ENDEV INDONESIA

Survey on Key Performance Indicators for Indonesian Micro-hydro Power Sites

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Compiled for:
Energising Development (EnDev) Indonesia

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Abbreviations

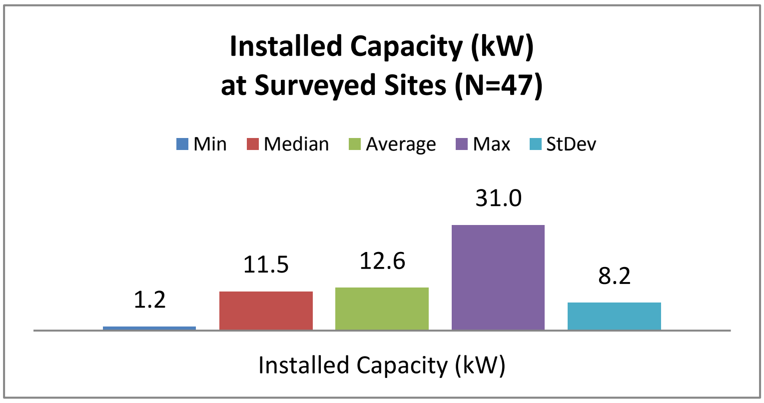
AF	Availability Factor
CF	Capacity Factor
EnDev	Energising Development; a Dutch-German Energy Partnership to promote sustainable access to modern energy services in developing countries
GIZ	Gesellschaft für Internationale Zusammenarbeit
HH	Household
IDR	Indonesian Rupiah (1 USD = IDR 9,633 on 14/11/2012)
KPI	Key Performance Indicators
kW	Kilo Watt
kWh	Kilo Watt hour
MHP	Mini/micro Hydro Power
MHPP[2]	Mini Hydro Power Project for Capacity Development
MEMR	Ministry of Energy and Mineral Resources
NGO	Non-Governmental Organization
NREEC	Directorate General for New and Renewable Energy and Energy Conservation
PLN	Perusahaan Listrik Negara, the Indonesian National Utility Company
PMD	Directorate General for Community and Village Empowerment (Direktorat Jenderal Pemberdayaan Masyarakat Desa)
PNPM	National Programme for Community Empowerment (Program Nasional Pemberdayaan Masyarakat)
PUE	Productive use of energy
RE	Renewable Energy
SI	Social Institution
TSU	Technical Support Unit
VMC	Village Management Team

1. Executive Summary

In September 2012, Energising Development (EnDev) Indonesia launched a Key Performance Indicator (KPI) survey amongst 47 micro-hydro power (MHP) sites in Sulawesi and Sumatera. KPIs are a set of information that provides an indication of a MHP's performance and subsequent sustainability. The MHP sites surveyed have received substantial technical support through the MHP Technical Support Unit (TSU) from 2010 to 2012, which availed technical and training support to rural community through-out the entire process of the MHPs' establishment. MHP-TSU, a component of EnDev Indonesia, was specifically designed to ensure the quality and ultimate sustainability of community-operated MHP facilities. Funding for the MHP's was obtained via the Government of Indonesia's Green PNPM programme.

The KPI study coincides with a recently published study entitled Micro Hydro Power (MHP) Return of Investment and Cost Effectiveness Analysis (Final Report, 17 September 2012) by The World Bank Group (WBG). This report was also reviewed and compared with the KPI results, and an overview comparison included as **Appendix C**. In general, both studies arrive at very similar conclusions.

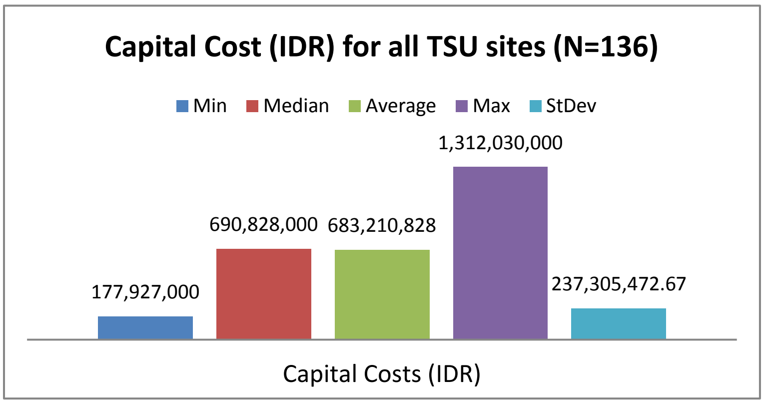
Figure 1-1: MHP installed capacity (kW)



Under the KPI survey, the average installed measured capacity for the MHP plants was 12.6kW.

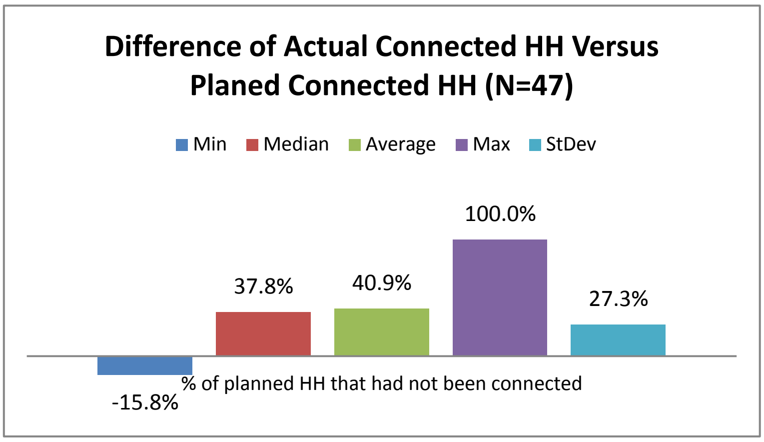
At this "low" installed capacity, the economic performance in terms of capital cost per installed kW is poor, but improves dramatically with higher capacity MHPs.

Figure 1-2: Capital costs (IDR) of MHP-TSU sites



MHP-TSU has supported the establishment of 136 MHP sites in Sulawesi and Sumatera. The capital investment, as provided by Green PNPM, is substantial. Due to the high degree of site-specific customisation, the costs of an MHP scheme can only be reliably assessed, once a site inspection was conducted and a detailed engineering drawing and bill of quantities drawn up. This implies that initial consulting-type services are required and the cost and time requirements thereof should be considered in MHP projects.

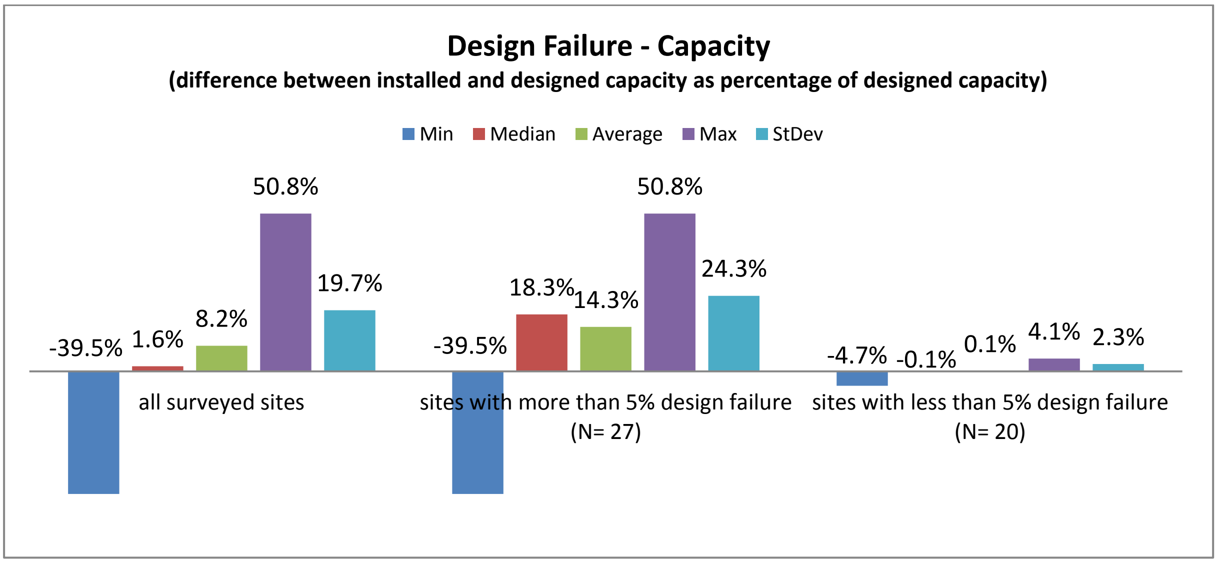
Figure 1-3: Households not connected



During the initial site verification, which then led to detailed planning, engineering drawings and bills of quantities, many more households were identified than were ultimately connected. In average, only about 60% of the planned households in a village were actually connected by the time of the KPI survey. There are several reasons for this including wrong counting during the initial planning phase, inability of households to pay for a connection, expansion of the PLN grid, migration from the village, and insufficient MHP capacity (i.e. actual capacity is less than planned).

