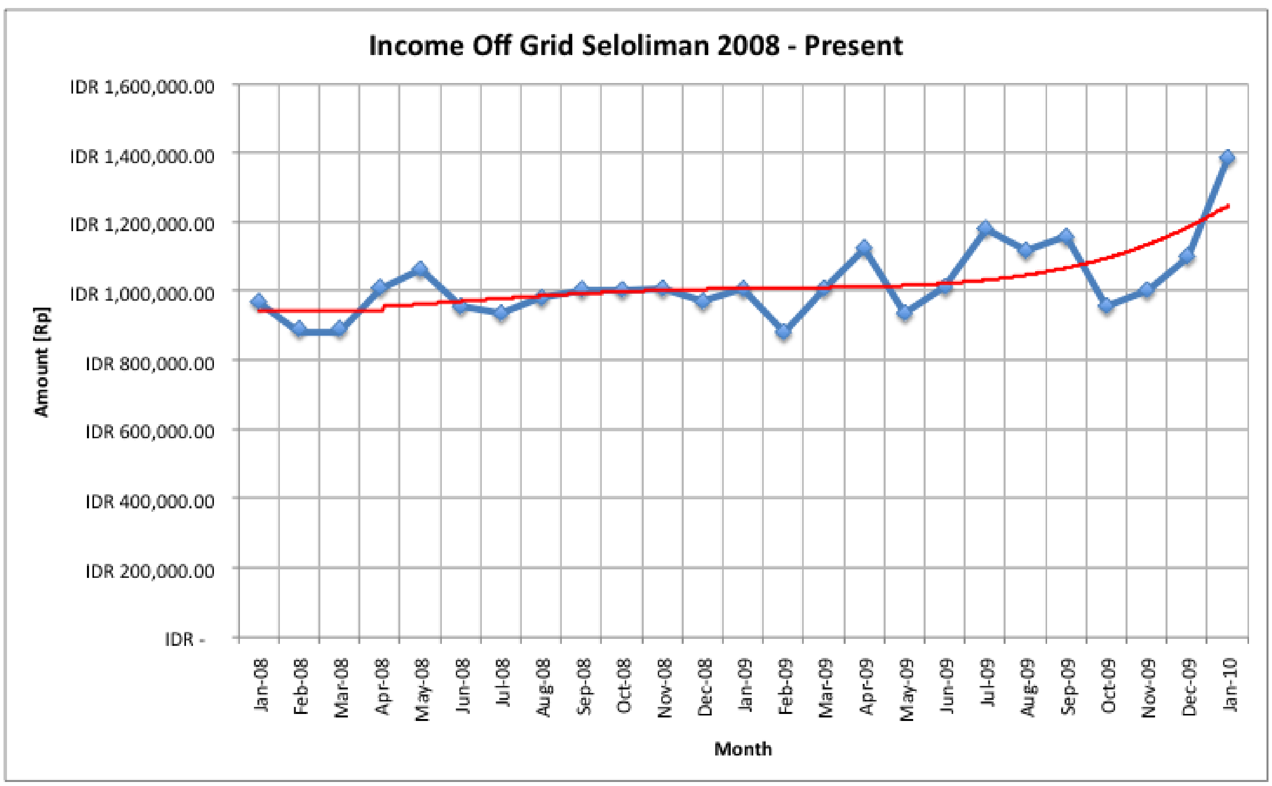
Total Price = IDR 84,510 + 84,510(.03) = IDR 87,045

Finally, we can observe that in general the electricity produced from micro hydro plants is cheaper than the one produced by the electricity company, even though is subsidized by the government (2010 is IDR 16.7 Trillion.)

An evaluation of the economic situation in Seloliman and Wotlemah micro-hydro plants was made. Thanks to the support of the plants treasurers the following data was acquired for both plants:

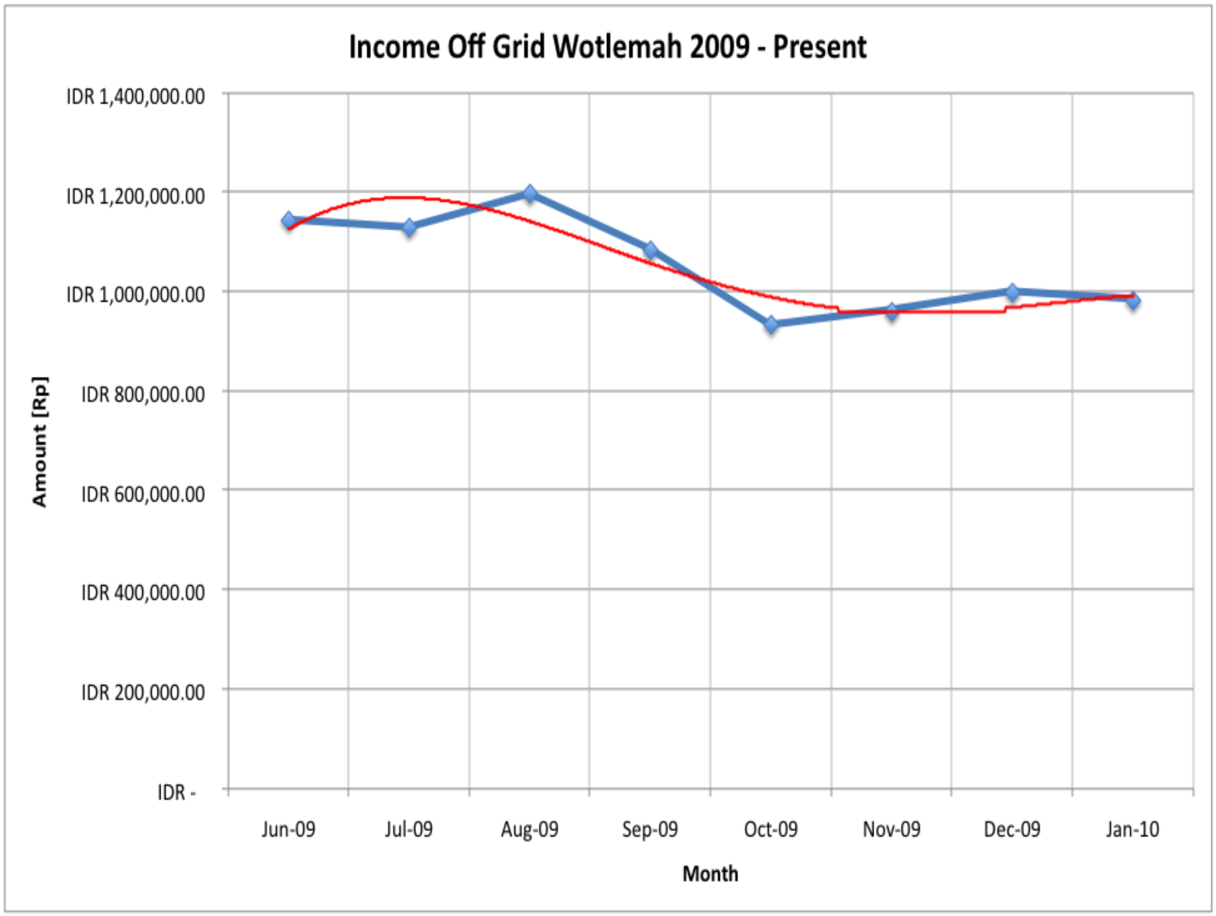
- Off Grid Income
    - Seloliman MHP
    - Wotlemah MHP
- On Grid income (both plants)
- Operational Costs
- Maintenance Costs
- Loan status.

Seloliman MHP's off grid incomes are more or less constant, with a tendency to increase in time, this may be because it's a more consolidate plant, with almost 14 years of operation. The season of the year has a small influence in the income. Over the last two years no big drops are observed, on the contrary due to the increase in tariff for 2010 we observe an increase in incomes as well



Graph 8.2. Off Grid: Seloliman's Income changes in time

For Wot Lemah plant the situation is different, as mentioned before, during the first 3 months of operation the electricity was supplied to the community for free, this may have caused an un-rational use of electricity by part of the community. When fares started to apply costumers started reducing their consumption, decreasing the plants incomes. It is expected that incomes will tend to a more stable value with time.



Graph 8.3. Off Grid: Wotlemah's Income changes in time

It is clear that the income from Seloliman plant is slightly higher than Wotlemah's, but the price per kWh for Seloliman is half the price of Wotlemah, so it can said that electricity consumption from Seloliman is much higher than that for Wot Lemah, both having a similar amount of consumers.

On the other hand, the income from the power supplied to the Grid (from both plants), is directly influenced by the electricity consumption from the off grid customers (extra power is supplied to the grid) and also by problems such as grid network connection break downs.