The latter raises issues around the accuracy of the initial site verification and the subsequent planning, but also the compliance of the MHP construction with the engineering plans. Site difficulties often hamper a strict adherence to the engineering drawings, which can result in losses in head and water flow. This impacts the available power output by the MHP.

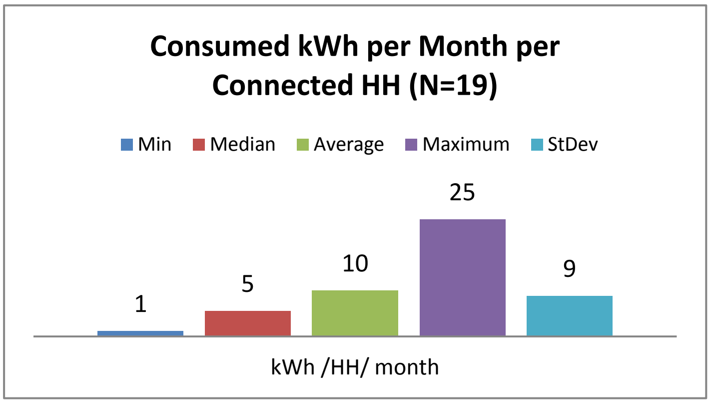
Figure 1-4: Design failures in terms of MHP capacity (kW)



For the 47 MHP-TSU sites surveyed, the average design failure was about 8% between planned and actual capacity (i.e. on average 8% less kW output than planned). The maximum was 50% less capacity, while some sites exceeded the planned capacity by as much as 40%. Given the challenge of correct construction and the fact that civil work was performed by the community (with regular supervision by MHP-TSU field staff) the design failure ratio is most acceptable.

Rural electrification serves a greater purpose of facilitating rural development, in the assumption that access to electricity will improve rural livelihoods. Rural electrification is costly though and off-grid electrification in particular has general limitations regarding the amount of electricity available to each household, rural business and social institution. The graph below reflects the electricity consumed per household per month, based on MHP sites with installed kWh meters (19 metered sites with reliable data).

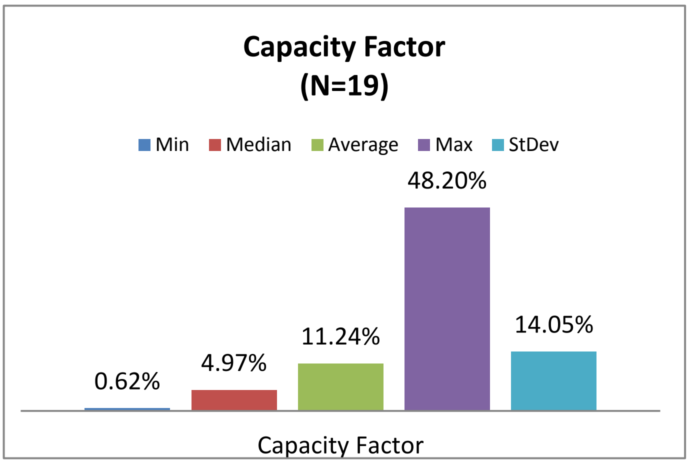
Figure 1-5: Household electricity consumption (kWh/month)



It is interesting to note that the World Bank Group (WBG) study (see **Appendix C**) recorded an average 64kWh per month per household (with maximum 152 kWh and minimum 7 kWh). This significant discrepancy can be ascribed to the fact the WBG study considered only the installed capacity (and a spot reading) in its calculations and not actually metered kWh supplied to the households.

Electricity consumption in rural households is generally very low and in most cases the collective consumption and demand is well below the available capacity of the MHP. The capacity factor of MHP shows the proportion of effective capacity compared to installed capacity that is expected to be delivered by the MHP to the community. The calculation is by comparing the electricity generation (kWh) from MHP compared to total kWh that is expected to be generated from MHP plant which is working at full capacity continuously (100% availability factor).

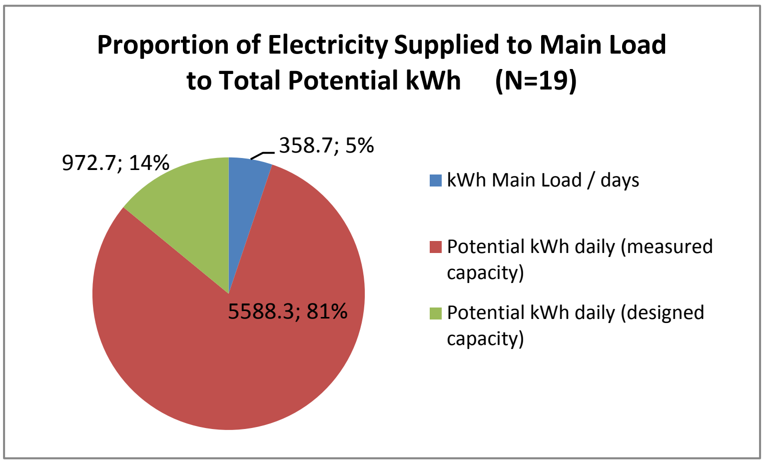
Figure 1-6: MHP operation - capacity factor



From 19 sites, the average MHP capacity factor is only 11.24%, with median of 4.97%. The low median value is caused by the majority of sites that are underutilized while only a few sites had been highly utilized. The poor capacity factor is primarily related to low electricity consumption (further details regarding the influencing factors and scenarios for capacity factor improvement are included in Appendix A).

Despite the currently poor capacity factors for most sites, the KPI survey also recorded an improvement in the capacity factor the longer the MHP operates. This is due to an increased electricity consumption per household over time, productive use of energy applications (i.e. rural businesses using electrical appliances) and greater operational experience by the MHP operator.

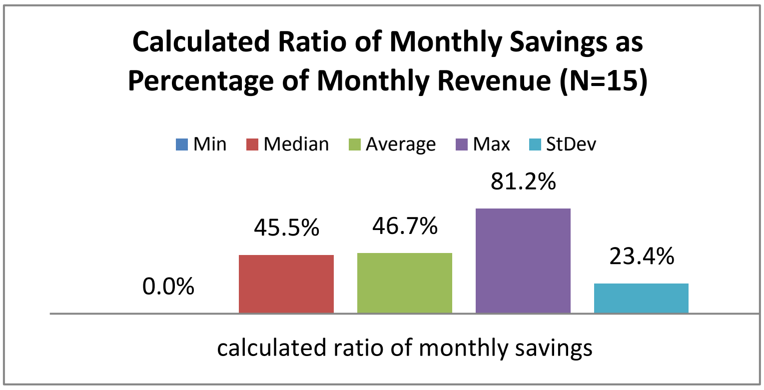
Figure 1-7: Proportion between electricity consumption and potential



From the data of 19 metered MHP sites, only 5% (358.7 kWh/days) of electricity is used to supply main load. Another 81% (5,588.3 kWh/days) is estimated to be lost through limited operating times (i.e. low availability factor), not fully opened turbine and/or the ballast via the electronic load control (ELC).

Under the programme GreenPNPM, the community is "owner" of the MHP installation, with a dedicated Village Management Committee (VMC) comprising at least an operator, treasurer and manager, elected and trained to operate and administer the MHP.

Figure 1-8: Financial saving for MHP sustainability



In order to ensure the MHP's sustainability, revenue is collected from connected households, which is used to pay the VMC members and save funds for maintenance and future replacement. VMC training is conducted under MHP-TSU and the proportion between savings and operational overheads is an indication of how well a VMC accommodates future expenditures.

Of the 47 sites surveyed, only 15 sites maintain sufficiently concise financial records to determine whether the community will have sufficient resources, by saving an average of 45% of total revenue for future expenses.

The KPI survey collected a wealth of information, with the most pertinent information presented in this report. Since the capacity factor, and its subsequent effect on economic feasibility of MHP-based rural electrification, has emerged as one of the most critical shortcomings of the surveyed sites, **Appendix A** analyses the capacity factor in more detail and assess its sensitivities and root causes. **Appendix B** of this report summarises all formulae used for during data analysis, as well as the data type and source. **Appendix C** provides a comparative overview between the data collected and information presented by this KPI survey and the *Micro Hydro Power (MHP) Return of Investment and Cost Effectiveness Analysis* (Final Report, 17 September 2012) by The World Bank Group (WBG). Considering that most MHP have surplus capacity, **Appendix D** takes a closer look at electricity utilisation and the potential for a) additionally connected households, b) increased household consumption and b) expanding the productive use of electricity (PUE).

2. Background

As small-scale hydro power has become a solution high in demand for rural electrification, the ever faster growing Indonesian MHP-sector risks to be overtaken by its own success at the expense of declining quality. The process of massive scaling-up of MHP-access requires as multiplication of local capacities, which is holistically supported by the project Energising Development Indonesia (EnDev Indonesia), implemented by the Gesellschaft für Internationale Zusammenarbeit (GIZ).

Since the late 80's, GIZ (GTZ at that time) directed its attention towards a systematic up-scaling of rural electrification through MHP beyond demonstration efforts. During the first phase of EnDev (2006-2009), MHPP built up the expertise and management competency of actors engaged in constructing and operating mini-hydropower schemes in rural areas towards a systematic scale up. It facilitated contacts between service providers and users transferring the necessary know-how to various actors: operators, political authorities and user groups.

Under EnDev 2, starting in May 2009, the program was initially split into two complementary components: (1) The Green PNPM Micro Hydro Power Technical Support Unit (MHP-TSU) to directly support the access to energy through MHP in rural areas, and (2) The Mini Hydro Power Project ($MHPP^2$) as a capacity development component to institutionalise know-how and learning from experiences for a sustainable MHP sector development in Indonesia. While the MHP-TSU project partner is the Ministry of Home Affairs (MoHA), MHPP2 works closely with the Directorate General for New and Renewable Energy and Energy Conservation (DGNREEC) under the Ministry of Energy and Mineral Resources (MEMR). MHP-TSU was established specifically to support the Government's Green PNPM rural development programme. Recently though both components have synchronised their complementary activities to such a degree that the separation into two components is no longer required. This was also necessitated by the fact that the Green PNPM will be concluding in December 2012. Thus, EnDev 2 has reverted to the title "EnDev Indonesia". EnDev Indonesia has quantifiable targets of providing access to electricity to a set number of beneficiaries, social institutions and productive-use-of-energy enterprises in rural Indonesia.

The combination of the two components allows for the nation-wide scaling up of good practice approaches in MHP dissemination via Indonesia's community empowerment program , while the extensive on-the-job capacity building activities supported by the TSU, together with the actual implementation of MHP schemes following a community driven development, has provided a wealth of knowledge and experience across different stakeholders.

To ensure that people could get continuous supply from the installed MHP, technical, social and financial sustainability is critical. In order to assess this sustainability, monitoring is essential. Through monitoring and evaluation, improvements of the implementation process can be made, ensuring and enhancing the quality of the MHP schemes. It is against this background that the Key Performance Indicator (KPI) survey was conducted.

3. The KPI Survey

In June 2012, 60 MHP sites under MHP-TSU supervision were commissioned and had already been operated by the community for several months. In September 2012 a KPI survey was launched, at 47 commissioned sites (20 in Sulawesi and 27 in Sumatera), in order to verify the performance of the MHP plants to date, confirm whether the targets set under EnDev Indonesia are being met, and to resolve discrepancies from previous data sources.

For instance, current data on expected households to get electricity were based on TSU data during site verification. The number of actual connected households in the field could differ because:

a. According to commissioning reports, the actual capacity is generally lower than design capacity
b. Scattered and distributed households in rural settlements often prevent immediate connection to MHP distribution grid
c. The data of expected households to be connected might differ with the actual connected households

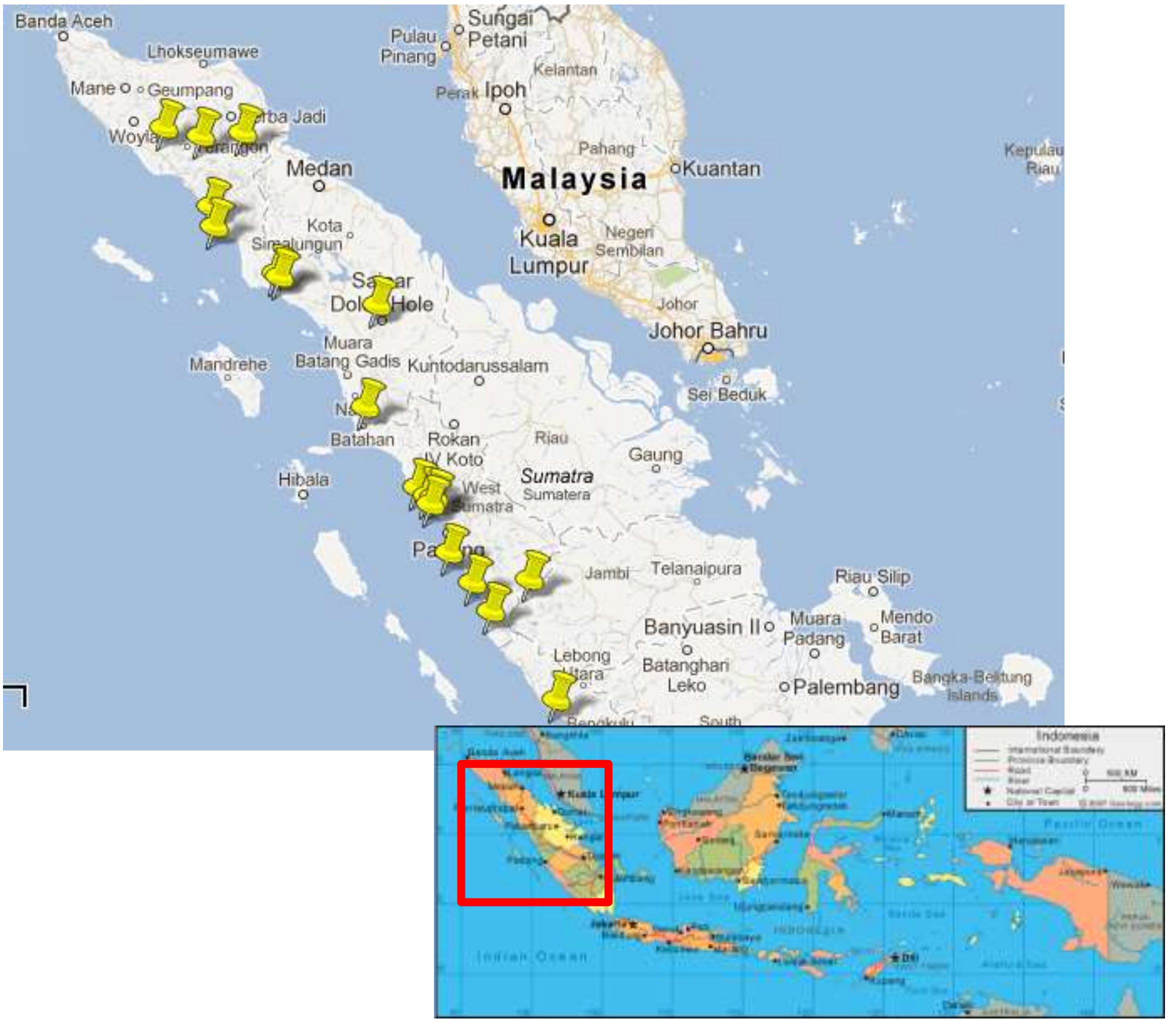
Therefore the Key Performance Indicators (KPI) survey aims to get more reliable data of connected people to the MHP sites and to understand what caused the discrepancies.