The On grid income is calculated as follows

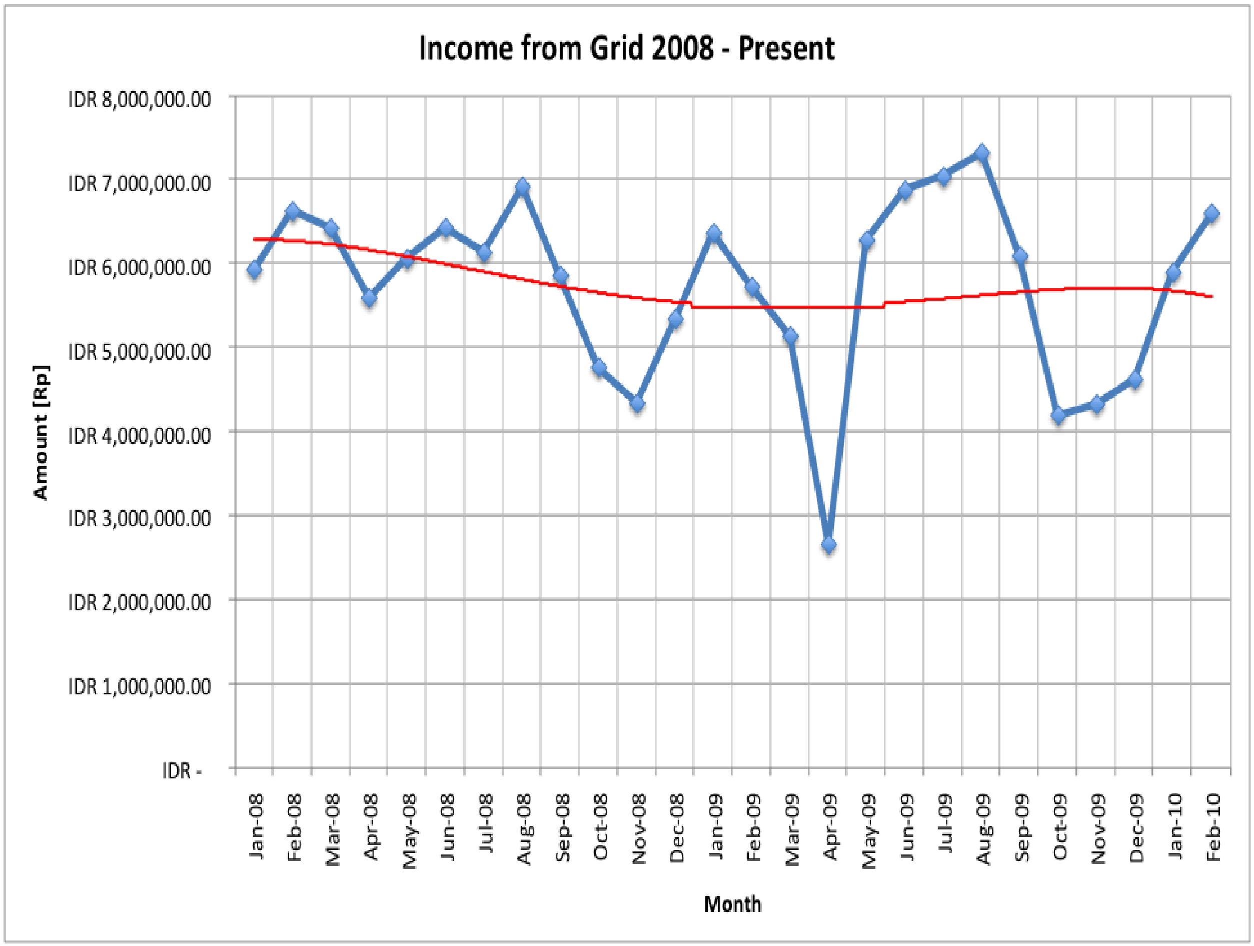
$$Total\ Price = P_{consumed} * Const * Tariff$$

Where

Const = 9.6 (value agreed by the electricity company and PKM)

Tariff = IDR 533 (fixed independent of the power consumption)

The **on grid** incomes from the last 2 years are shown in Graph 7.4.

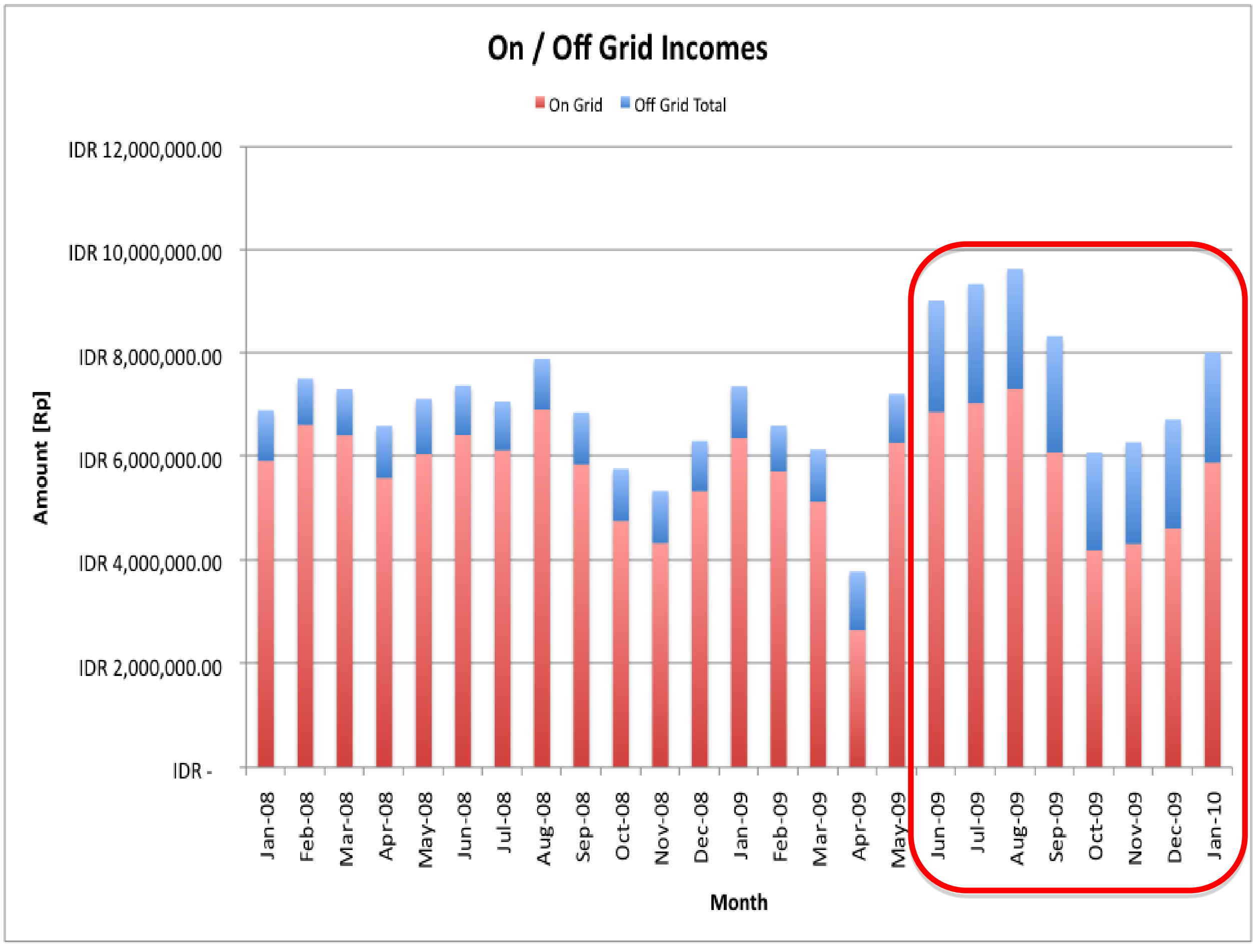


Graph 8.4. On Grid Income changes in time

A stable behavior is observed, with an average income of approximately IDR 6,000,000.00 per month, which makes on grid incomes their major profit.

In Graph 7.5. we can see the on-grid and off-grid incomes together. Since June 2009 (after the three free months of Wot Lemah) the off grid incomes have increased, but the on grid incomes have stayed more or less the same.

Currently around 28% of the incomes come from the off grid network (Seloliman and Wotlemah) and the rest from the on grid, perceiving in average (since June 2009) IDR 7,958,946.28 per month.



Graph 8.5. PKM Total income (On/Off grid).

By now we have only mentioned the incomes of the organization, but PKM has expenses as well, this in order to run Seloliman and Wotlemah Plants as best as possible. These expenses include:

Investment costs – include the loan that PKM is still paying to PLN for Wotlemah Plant. Seloliman MHP plant has no debt.

Table 8.4. shows the complete investment for Wotlemah MHP construction and the different organisms involved.

Table 8.4. Total investment cost Wotlemah MHP

Investment Cost WotLemah		
From the Communities	IDR	75,000,000
Pemkab (local governm	IDR	50,000,000
Loan from PLN	IDR	100,000,000
GEF	IDR	225,000,000
Total	**IDR**	**450,000,000**

The only debt for PKM organization is the loan of IDR 100,000,000.00 from PLN with a fix interest of the 16%, which means at the end they will have to pay IDR 116,000,000.00; the first payment was done in January 2008 and it will be completely paid at the end of 2012.

Table 8.5. Total debt Wotlemah MHP.

Loan from PLN for Wotlemah	
Loan	IDR 100,000,000.00
Total Debt	IDR 116,000,000.00
Paid at end 2009	IDR 48,000,000.00
Paid per year	IDR 24,000,000.00
Debt left	**IDR 68,000,000.00**

Operational costs – include the salary of all employees in both plants.

Table 8.6. shows the value and salary per month and year. The increase in salaries is not regulated, since Seloliman plant was created the salaries for its workers have increased 2 times.

Table 8.6. Seloliman and Wotlemah MHP operational costs.

Position	Person in Charge	Salary per month	Salary per year	Salary 2008	Salary 2009
Badan Pengurus - Caretaker Agency					
Chief	H Achmad Suroso a.k.a Cak Su				
Secretary	Mochamad Choirul Anam a.k.a Cak Beken				
Treasurer	Wijayanti a.k.a Jay				
Staff 1	Sukadi				
Staff 2	Wagimin				
Pelaksana harian					
Chief	Bambang Suwarno a.k.a Om Ndut	IDR 475,000.00	IDR 5,700,000.00	IDR 5,700,000.00	IDR 5,700,000.00
MHP Seloliman					
Treasurer	Achmad Maksum a.k.a Cak Mad	IDR 300,000.00	IDR 3,600,000.00	IDR 3,600,000.00	IDR 3,600,000.00
Operator	Abdul Manan a.k.a Si Doel	IDR 375,000.00	IDR 4,500,000.00	IDR 4,500,000.00	IDR 4,500,000.00
MHP Wot Lemah					
Treasurer	Rochmadi a.k.a Cak Di	IDR 250,000.00	IDR 3,000,000.00	IDR 0.00	IDR 1,750,000.00
Operator	Mulyono a.k.a Cak Mul	IDR 250,000.00	IDR 3,000,000.00	IDR 0.00	IDR 1,750,000.00
Total			**IDR 19,800,000.00**	**IDR 13,800,000.00**	**IDR 17,300,000.00**

*it must be considered that Wotlemah plant has not been working a complete year yet, therefore for the 2008 and 2009 economic analysis present at the end of this section the total of operational cost use may change.

Maintenance Costs – include all expenses for maintenance of the plant.

These are different for Seloliman and Wotlemah, as shown in Tables 8.7. and 8.8. If the plants are well maintained the costs will not increase too much in the following years.

Table 8.7. Seloliman MHP maintenance costs

Maintenance Seloliman mhp		Hour Operated Frequency	Condition	Amount [gr]	Cost [IDR]	Cost per year
Method	Object					
Grease	Turbine Bearing	2000		32	IDR 3,876.65	IDR 16,979.74
	Turbin Valve	2000		32	IDR 3,876.65	IDR 16,979.74
	Generator Bearing	2000		32	IDR 3,876.65	IDR 16,979.74
	Plummer Block Bearing	2000		32	IDR 3,876.65	IDR 16,979.74
Change Parts	Plummer Block Bearing	26280		1	IDR 1800000 every 3 years	IDR 600,000.00
	Flat Belt	43800		1	IDR 750000 every 5 years	IDR 150,000.00
Cleaning	Intake		Dirty		IDR -	IDR -
	Filter		Dirty		IDR -	IDR -
	Channel		Dirty		IDR -	IDR -
	Ballast Tank		Dirty		IDR -	IDR -
Total Cost per year						**IDR 817,918.94**

Table 8.8. Wotlemah MHP maintenance costs.

Maintenance Wotlemah mhp		Hour Operated Frequency	Condition	Amount	Cost	Cost per year
Method	Object					
Grease Give	Turbine Bearing	170		3	IDR 363.44	IDR 18,727.65
	Turbin Valve	170		3	IDR 363.44	IDR 18,727.65
	Generator Bearing	170		3	IDR 363.44	IDR 18,727.65
Change Parts	Bearings	26280		1	IDR 1800000 per 3 years	IDR 600,000.00
	Flat Belt	43800		1	IDR 750000 per 5 years	IDR 150,000.00
Cleaning	Intake		Dirty		IDR -	IDR -
	Filter		Dirty		IDR -	IDR -
	Channel		Dirty		IDR -	IDR -
	Ballast Tank		Dirty		IDR -	IDR -
Total Cost per year						**MEX$ 806,182.95**

*In the case of Grease for the different components of the plant, a cost of IDR 55,000 per can (this is the price for 1 can of "Top 1 Grease" containing 454 grams) was considered.

Other costs – This includes the payment of IDR 4,000,000 during 20 years, starting in 2009, for two landlords (IDR 100,000 per year per landlord) who own the lands where the channel and penstock for Wot Lemah plant were built.

It also includes the irrigation agency payment (IDR 600,000.00 per year) and taxes, which are currently 14% of the profit (before 2010 taxes where only 2.5 % of the profit).

Economic Balance

The following table shows an approximation of the profit of PKM organization in 2008 and 2009, which has been conserved in order to be able to face any problem, if so, in the future and also for being capable of investing in a new plant if necessary.

It also shows an estimation of profit for 2010, assuming that the monthly incomes of PKM will be similar to those of January 2010, for both off grid and on grid income. Also, it is assumed that the maintenance cost remain the same, "other costs" are also considered.

Table 8.9 Economic Balance for Seloliman an Wotlemah MHP

BALANCE		2008		2009		2010
Income Customer Seloliman	IDR	11,695,190.00	IDR	12,498,646.00	IDR	16,646,268.00
Income Customer Wot Lemah	IDR	-	IDR	7,393,800.00	IDR	11,698,800.00
Income Grid Both	IDR	70,441,450.56	IDR	66,657,065.28	IDR	70,777,624.32
Maintenance Cost Both	IDR	806,182.95	IDR	1,624,101.89	IDR	1,624,101.89
Operational Cost Both	IDR	13,800,000.00	IDR	17,300,000.00	IDR	19,800,000.00
Debt payment (loan to PLN)	IDR	24,000,000.00	IDR	24,000,000.00	IDR	24,000,000.00
Charge for landlords (Wotlemah)	IDR	-	IDR	200,000.00	IDR	200,000.00
Charge for irrigation Agency	IDR	600,000.00	IDR	600,000.00	IDR	600,000.00
Profit	IDR	42,930,457.61	IDR	42,825,409.39	IDR	52,898,590.43
Taxes	IDR	1,073,261.44	IDR	1,070,635.23	IDR	7,405,802.66
BALANCE	**IDR**	**41,857,196.17**	**IDR**	**41,754,774.15**	**IDR**	**45,492,787.77**

We can observe that with the considerations mentioned before, the profits will increase around 8% in 2010, which is considered as good, but there are still some recommendations for a better management of the resources, and the way calculations are made.

During the collection of data some problems were faced, the books before 2006 for Seloliman plant were lost, and the ones for Wot Lemah plant were written in different sources, some by computer, others by hand, also there were some calculation errors in both plants books, also some considerations are taken, which are not explained in the books (electricity metering broken, consumption average per month charged).

9. Social and Environmental Impact

A social impact evaluation was carried out for the localities beneficed from Seloliman, Wotlemah and Sendi micro hydro plants during the 3rd week of February 2010.

The study's main objective was to identify the direct and indirect impacts of the MHP Projects in Seloliman zone.

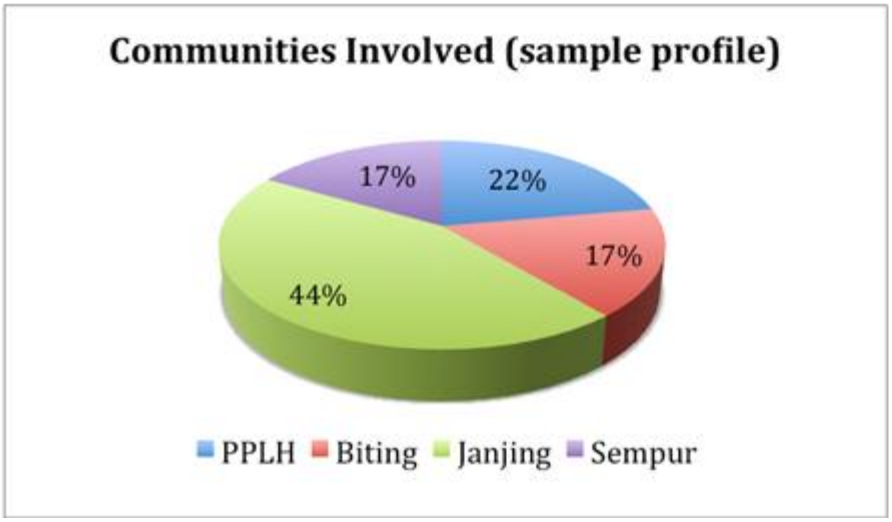
This evaluation was carried out through a quick research combining qualitative and quantitative data gathering, such as interviews and the application of sample survey questionnaires for each locality.

The beneficiaries of these MHP projects consist of people who live in "villages" or "urban settlements" located in rural areas and who also happen to have farming lands. It should also be said that the most impoverished families live in their own farms, that is, in agricultural lands.

According to the sample survey, most of the beneficed families have farmlands or are farmworkers, and a small part works for the Enviromental Center or small businesses.

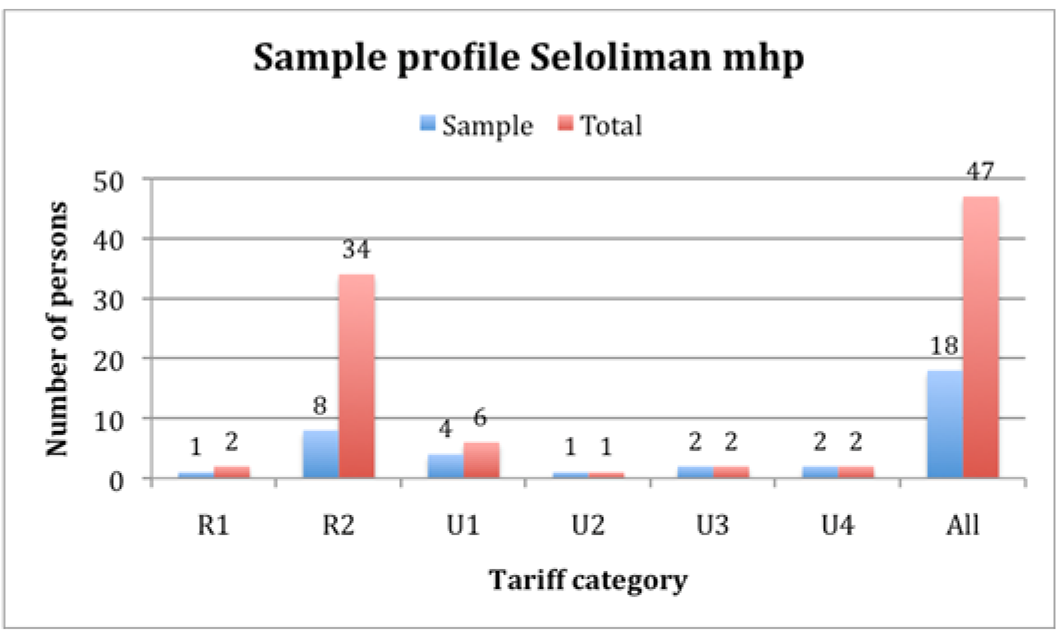
Seloliman plant was the first to be analyzed; it feeds 2 communities: Janjing and Sempur villages, PPLH (Environmental Center), 2 more business and PKM (the last two are located in Biting), this means that around 300 people are benefited with the electricity service.

From 47 customers, 18 were surveyed and the sample distribution was done as follows:



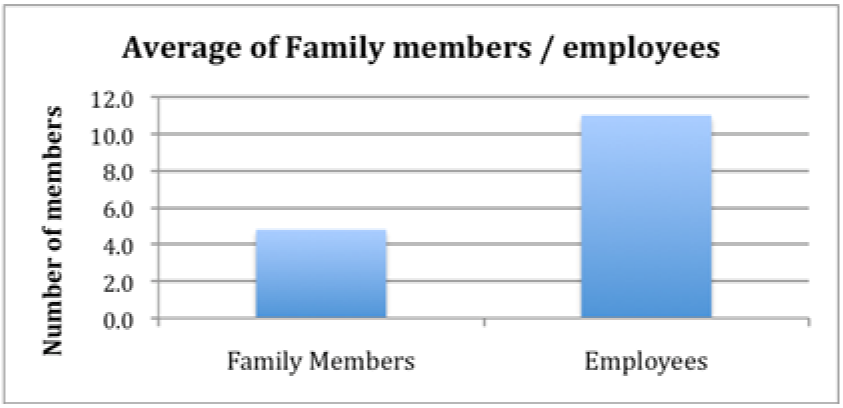
Graph 9.1. Communities fed by Seloliman MHP.

Graph 8.2. shows the sample distribution depending on the category on which they belong to (this categories depend on the load of each customer and are explained in "Cost and Economics" section), and compares the sample with the total surveyed, which was planned to cover all of the categories.