In addition, the KPI Survey aims to evaluate the current situation of post-commissioned MHP sites and predict future performance using sustainability indicators. Those indicators refer to the operational performance, the administrative system and the current physical condition.

Figure 3-1: Map - KPI survey in Sulawesi[1]

[1] Source for Indonesia political map: http://geology.com

Figure 3-2: Map - KPI survey in Sumatera[2]



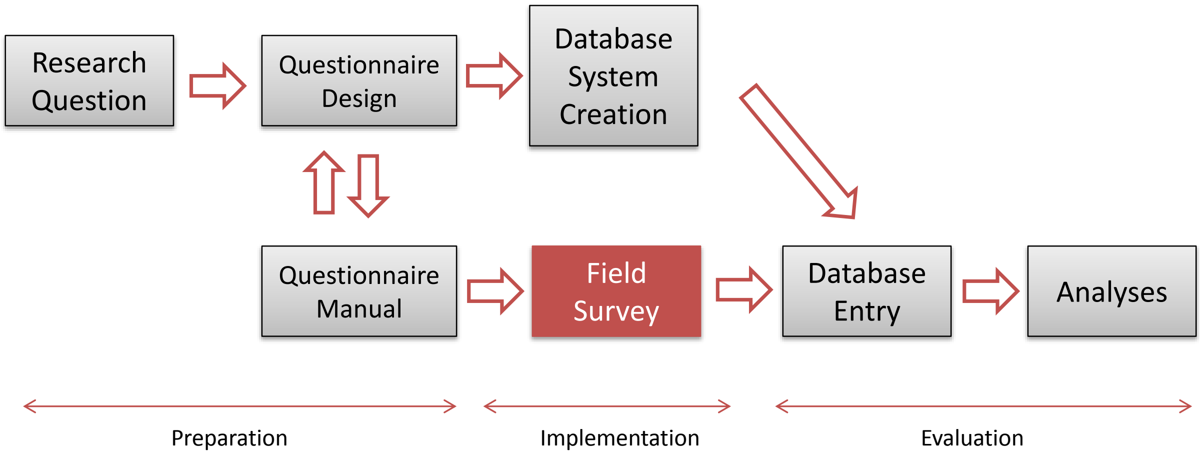
Note: of the 27 sites surveyed in Sumatera, only 18 are pinned in the map above due to discrepancies in the GPS data.

[2] Source for Indonesia political map: http://geology.com

4. Survey Methodology

There were several processes involved in conducting KPI Survey which will be discussed in detail in the following paragraphs and graphically summarised in the figure below.

Figure 4-1: Flow Chart of KPI Survey Methodology



4.1. Formulation of Research Questions

There are several main research questions that needed to be answered under the KPI Survey. Since these questions are very broad and had many complex aspects, specific questions were formulated to facilitate easier questionnaire design and mentioned as derivative questions.

Table 4.1: List of Main and Derivative Research Questions

No	Main Research Questions	Derivative Research Questions
1	What is the number of beneficiaries from MHP system? How far is it capable to support the need of electricity in the target area?	What is the number of HH/SI/PUE connected to MHP? What is the number of HH/SI/PUE connected to PLN, other off-grid sources and not connected at all?
2	How is the system performing technically?	Is the MHP still delivering electricity? If not, why? How much energy had been delivered from MHP to beneficiaries? For how many hours are MHP beneficiaries provided with access to electricity per day/week? How effective is the MHP potential being utilized by the community in terms of availability and capacity factor?
3	How good is the management team in managing the system sustainability?	Are all of basic MHP management functions being fulfilled? What occupational and skills backgrounds do the management team have? How good is MHP management performance in terms of book keeping and administration? How is the condition of MHP management's knowledge and responsibility transfer amongst the village and management team? What kind of tariff system is used on the village? How far MHP management team can enforce fee collection rule? How is the financial condition of MHP management?
4	What type of social institution and productive use of energy enterprises are connected to the MHP?	What type and how many school/health centre/community centre/religious buildings had been/had not been connected to MHP? What kind and how many of *'warung'*/water pump/small business/community business/workshop/other businesses had been/had not been connected to MHP?

No	Main Research Questions	Derivative Research Questions
5	What are the reasons for data discrepancies between design and actual plan?	What are the reasons that some households/SI/PUE are not connected to MHP at this moment?
6	How high is community satisfaction with the quality of electricity?	How satisfied are households with quality of electricity? What type of electricity quality problems are encountered and how frequently?
7	How is the condition of MHP operation and maintenance?	Are there any water-use conflicts at the MHP site? What kind of conflict, if any? What are the MHP operating hour schedules? How adequate are the available supporting tools and services and its usage in location? What is the schedule for repair and maintenance for MHP components? What kind of damage had occurred? What kind of damage had occurred due to customer abuse?

4.2. Questionnaire Design

Designing the questionnaire considered several aspects, which include:

a. The question wording being simple enough to be understood by unskilled surveyor and asked to rural people
b. The question is arranged in logical order and working flow so that unskilled surveyor can naturally converse with the interviewee and complete all questions smoothly
c. Tick boxes are used extensively. The advantages are: a) minimize narrative answers by pre-defining multiple answers beforehand, b) occurrence and frequency of set answers are more easily quantified (while unanticipated reasons can be addressed through “other” option), and c) easier to handle conditional questions effectively
d. The question arrangement accommodates consistency verification of data surveyed
e. Anticipating most common and typical situation in the village that might potentially disturb survey processes and data integrity

In order to help field surveyors to conduct the KPI Survey, a questionnaire manual was also prepared.

4.3. Preparation of Questionnaire Manual

Purpose of the questionnaire manual was to provide an illustrative guide on each question. The manual was designed to assist the field surveyors by:

a. Providing step by step instructions on required survey equipment, time allocation and recommended survey work flow
b. Providing example on how to answer the question correctly
c. Providing explanation about where to get the data, alternative data source and source person
d. Explanation on the terminologies used in the survey
e. Explanation on data reading and interpreting electric meter
f. Providing guidelines when estimated data can be used and when detailed record is needed
g. Providing guidelines on interpreting vague answer from uncertain/unpredictable condition in rural area
h. Providing examples about what kind of wording can be used

It serves to mention at this juncture that the surveyors were experienced field operatives with several years of experience working under the TSU project, with well-established networks across the target communities.

4.4. Database System Creation

Database system creation was done in parallel with field survey design in order to ensure not only speedy data analyses after field survey ended, but also to ensure that survey data is in a suitable format for analysis. The electronic database system composes the following two components:

a. Date entry platform via Lime-Survey (on-line tool)
b. Spreadsheet evaluation

In order to create an efficient data entry platform for the collected information, an online survey was built with the PHP survey software Lime-Survey (www.limesurvey.com). The advantages of using this software are:

a. Multiple user can enter data simultaneously
b. Entry fields can be predefined so that only specified data types can be entered
c. User friendly interface
d. The data can be exported to Excel, SPSS or other evaluation tools

Despite numerous positive aspects of the survey tool, challenges occurred during the process. First, structural changes in the survey cannot be done after its activation. Moreover, the export to spreadsheet format (Microsoft Excel) should only be done after data entry is completed because updating an existing spreadsheet is not an option.

The KPI data received from the Lime-Survey has been processed in an Excel file. Raw data and indicators were collected in separate sheets, which are data sheets and result sheets respectively.

4.5. Field Survey

Field survey was conducted on September 2012 at 47 different MHP sites across Sumatera and Sulawesi and in general the survey processes followed the below steps:

a. Make appointments for the upcoming surveyed site with MHP management teams
b. Travel to site with a team consisting of at least two(2)-persons (this ensured smoother interviewing, division of labour and opportunities for immediate reflection on data accuracies)
c. Conduct visit and physical site check on civil structure, power house and customer grid condition
d. Visit management team, conduct the interview based on questionnaire, checking their record
e. Conduct interview with most respected person in the village such as village heads, community leaders
f. Final check, to ensure all pre-defined photos were taken and all questions had been completed

Parallel to the data collection on the field, incoming questionnaires were entered in Lime-Survey and transferred to Excel. Misunderstandings of perception and purpose of some questions as mentioned in Survey Challenges and Solution chapter resulted in inconsistent data and therefore pre-processing of the raw data is required. In addition to the challenges in the field, data entry also posed risk of errors. In particular, it has to be emphasised, that the type of data (e.g. days, month, number, text) should be clearly defined in advance (even then, units and decimal positions can sometimes be misleading). Data pre-processing was thus essential.

4.6. Data Analysis

4.6.1. Data Pre-Processing

Pre-processing of the raw data was required for data on households, social institutions and PUE as well as for the financial data. In general, data processing was a form of screening. Where possible corrections were made to data, but where data was inconclusive, unavailable or nonsensical, it was not considered for further calculations. For this reason the sample sizes ("N") for various analyses differ and they are stipulated in the graphs of this report.

4.6.2. Data Inconsistencies

Inquiring the connected and not connected households, social institutions and productive use of energy, two entry sections are used in the KPI survey. They are the Part "KPI" (Questionnaire Part 1) and in section "PUE/HH/SI" (Questionnaire Part 2) for more detailed information. This had been done for two reasons:

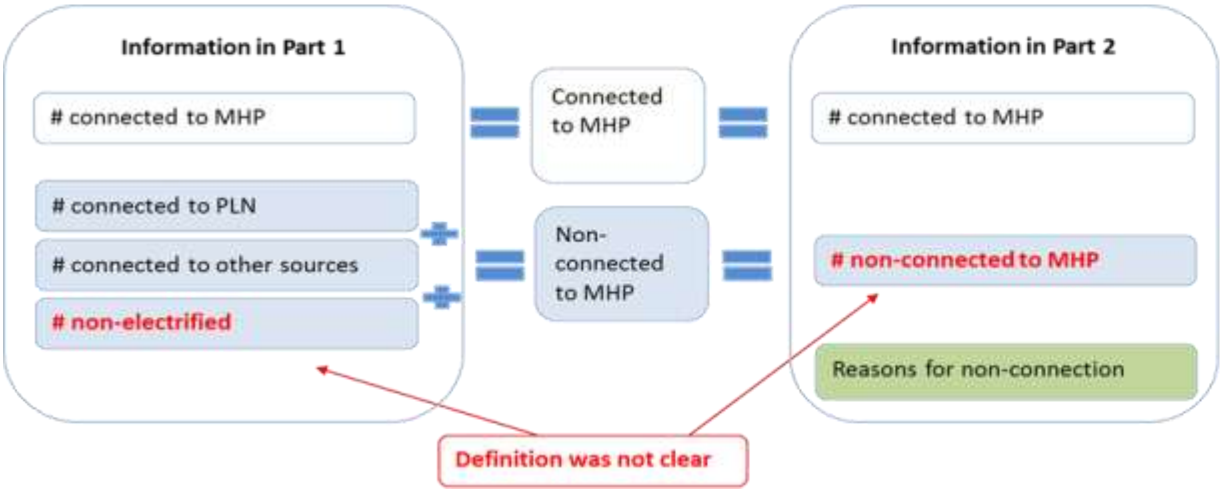
a. To avoid inconsistencies, by incorporating a cross check
b. To emphasize most important data (KPI) in the beginning and later refer to more detailed questions including reasons of non-connection

Ironically however, challenges arose with this approach especially regarding data consistencies. The number of connected and non-connected HH, SI and PUE differs in each part and requires a thorough selection of data and adaption of data entries. The following paragraphs are summarizing available information, common misunderstandings that occurred and how the evaluation data had been selected.

4.6.2.1. Households

The diagram shows the available information in each part of the survey. Concerning the number of non-connected households (HH), different interpretations occurred in each part and led to observed discrepancies. The attribute "non-connected" either describes households that are not connected to any electricity source (non-electrified HH) or HH that are not connected to the MHP (non-connected HH). The later definition also includes those which are connected to the PLN grid or their own diesel generator. Data inconsistencies occurred due to this misunderstanding.

Figure 4-2: KPI Survey - Information Structure on Households



For future considerations, the table below visualizes the two concepts and their interdependencies.

Not connected to MHP	→ Connected to electricity (PLN or other sources)
Non-connected HH	→ Not connected to electricity (non-electrified HH)

The KPI data analysis which was used in this report refers to the data of the first part due to more information and a higher reliability.

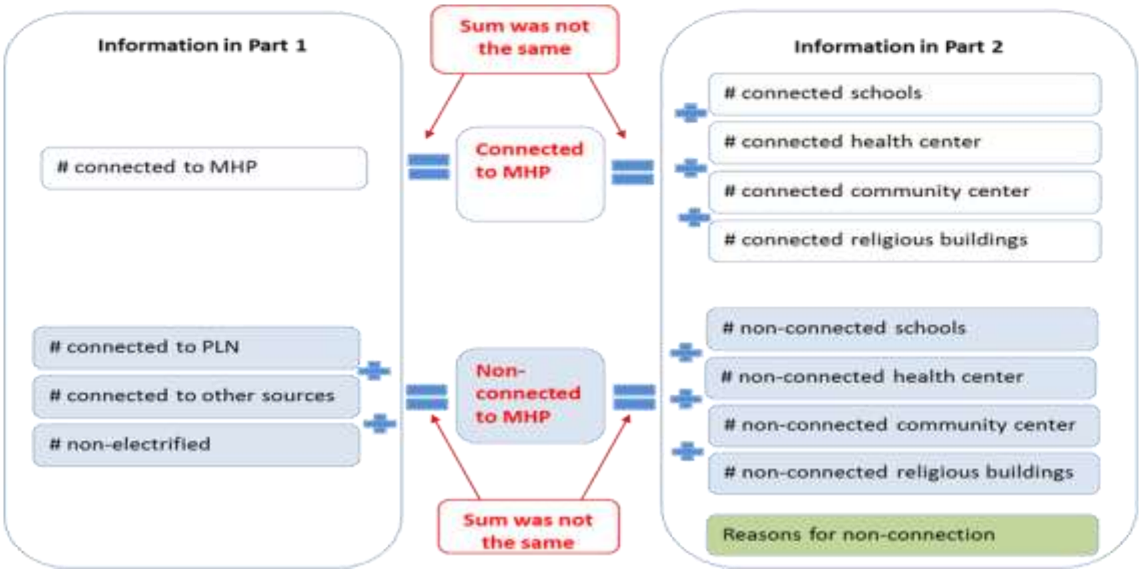
Review of the raw data is required to guarantee a representative distribution of non-connection causes. The possible reasons for non-connection include “Connected to PLN Grid” and “Energy supply from Generator set”. When “Connected to PLN Grid” is not given as a reason although PLN connection exists according to Questionnaire Part 1, surveyors only considered households that don’t have access to electricity. Therefore, “Connected to PLN Grid” has to be given as a reason, when adding the PLN-connected HH to the non-electrified number.