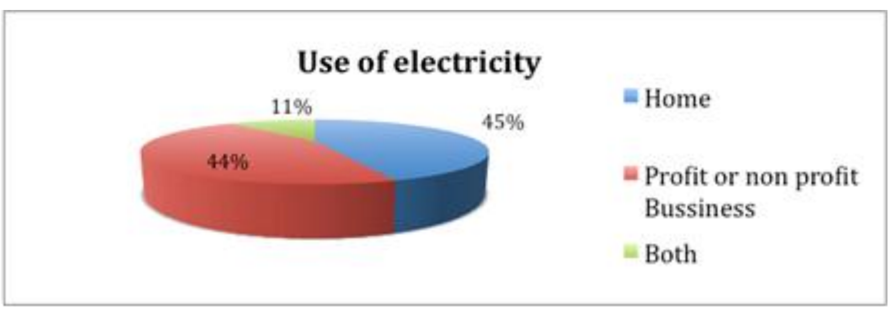
Graph 9.2. Seloliman MHP Sample profile by tariff category

In terms of composition, most families have an average of 4-5 members. And the small businesses have an average of 11 employees.



Graph 9.3. Households and Business composition in Seloliman area.

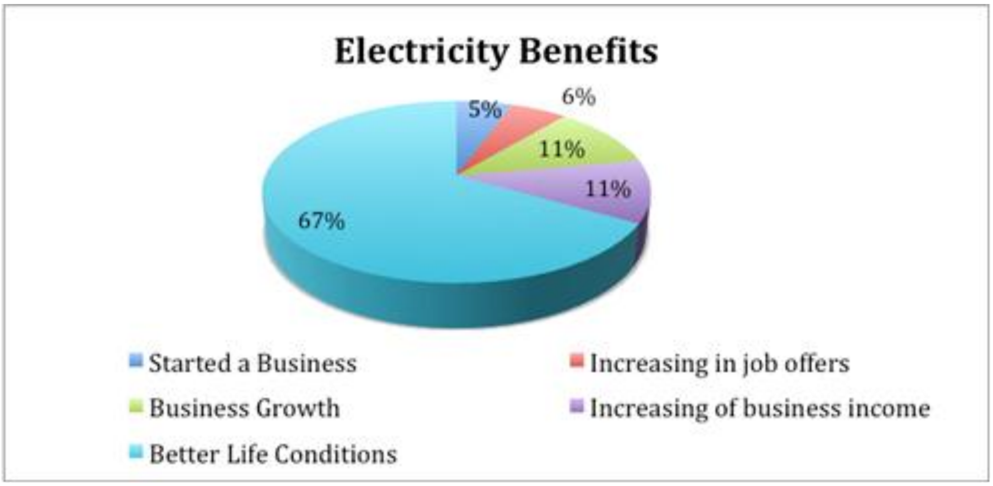
The survey shows that households with a mixed use (both, residence and business) are in the order of 11% and households that are exclusively used as homes around 45%, leaving for profit or non-profit business with 44%, but due to the intention of the survey of covering all tariff categories, where the last 3 are purely business, the result on this matter is affected.



Graph 9.4. Sample Results of Electricity use in Seloliman.

In general terms energy is predominantly used for residential or mixed purposes (when households are also used for business purposes), and only few beneficiaries use energy just for business purposes.

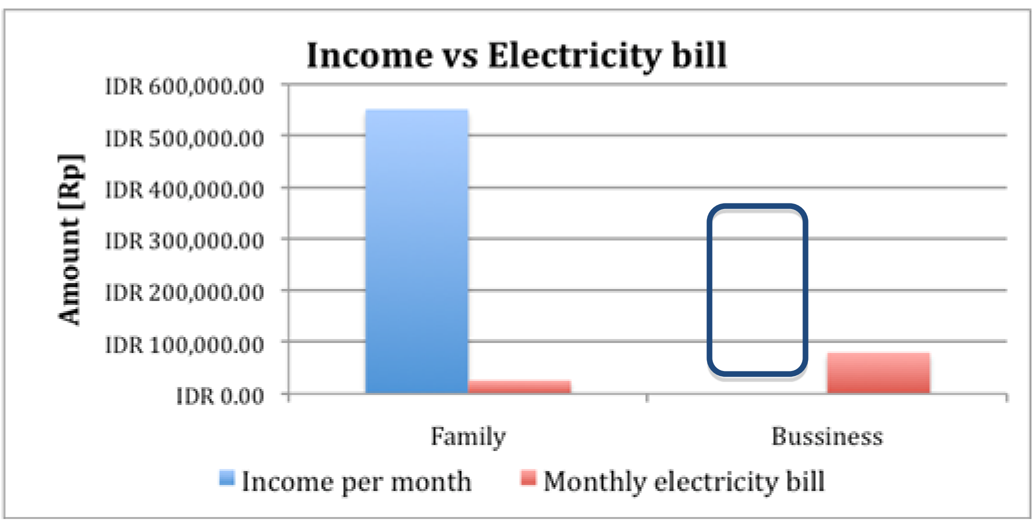
The benefits that people perceive about electricity reflect the particular utility of energy as a life style, but also as an economic driver, which impulses the growth of incomes and business opportunities.



Graph 9.5. Benefits gained after Seloliman MHP installation.

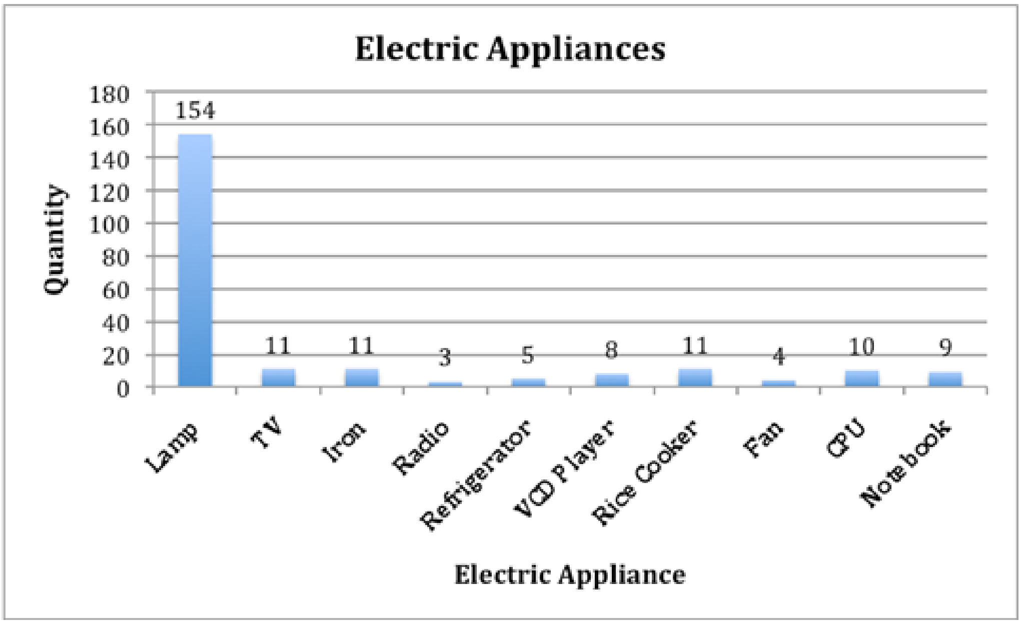
One important factor that should also be considered is the very low tariff price for off grid costumers if we compare it to their incomes. Even though the information of the average incomes from the benefited businesses was not available, we assume the tariff for the electricity is still much lower than their incomes (less than 5% of the income).

Also, the customers expressed their conformity regarding the tariff commenting the price was cheap.



Graph 9.6. Income and electricity bill comparison for Seloliman customers.

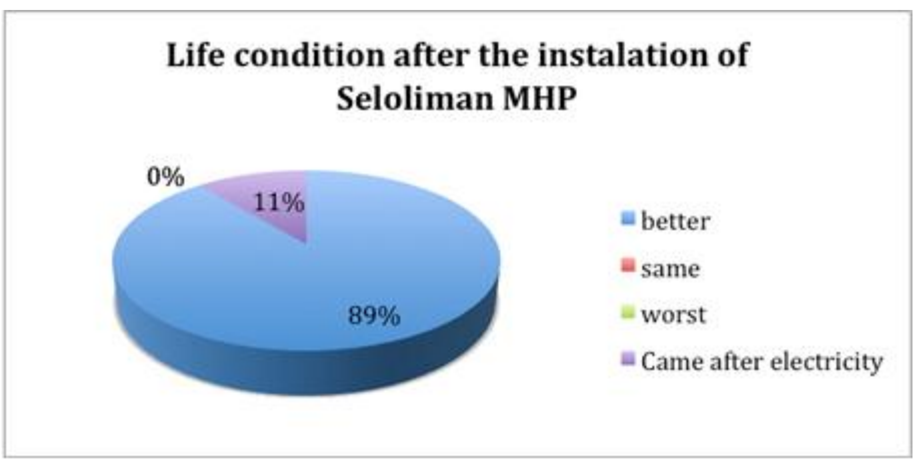
As mentioned, 67% of the sample refers to the comfort associated not only with the use of illumination, but also, of appliances such as rice cookers, irons, etc. which contribute to ease the life and generate comfort to the families.



Graph 9.7. Electric appliances most used in Seloliman.

When mentioning the benefits that electricity brings for children, different opinions emerge; some say children have benefited the most, particularly in terms of education, now they have light at home and may dedicate more time to schoolwork, on the other hand, some television entertainment, may become a big distracter for the kids.