4.6.2.2. Social Institutions

Contrary to the household data, the data on social institutions (SI) is given in a different way. As visualised in the diagram below, there is asymmetrical information between two parts regarding social institution. The KPI data analysis refers to the second part of the survey due to several reasons:

a. More detailed information on the type of SI
b. Detailed questions ensure more reliable answers
c. Few SI had been connected to PLN or other sources according to part 1

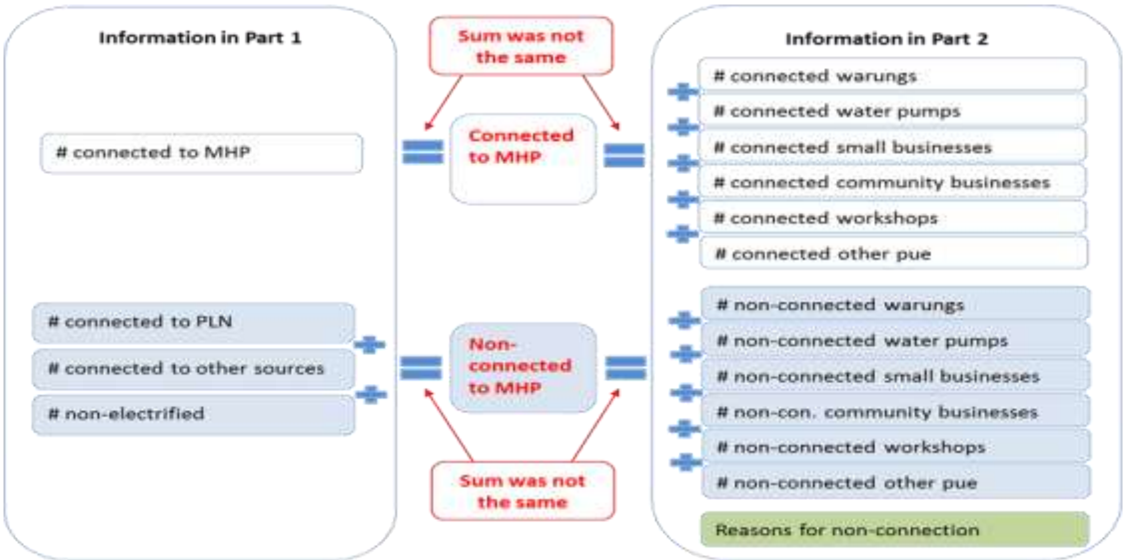
Figure 4-3: KPI Survey - Information Structure on Social Institutions



4.6.2.3. Productive Use of Energy

Similar to the data structure on Social institutions, detailed productive use of energy was specified in the second part of the survey. Generally, there was a common misunderstanding in using term of productive use of energy which resulted in different calculation among both PUE parts. Data in second part is considered more reliable due to the more detailed information.

Figure 4-4: KPI Survey - Information Structure on Productive Use of Energy



4.6.2.4. Financial Data

Communities apply diverse tariff systems, and, as the KPI survey could not capture all the various tariff systems, a categorisation is used in the evaluation. Furthermore for some sites tariff system had not been applied yet or there was insufficient and inconclusive information from MHP management. Some misinterpretation on the required information was particularly regarding:

a. Expected fee
b. Collected fee (monthly or over the whole period)
c. Maintenance cost (monthly or over the whole period)

To overcome this data challenges, reliability check was incorporated during data analysis, which removed inconsistent and incomplete information from further calculations. The criteria for this reliability check are summarised in the tables below, along with the number of sites affected:

Table 4.2: Reliability of information on expected fee

Indicator	Criteria		No sites
Expected average fee/HH	Yes	Expected average fee/HH is in higher than the lowest category and lower than the highest category	29
	No	Expected average fee/HH is below the lowest and above the highest category	18

Table 4.3: Comparability and reliability of maintenance expenses

Indicator	Criteria		No sites
Maintenance cost	One month	Can be deduced from the pictures	4
	Total	Collected monthly income - (salary + maintenance) is less than 0	19
	Not sure	Interpretation of maintenance cost cannot be deduced from pictures or calculation	4
	No data	Empty entry field	20

Table 4.4: Complete and reliable data set

Indicator	Criteria		No sites
Complete data set	Yes	All data exists and is reasonable	15
	No	No data in one or more fields No reliable information on expected monthly fee Collected fee is significantly higher than expected fee Maintenance: no data/ not sure	32

5. Survey Results

5.1. Overview

The numbers of households, social institutions and productive use of energy that are connected to the MHP are essential for evaluating the EnDev Indonesia progress. In 47 commissioned sites, there are 3,211 households, 253 productive use of energy and 129 social institutions that have been connected to the respective MHPs.

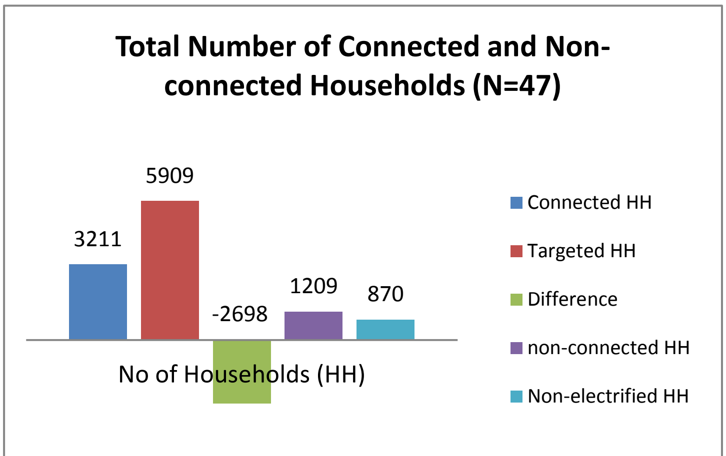
Table 5.1: EnDev Indicators

Indicator		Connected	Non connected
Households		**3,211**	**1,209**
Social Institutions (SI)	Schools	24	21
	Community centre	16	12
	Health centre	22	9
	Religious building	67	23
TOTAL SI		**129**	**65**
Productive Use of Energy (PUE)	*Warungs*	225	32
	Water pumps	5	0
	Small Businesses	15	26
	Community Businesses	1	15
	Workshops	2	20
	Other	5	6
TOTAL PUE		**253**	**99**

5.2. EnDev Indicator: Households

In 47 surveyed sites, there are 3,211 households identified as connected to MHP. Earlier estimations on targeted households differ significantly and only 54% of the targeted households were actually connected.

Figure 5-1: KPI - Connected and non-connected households

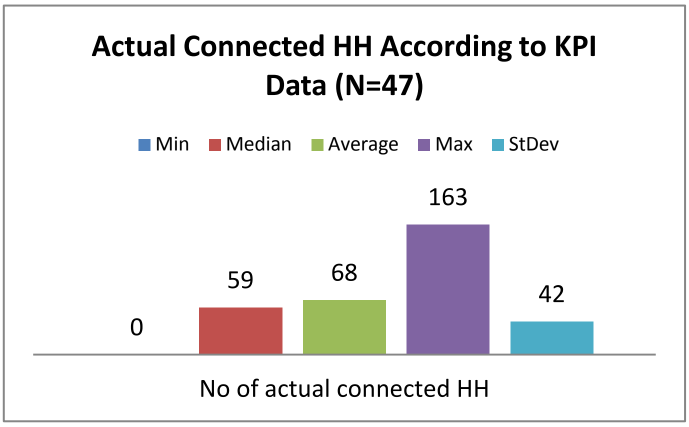


However, there are 1,209 households have not been connected to the MHP yet and 870 of those have no access to any source of electricity supply.

The targeted number of households (5,909) was the expected number as per previous site inspections and subsequent detailed design as conducted by TSU (recorded in the database as Form B).

The average number of connected households per surveyed MHP site is 68. This number does however not serve as indication of the capacity of the MHP though, since the capacity is determined according to the available resource. Nor does this number reflect the total number of households in the village, since in many instances there are numerous households that were not (yet) connected to the MHP during the time of the survey.

Figure 5-2: KPI - Connected households per MHP site



In 72% of all surveyed sites, there are non-connected households. The main reason for non-connection was difficulty in establishing connection to the electricity distribution network for each house, mostly due to technical and location reasons. MHP sites which were surveyed had been commissioned for at least 1 month, but for some the distribution facility was not completely set up yet. In addition, 26% of the households had already been connected to the PLN grid or their financial budget was insufficient to pay the connection cost.