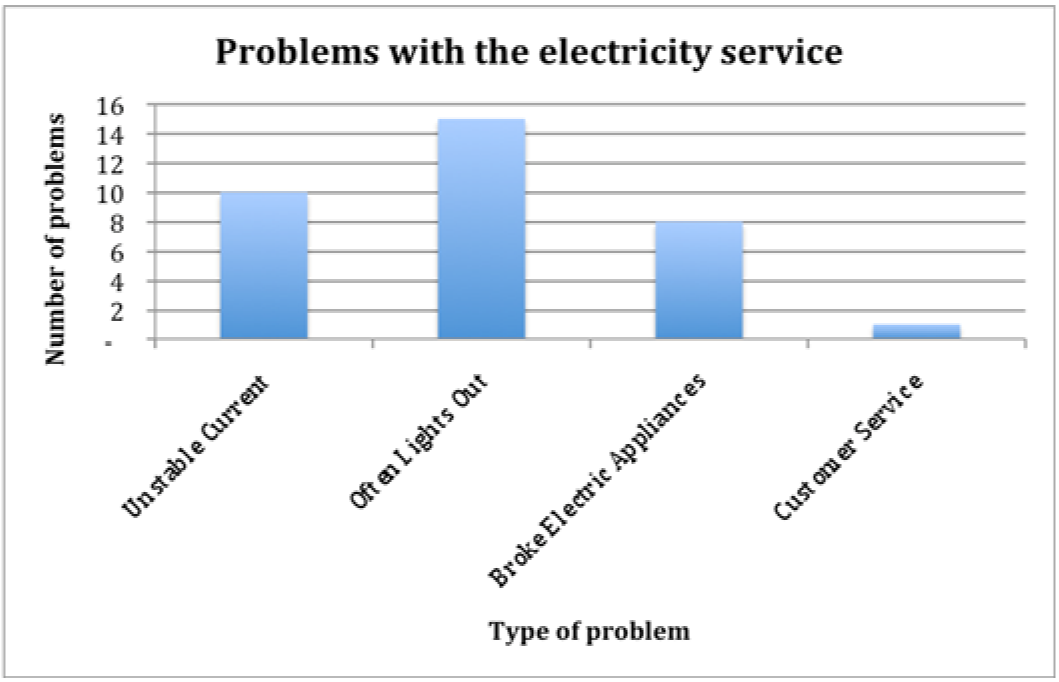
To conclude, 90% of the sample says life condition has improved after the installation of the micro hydro plant. The other 10% had no opinion about it since they arrived to the village after the MHP was installed.



Graph 9.8. Life Condition after Seloliman MHP installation.

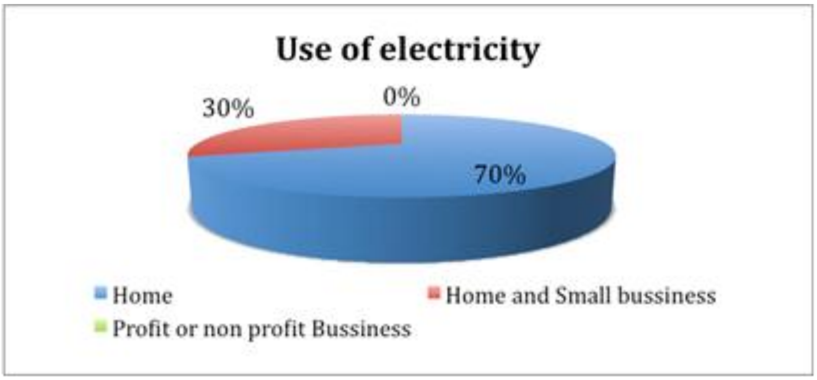
There are small problems to be solved regarding the electricity service; most of them are related with the lights out, but as presented in the "technical part of the report" the plant is working on the expected efficiency rate and lights out are mostly due to externalities.

On the other hand, continuous unstable current can cause damage to electric appliances; this is a normal problem of small scale power plants. Referring to the population surveyed, one person wasn't happy with customer service, expressing that he doesn't know who to approach for complains or general information about the services.



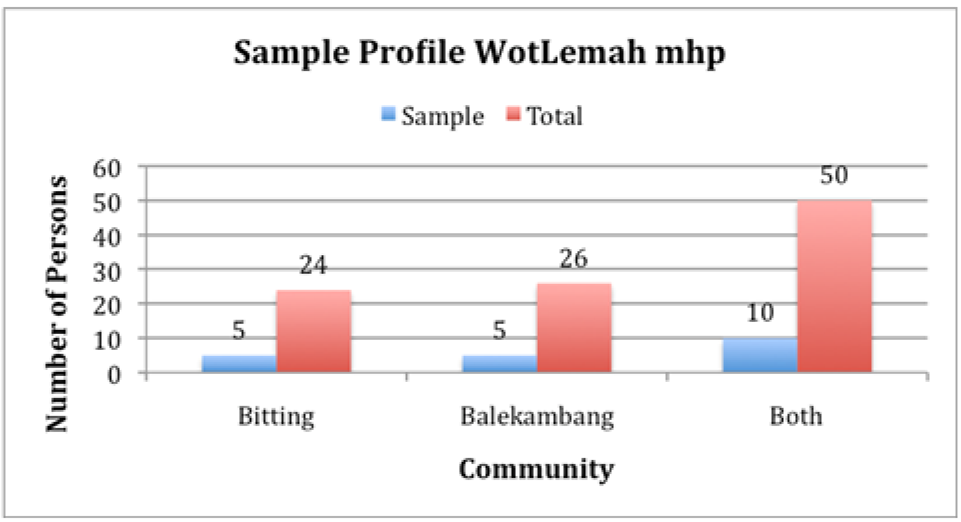
Graph 9.9. Electricity service problems with Seloliman.

Wot Lemah plant feeds 2 Communities in the same area of Seloliman, they are Bitting and Balekambang villages, with a number of customers similar to Seloliman MHP. Wot Lemah MHP supplies electricity mainly to households and family business, with 3 to 4 family members.



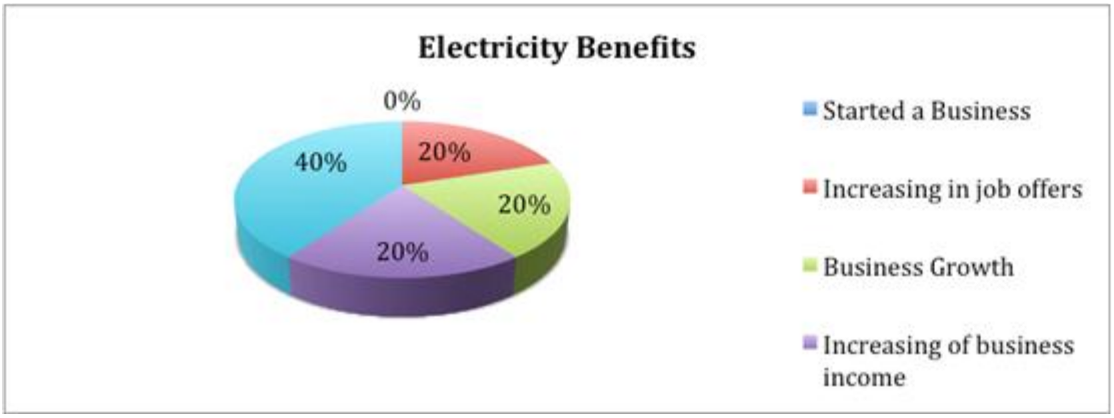
Graph 9.10. Sample Results of Electricity use Wot Lemah.

The survey was applied to 20% of the customers, and the distribution for both communities was as follows.



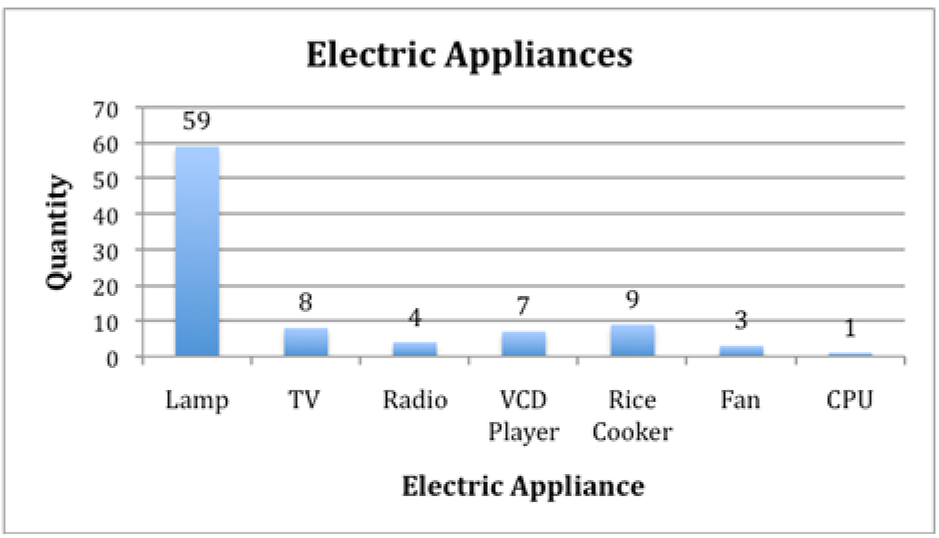
Graph 9.11. Communities fed by Wot Lemah MHP.

All of surveyed sample expressed that there has been a clear improvement in the life condition of their families, some of them have even started or have made their business grow thanks to the electricity supply, and some say job offers have increased as well.



Graph 9.12. Benefits obtained after Wot Lemah plant installation.

As in the study for Seloliman MHP, the main use of the electricity produced in Wot Lemah is used for lightning purposes, but they have also started using electric appliances, which help improve their life conditions; instead of using wood for cooking, now the rise cookers play an important role in their daily life.

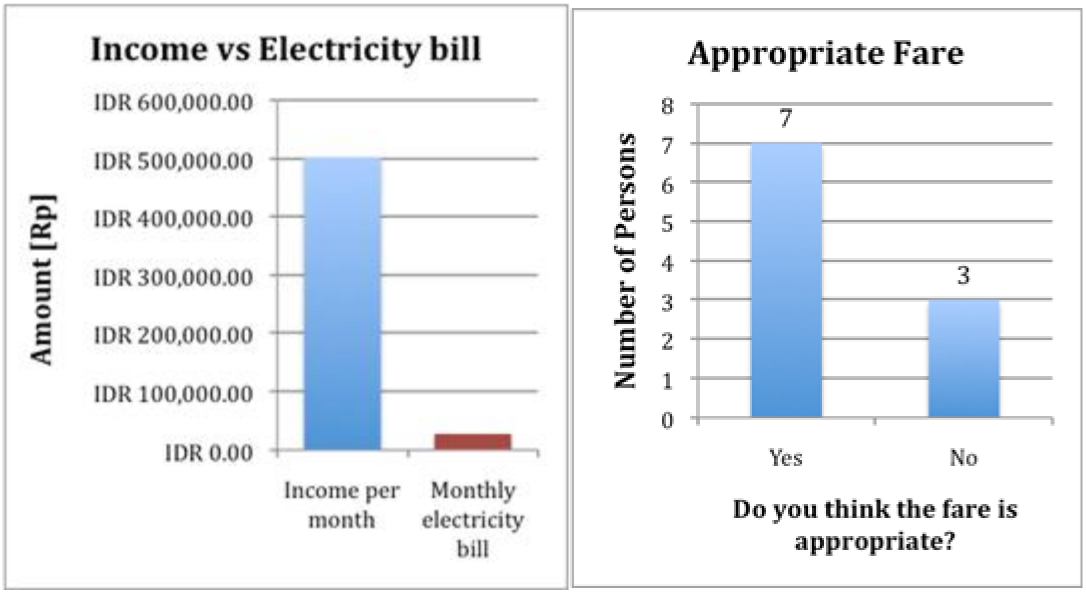


Graph 9.13. Electric appliances most used by Wot Lemah consumers.

About 90% of the lamps in Seloliman use saving bulbs, which reduce approximately in 1/5 the electricity consumption.

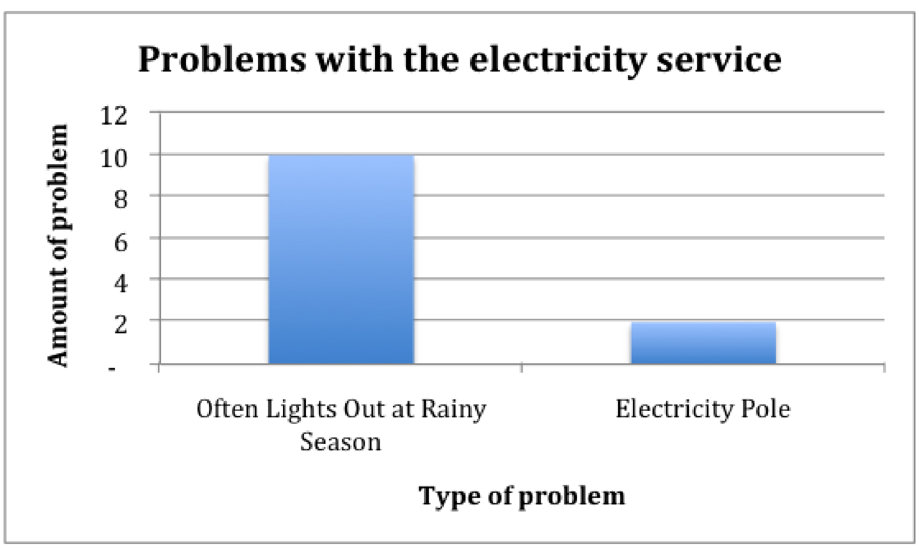
Regarding the electricity tariff, 70% of the surveyed customers expressed their conformity with the price established by PKM, but 30% think the tariff is not appropriate.

With the gathered data, a comparison between the average income per household and the electricity bill per month was made, and the results show that the electricity bill corresponds to less than 6% of the monthly income of the costumer, therefore we conclude the price is fair and the inconvenience expressed by 30% of the costumers surveyed may be caused by a lack of appreciation for the service proportioned to them. In comparison with consumers of Seloliman Plant, which all agreed in the tariff they pay, the tariff for Wot Lemah consumers is lower, and unconformities still arise.



Graph 9.14. Income and electricity bill comparison for Wot Lemah consumers.

In general terms, the communities are comfortable with the service, but in the case of Wot Lemah Plant the lights out in rainy season is a common problem, but this is caused by externalities. Other problem was an electricity pole falling down, and customer discontent about the response time of PKM to fix it.



Graph 9.15. Electricity service problems according to Wot Lemah customers.

10. SENDI PLANT

Sendi Micro Hydro-power plant is sited on Sendi village, Pacet- Mojokerto, in east Java and feeds 51 consumers; the project started in 2008 by hands of PPLH, regional government, and GEF (Global Environment Foundation), and was commissioned to Forum Perjuangan Rakyat (FPR), organization first created to solve the land dispute between the villagers and the local Forestry Department which started in the year 2000, and now in charge of the correct performance of the plant. The Sendi MHP purpose is to produce electricity for the Village, which couldn't be acquired before by on grid network or by Seloliman or Wotlemah plants, due to distance issues.

Sendi Micro Hydro Plant has a gross head of 12m and a net head of 10m. Water from irrigation is fed into an open channel, then to the intake and finally to the forebay tank. The penstock is a PVC pipe, 38cm diameter and 55m long. The turbine house situated 12 m below is a closed structure (3x3 m2) with windows for ventilation. It houses the Cross Flow T14 turbine rated at 8kW. The generator is connected to Sendi village.

Table 10.1. Sendi Micro Hydro Plant Characteristics.

Plant Characteristics	
Power	8kW
Head	12m
Net Head	10m
Design Flow	110 l/s
Spillway	Integrated with sand trap
Penstock	PVC, 55m long and diameter of 254mm
Penstock Efficiency	83% *
Power House	3X3m^2 with ventilation

*The efficiency of the penstock was calculated considering the 2m head loss.

Table 10.2. Sendi Micro Hydro Plant Components.

Mechanical and Electrical Components of the Plant	
Turbine	Cross Flow T14
Efficiency of Turbine	80%
Driver/Converter	Flat Belt
Generator Type	Asynchronous
Generator Capacity	10kVA
Generator Efficiency	90%

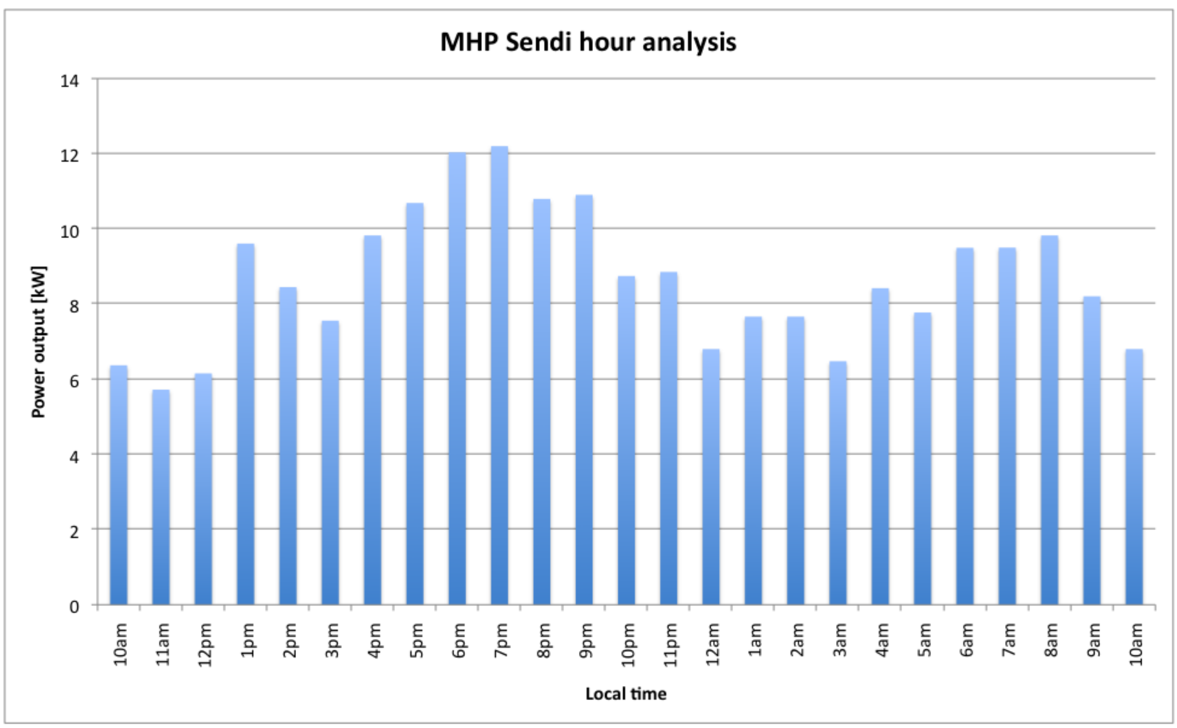
10.1 Plant Performance

For the performance evaluation of this plant a 24 hour data record was performed. The organization had no records of power performance of the plant.

The information provided by the 24 hours data is:

- Hours the plant has operated since October 2009 till now (7,007 hours)
- Frequency (50Hz)
- Voltage (about 220V)
- Power to the grid and the village at day and at night [kW]

Unlike the other plants, Sendi MHP only provides electricity to the community, during the morning most of the villagers work out of their houses, mainly in farms, children attend school, so it's mostly housewives and small children who stay at home, decreasing electricity consumption during this time. The electricity consumption for the village doubles its value in the afternoon, when the workers and children return home. The power output to the village sometimes surpasses the plants' limitation (at 2 and 3 pm).



Graph 10.1. Electricity to the village per hour

Sendi plant plays an important role in the growth of Sendi village. Based on the 24 hour record, the plant generates in average 8.8kW. If we compare this to the 8kW capacity of the plant it can be said that this plant works over its limit, mostly during hours of high load, which is when the operator decides to open the valve completely, causing the plant to work its limits. On the long term, the lifetime of the plant will be affected by this incorrect use, it has been less than a year since the plant started operating and we can already see damages in civil works of the plant.

Image 10.1. Sendi MHP plant. We can observe a hole in the floor, near the generator (orange).

Since the grid doesn't reach Sendi, consumers only rely on the Micro-Hydro Plant for electricity, and can't expect to have electricity 100% of the time. Since all power generating plants need to shut down now or then due to maintenance, or situations in general, this plant has operated only 7,007 hours since February 2009, comparing this with the real time that has elapsed since then (9,504 hours) we obtain the availability and capacity factor for Sendi plant,

$$AF = \frac{7007[h]}{9504[h]} * 100\% = 74\%$$

$$CF = \frac{7007[h] * 8.8[kW]}{9504[h] * 8[kW]} * 100\% = 81\%$$

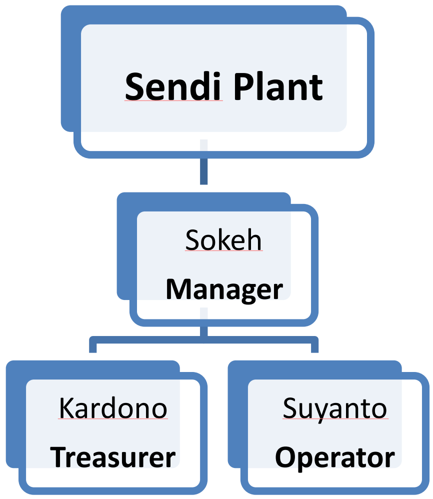
The efficiency of the plant according to the plants manual is:

$$Efficiency = (0.83)(0.80)(0.90) * 100\% = 60\%$$

$$Efficiency = \frac{8{,}000[W]}{1000[k/m^3] * 9.81[m/s^2] * 12[m] * 0.110[m^3/s]} * 100\% = 62\%$$

11. PLANT MANAGEMENT

FPR "Forum Perjuangan Rakyat" Sendi, is the cooperative responsible of the management of Sendi micro-hydro plant and is organized as follows:



The responsibilities of FPR Micro-Hydro Plant members are:

Manager – Staff leader, who is responsible of the coordination of employees and the correct management of Sendi Micro-Hydro Plant.