Figure 5-3: Discrepancy on Household indicator

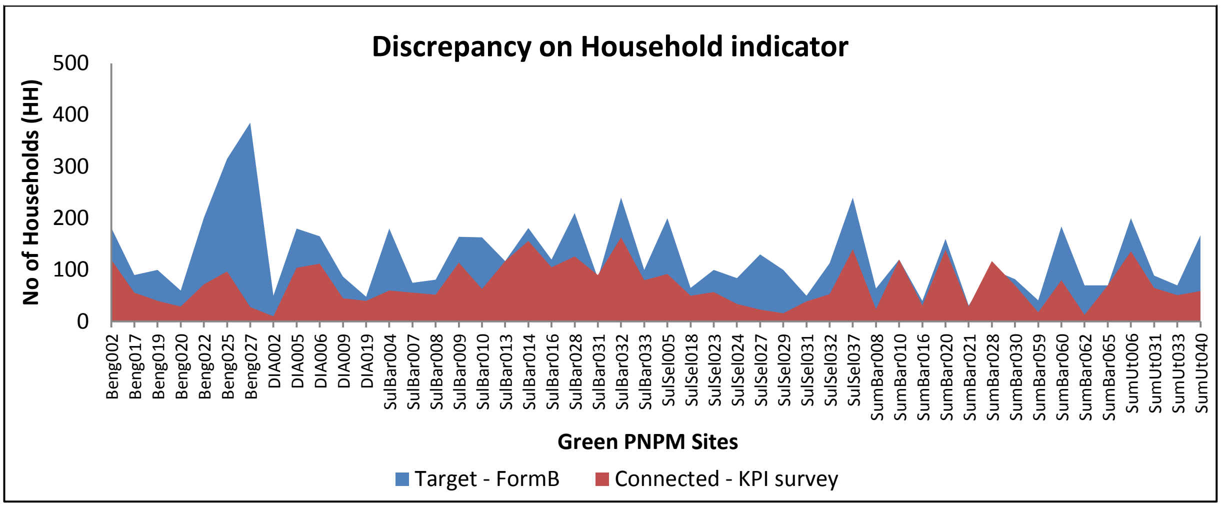
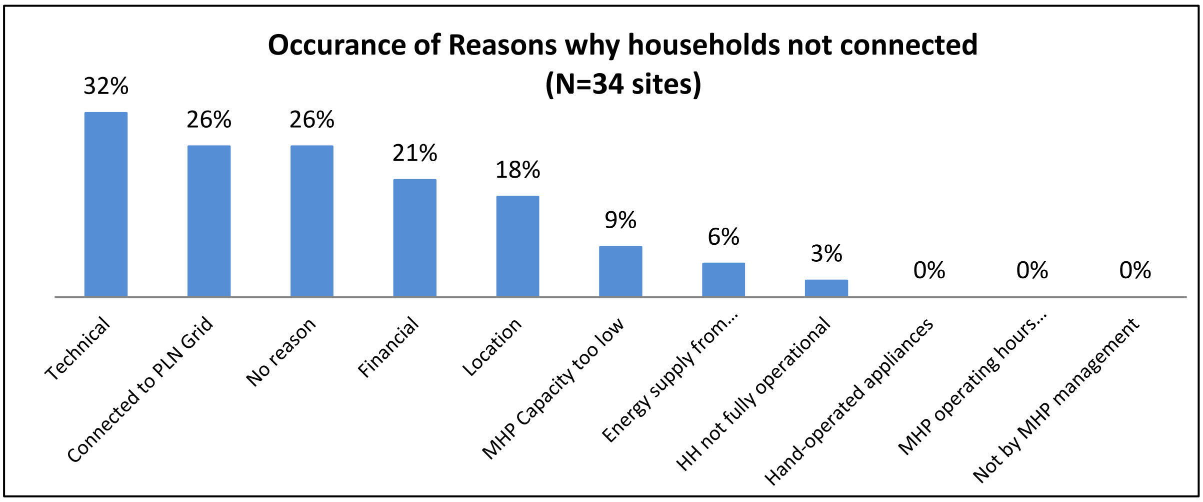


Figure 5-4: Reasons of non-connected households

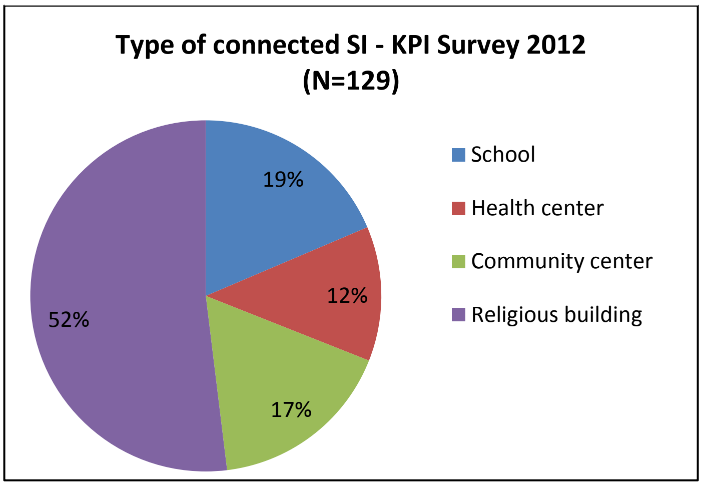


The questionnaire allowed ticking more than one answer as a reason for non-connection. Therefore multiple reasons were mentioned in some sites. On the other hand, in 9 sites (26%) where non-connected household were counted, no reason was given.

5.3. EnDev Indicator: Social Institutions

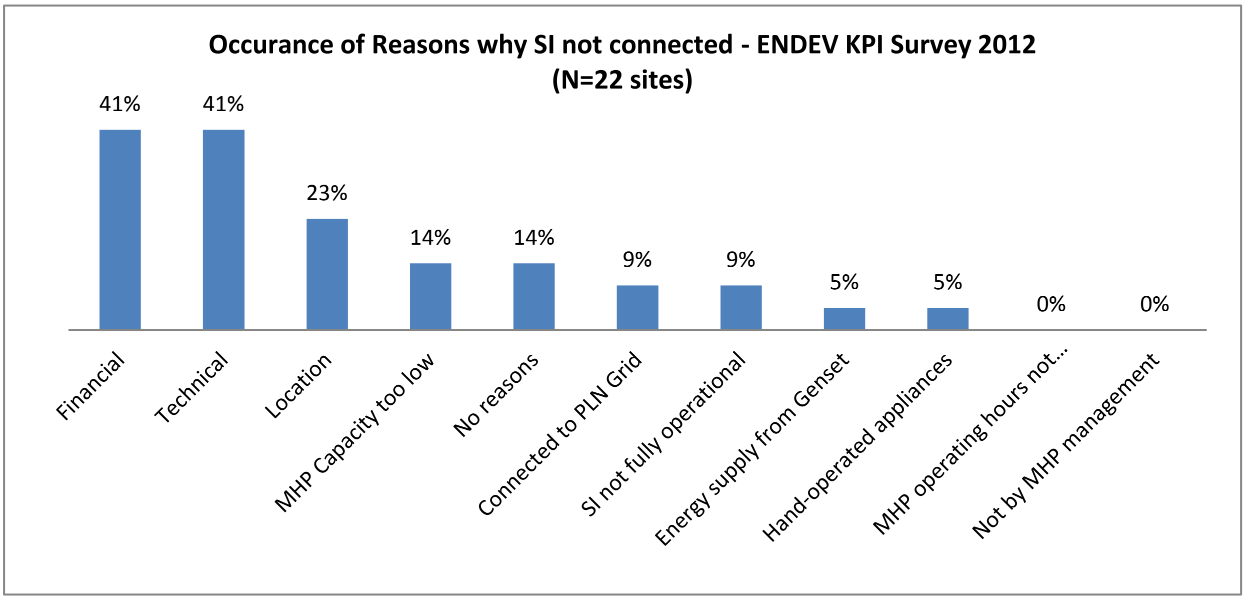
Out of 129 connected social institutions, 52% are used for religious purposes such as mosques and churches. The remaining connected social institutions comprise of 19% schools, 17% community centres and 12% health centres.

Figure 5-5: Type of connected SI



There are still 65 non-connected social institutions which are mainly caused by the similar reason with the non-connected households. In some sites the survey was shortly after commissioning and therefore wiring had not been installed yet. These reasons are summarized in Technical (no wiring) and Location (too far from grid). Another obstacle in getting connected to the MHP is financial reasons (41%) to pay for electricity cost.