Main activities:

- Organize activities
- Public relations
- Negotiations when needed
- Meeting leader
- Admonitions
- Authorize documents
- Responsible of anything that happens to the organization

Treasurer – Responsible of the correct and transparent administration of the micro hydro plant's incomes and outcomes.

Main activities:

- Keep the organization's money safe
- Monthly record of incomes
- Manage the savings
- Report of the accountancy of the plant, monthly and annual

Operator – Responsible of the manual operation of the plant.

Main activities:

- Run and operate the plant
- Give maintenance to the plant
- Secure the plant
- Consider the plant as his first priority

The FPR members don't receive any salary for their work, the only person receiving a payment is the plant operator.

12. COSTS AND ECONOMICS

Sendi MHP project was constructed thanks to the investment of different organizations, with a total cost of IDR 357,000,000.

Table 12.1 Total investment cost Sendi MHP

Investment Cost for Sendi MHP	
From the Villagers	IDR 44,000,000
Local Government	IDR 17,000,000
PPLH	IDR 296,000,000
Total	IDR 357,000,000

The FPR "Forum Perjuangan Rakyat" organization was responsible of establishing the electricity tariff for the customers.

Currently, the tariff for the customers is classified depending on the customer's appliances (not on the electricity consumption), and has been fixed as follows:

Table 12.2. Sendi Electricity Tariff.

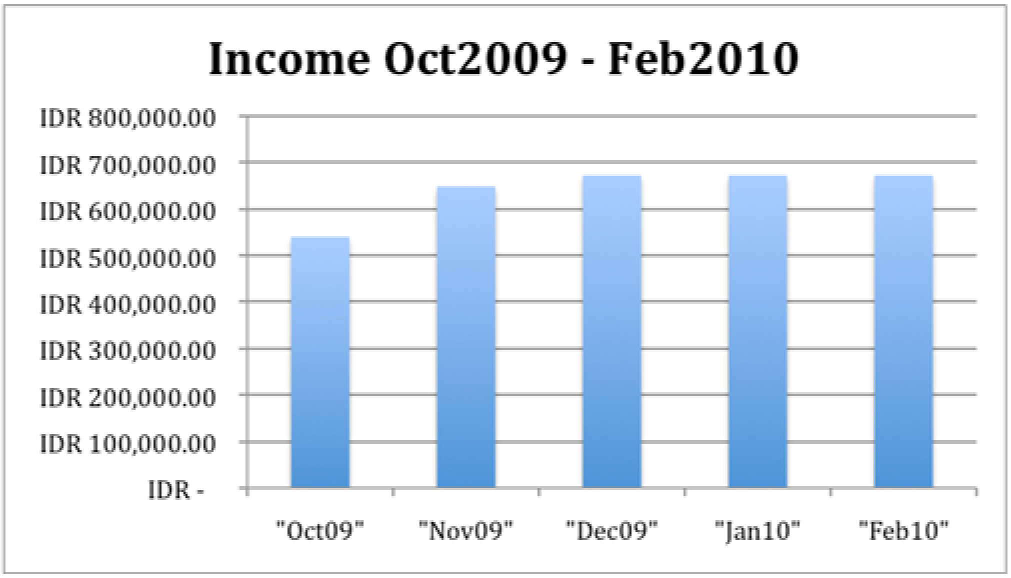
Appliances	Price
Lamp (per watt)	IDR 100
Television	IDR 5,000
VCD Player	IDR 2,500
Iron	IDR 2,000
Game Console	IDR 2,500
Blender	IDR 2,500
Rice Warmer	IDR 2,500
Rice Cooker	IDR 5,000
Refrigerator	IDR 5,000

In average each customer pays monthly IDR 18.500.00 plus IDR 5,000.00 administration fee in Sendi plant. This is very cheap compare to the other mhp plants and specially to the PLN tariff mentioned before.

An evaluation of the economic situation in Sendi micro-hydro plant was performed, for this purpose all data available was collected with the support of the treasurer, such as:

- Off Grid Income
- Operational Costs
- Maintenance Costs

Income for Sendi MHP is only from off grid service, and has no significant variation during the year. The first 5 months of service were for free, but in October 2009 the fare was fixed for each customer to IDR 20,000.00 per month, this changed in November 2009, when FPR started the tariff regulation mentioned before, increasing the incomes of the plant.



Graph 12.1 Income from Sendi village

Operational costs – only include the salary of one plant employee.

The salary per month and year of the employee is shown next (Sendi plant has not been working for a complete year yet).

Table 12.3 Sendi MHP operational cost

Position	Person in charge	Salary per month	Salary per year
Manager	Sokeh	IDR 0.00	IDR 0.00
Treasurer	Kardono	IDR 0.00	IDR 0.00
Operator	Suyanto	IDR 100,000.00	IDR 1,200,000.00
Total			IDR 1,200,000.00

in order to keep the plant working appropriately, maintenance is very important, and some expenses are made in order to fulfill this.

Maintenance Costs – includes all the expenses made in order to maintain the plant.

For this matter, a maintenance manual was developed; but it is not being followed properly. Table # shows the maintenance plan according to the manual. It is important to mention that if the plant is taken care of, expenses will not increase much in the next years.

Table 12.4 Sendi MHP maintenance costs by manual.

Facility and component	Check list	Action	Frequency
Intake, penstock, and tailrace	Leakage	Keep the log and fix it	6 months
	Structure deformation	Keep the log and fix it	6 months
Turbine	Axis	Give grease	6 months
		Check and change it if necessary	3 years
	Screw	Check and fix it if necessary	1 year
Generator	Axis	Clean and give grease	6 months
		Check and change it if necessary	3 years
	Winding isolation	Check and change generator if necessary	6 months
	Screw	Check and fix it if necessary	1 year
	Belt	Check and change it if necessary	6 months
Ballast stabilizer	Ballast stabilizer	Check it	6 months
	Heater	Check and change it if necessary	6 months
Valve inlet	Valve inlet leakage	Check and change it if there's a leakage	1 year
Transformer	Fluid leakage	Check and change it if there's a leakage	1 month
Transmission and distribution	Nearest branch	Check and cut it if necessary	1 month
	IDR 334,052.51		

*In the case of Grease for the different components of the plant, a cost of IDR 55,000 per can (this is the price for 1 can of "Top 1 Grease" containing 454 grams) was considered.

In reality, the maintenance is only done by giving grease to the plumber block every week so they spent about IDR 15,506.60 per month (IDR 186,079.02 per year), compared to the maintenance stated by the manual just for giving grease they should spend IDR 34,052.51 per year (on grease).

Economic Balance

The following table shows an approximation of the profit of FPR organization since October 2009 until February 2010, this profit will be used whenever problems occur.

Table 12.5 Sendi MHP profit

Balance	"Oct 09"	"Nov 09"	"Dec 09"	"Jan10"	"Feb10"	Total
Income from customer	IDR 540,000.00	IDR 648,500.00	IDR 672,100.00	IDR 672,100.00	IDR 672,100.00	IDR 3,204,800.00
Operational Cost		IDR 100,000.00	IDR 100,000.00	IDR 100,000.00	IDR 100,000.00	IDR 400,000.00
Maintenance Cost	IDR 15,506.60	IDR 15,506.60	IDR 15,506.60	IDR 15,506.60	IDR 15,506.60	IDR 77,533.00
Profit						IDR 2,727,267.00

During the data collection some problems were faced, the computer which stored the data was broken and no one ever backed up the data, so we had to take the data storage and open it on other computer.

13. Social and Environmental Impact

Micro hydro development itself was since long, desire of the villagers; therefore before this project was harnessed another attempt was done to produce electricity, it was a handmade micro hydro plant, which did not succeed. After that, in 2009, PPLH Seloliman volunteered to help build Sendi's MHP.

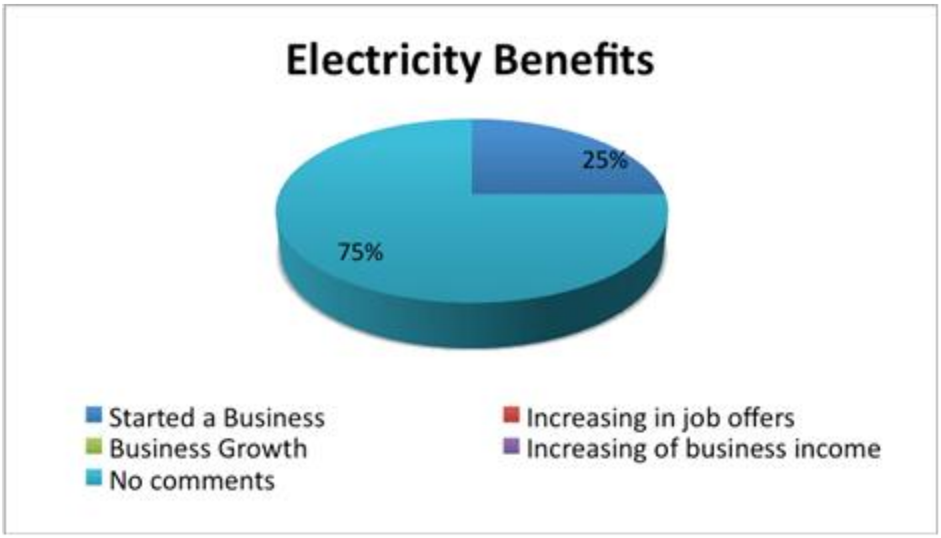
Sendi community is very united; they get together every Friday and work on social problems, such as collecting garbage from the nearby forest, etc.

Sendi Village is mainly formed by farm workers, which sometimes also have small businesses like Coffee shops, small restaurants or goat and cattle rising.

As stated in previous analysis for Seloliman and Wotlemah plant, the data for this study was gathered by applying a survey to the community and some interviews with local people. The results are explained next.

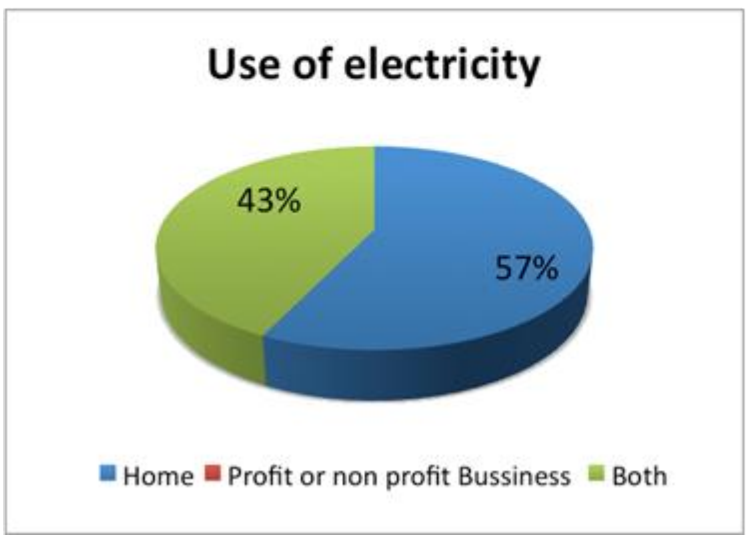
Most of the people expressed their gratitude about having electricity and all of them said the life condition has improved after the installation of Sendi MHP, and consider that the fare is cheap.

Since Sendi's MHP installation new businesses have been created and the job offer has increased, which indicates an economy growth for the community.



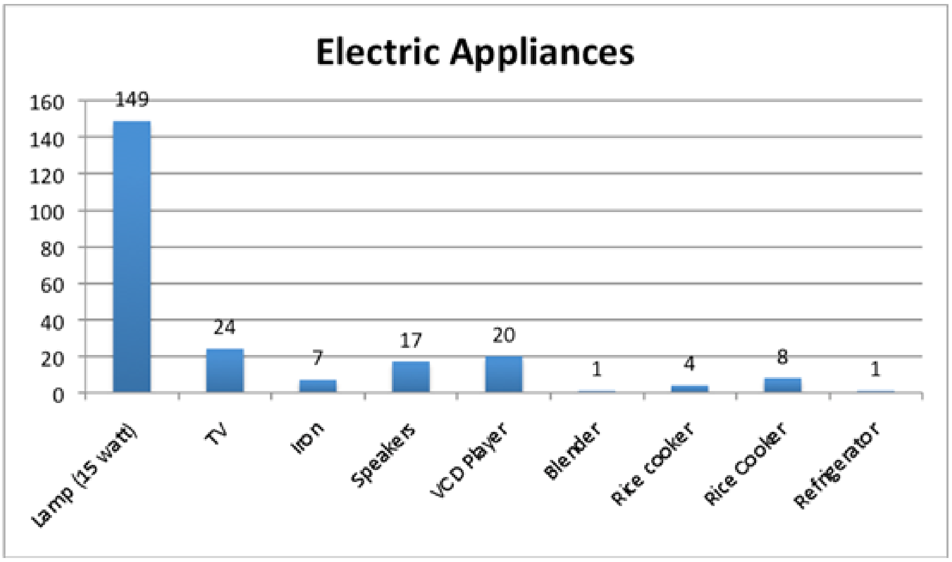
Graph 13.1. Electricity Benefits

More than a half of the customers surveyed use electricity only at home, and the rest on both home and small business.



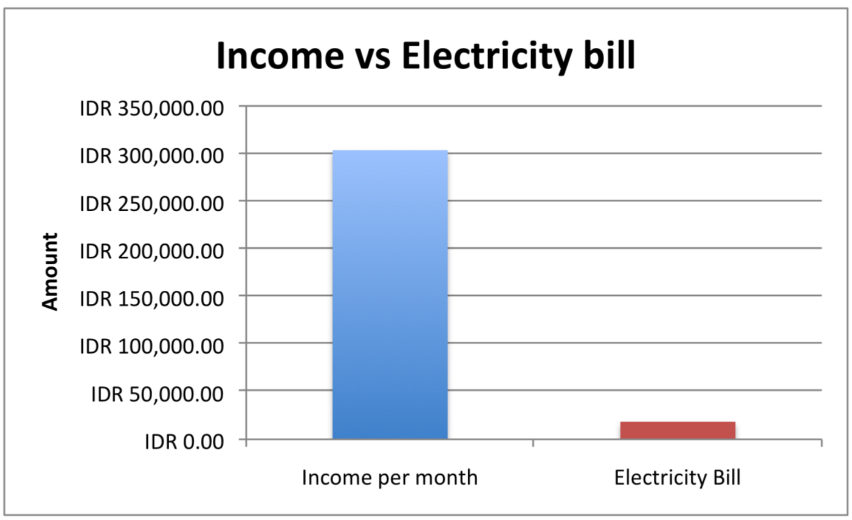
Graph 13.2. Use of electricity

The main use perceived has been lighting houses, which is shown by the big amount of lamps in the village, from which only 50% use saving bulbs; the people also commented that before the plant was built, the community was completely dark early in the afternoon. Other appliances are also used; half of the customers have a television at home, which they consider important as an information source.



Graph 13.3. Electric Appliances

Regarding the price tariff for the electricity service, the price is considered fair (it is around 6% of the income of the customer).



Graph 13.4. Electric Appliances

The problems mentioned by the customer were the increment of lights out during the rainy season, due to the garbage and rocks falling into the channel or coming from the river of Welirang Mountain forest and the need to manually restart the plant (the operator must open the valve around 5pm to satisfy the power need) when there is an overload.

Finally the people expressed their worry about the increase of households in Sendi, and the fact that the plant would not be able to handle bigger loads.

14. SUGGESTIONS

After analyzing the data gathered for Seloliman, Wotlemah and Sendi micro hydro plants, some recommendations, for a better performance of the plants, are presented next:

- As shown in the report, a daily record of the important parameters of a MHP system is very useful when analyzing its performance. We recommend for the three plants the use of a Logbook, taking as a model the one for Seloliman but with slight changes:
    - The total power should be also record at night (7pm)
    - The comments should be written in the same table. And when a problem appears should be described in more detail.

Time	Hour	Frecuency	Voltage	Current			Power [kW]				Power [kW]		Power Factor	Comments
				R	S	T	Grid		Vill		Total			
[days]	#	[Hz]	[V]	[A]			Day	Night	Day	Night	Day	Night		

- The Log Book should be always located in the same place, which should be safe from floods and easy to reach if necessary.
- A Monthly back up of the Logbook in the computer would be very useful for further studies and in case the logbook were lost.
- The data should be gathered every day at the same time (7 am and 7pm) in order to ease the analysis when comparing different dates. Therefore we recommend the operators to have a fix schedule, which also would help to know when and where to find the operator when needed.
- All new operators must be trained in order to reduce human errors.
- Each member of the plant should know its responsibilities and follow them.
- The maintenance manual should be followed in order to extend the lifetime of the plants.
- Regarding the administration of the incomes, a monthly record of each plant is also performed, we suggest to record not only incomes but also every expense to facilitate the economic balance at the end of the month and when calculating the profit each year. A monthly back up of the incomes and expenses will facilitate the calculations and reduce errors.
- In order to improve the customer service it would be useful to inform the communities, which are the responsibilities of each member of the organization and to whom they should approach for problems or concerns.
- Each plant has its own maximum power specifications, which should not be exceeded but sometimes they are, when opening the water valve too much; therefore we recommend to run a test, recording the output power values at different valve positions in order to know more precisely which is the correct position for different situations.
- In Seloliman plant, one of the main problems is the lights out due to garbage stocked in the filter. We suggest implementing a small filter before the intake, which would be easily clean without shutting the plant down as it works for Sendi plant, with an inclination in order to increase the area for catching the area.

- Wotlemah's ELC panel is different from the one use in Seloliman, in this case the total power output is not automatically shown, the operator must calculate it by adding the on and off grid power consumed. A mistake was found in the off grid power calculation, the correct formula is:

  $$P_{out} = \sqrt{3} \times V \times I \times PF$$
- The access to Wotlemah plant is considered dangerous, if it rains the stairs' floor gets slippery; we recommend placing a small fence there to avoid possible accidents.
- Sendi Plant is working a considerable part of the time over its power generation limits, knowing the correct position for opening the valve is just the first step to solve the problem, the community should also be aware that the load in peak hours is over passing the limits of the plant and will shorten its lifetime. It is responsibility of the organization to inform the villagers about the risks and how to manage their appliances on a responsible way:
  - Do not turn on many electric appliances at the same time
  - Turn off the lights you are not using.
  - Replace regular light bulbs with compact fluorescents.
- Sendi Plant should not admit any more customers, it has already over passed the load it can supply, unless its capacity is increased.
- Due to the lack of electricity metering in Sendi's households, the tariff calculation depends only on the number of appliances, this list should be updated regularly.
- There is some damage civil work in Sendi's floor which should be repaired before it gets bigger and cause other things to fail.
-

15. CONCLUSIONS

The geographical and climatological conditions in Seloliman make Micro Hydro a feasible way for obtaining electricity. It is located in a mountainous region, surrounded by a dense tropical forest, where great amounts of rain are present most part of the year.

It is also worth mentioning that small-scale hydropower is one of the most cost effective and reliable energy technologies to be considered for providing clean electricity.

Its advantages over wind and solar are

- A high efficiency (60-90%), the best of all energy technologies.
- A high capacity factor (typically > 50%), compared with 10% for solar and 30% for wind.
- High level of predictability, varying with annual rainfall patterns.
- Slow rate of change; the output varies only gradually from day to day.
- It is a long lasting and robust technology, systems can be engineered to last for 50 years or more.

In this region, other reasons for harnessing hydropower are

- Due to the abundant rains it is cloudy most part of the day during rainy season (7 months a year), not advantageous for PV.

- Humid conditions are not favorable for some PV cells.
- Wind conditions in this site are not optimal (mountains and trees reduce wind speeds).

Biomass on the other hand could have some potential; further studies can be made to determine the viability of this option.

Finally it is worth mentioning that the three evaluated plants have an enormous beneficial impact on society, most of the consumers are grateful for the service, which has improved their life conditions in many ways (more jobs, better education, entertainment, etc.), and for this reason it is important to keep the plants working as good as new.

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