Figure 5-6: Reasons for non-connected Social institutions



5.4. EnDev Indicator: Productive Use of Energy

In total 253 PUE had been connected and almost 90% of those are *warungs* or groceries kiosks using lighting to extend their opening hours. Concerning assessing the overall prevalence of productive use of energy (PUE), several challenges had to be faced. There was misunderstanding on what can be considered as PUE and this led to incomplete information. For some surveyors, business enterprises that used diesel/petrol-powered or manual appliances did not constitute PUE and were not classified as "non-connected PUE" and hence not counted. Thus, data on connected PUE is considered more reliable than for non-connected PUE.

Figure 5-8: Types of connected PUE

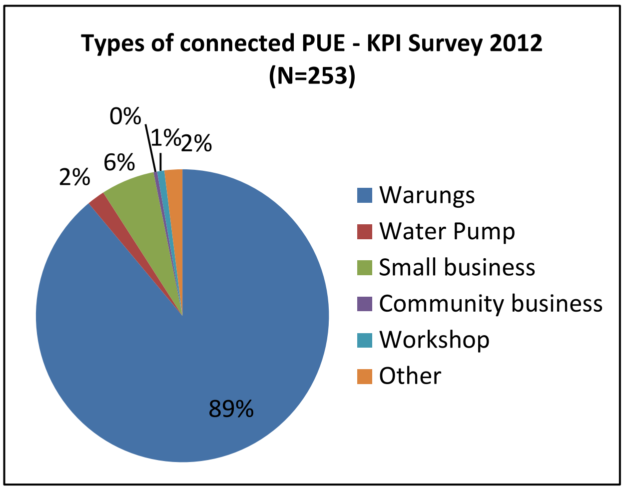
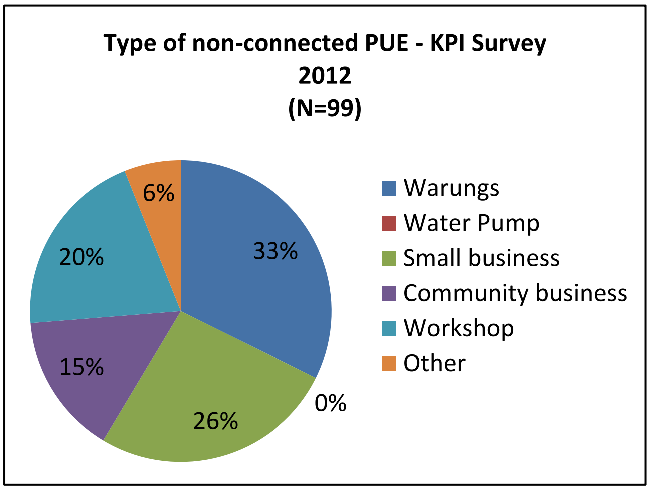


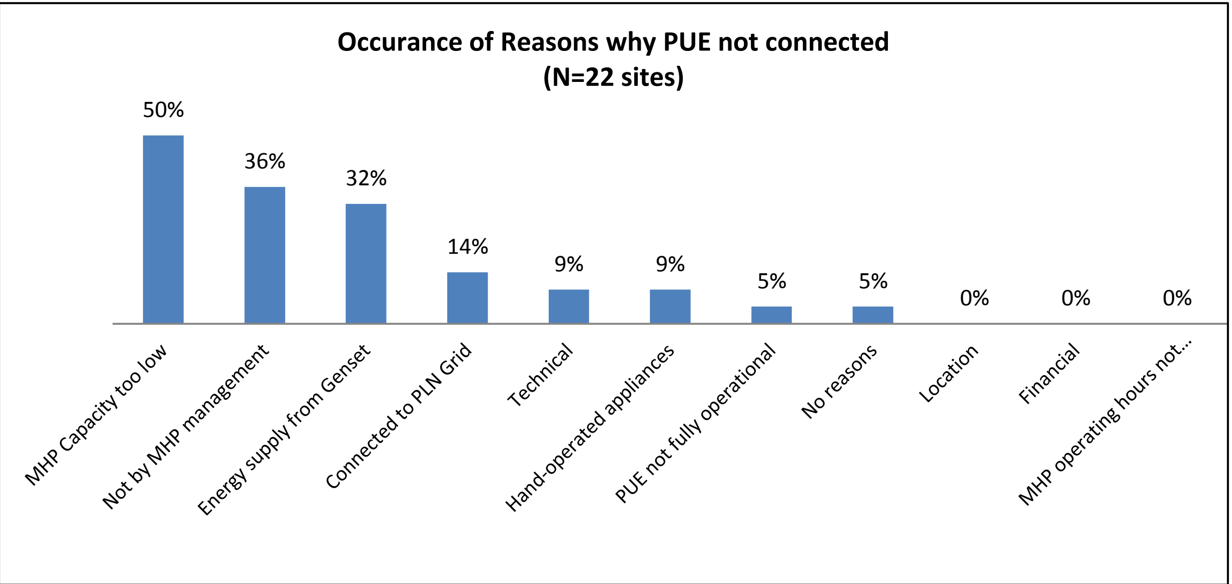
Figure 5-7: Types of non-connected PUE



"Non-connected PUE" are businesses which have manual appliances that can be replaced with new technology using electricity and/or connected to diesel generator. Although still a third of non-connected PUE are *warungs*, there are also 26% potential small businesses, 15% community businesses and 20% workshops had been identified in the sites.

For PUE the reasons of non-connection differ from the households or social institutions. Among surveyed MHP sites, non-connected PUE are found in 50% sites, 36% sites have not allowed the PUE to connect to MHP grid out of concern for the MHP's capacity and the impact overloads might have on households. A third of the non-connected PUE produce their required electricity with a generator set. These are the best candidates for a future connection the MHP grid.

Figure 5-9: Reasons for non-connected PUE



5.5. Technical Indicators

The indicators which are described below monitor the technical performance of MHP sites after commissioning, such as days of operation, recorded hours of operation, consumed kWh, availability factor and capacity factor. These indicators were acquired from KPI Survey for 47 sites. For each indicator, the sample sizes differ according to data availability and data integrity. For instance, some indicators require metering technology, which is not installed at all the surveyed sites. There are 39 sites out of 47 sites that have hour-meters while only 21 (of which the data of 2 sites shows substantial anomalies and were not used for further analysis) sites out of 47 sites that have kWh-meters.

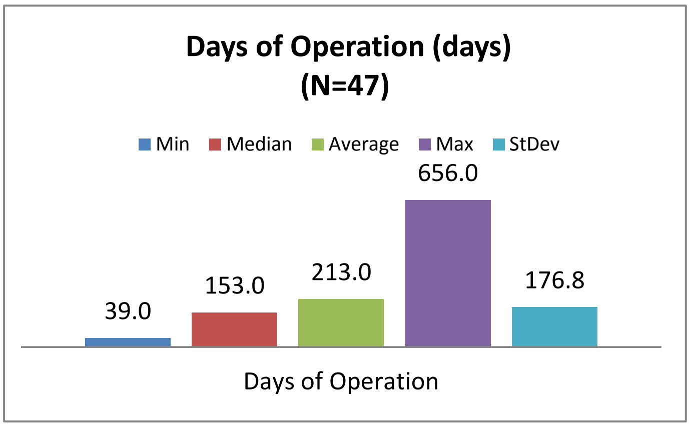
Table 5.2: Technical Indicators

Indicators	Categories	Min	Median	Average	Max	Number of Data	Std
Technical							
	Days of Operation (day)	39	153	213	656	47	177
	Hour-meter (h)	178	2,071	2,833	9,840	38	2,521
	Electricity Generated (kWh)	192	2,355	5,842	31,686	19	8,813
Factor							
	Availability Factor	11.1%	63.4%	62.7%	96.3%	38	23.5%
	Capacity Factor	0.6%	5.0%	11.2%	48.2%	19	14.1%

5.5.1. Technical Indicators of Post-Commissioning Sites

Most of the sites started official operation immediately after commissioning. However, some sites claimed that they started far earlier from commissioning process, such as Bokin (SulSel023) that started 86 days earlier and Ranto Panjang (DIA006) which started 78 days earlier. The longest time delay between commissioning to start of operation is in Limbadewata (SulBar009) with 180 days. Its commissioning report stated that distribution network to houses were not established yet when the commissioning was performed.

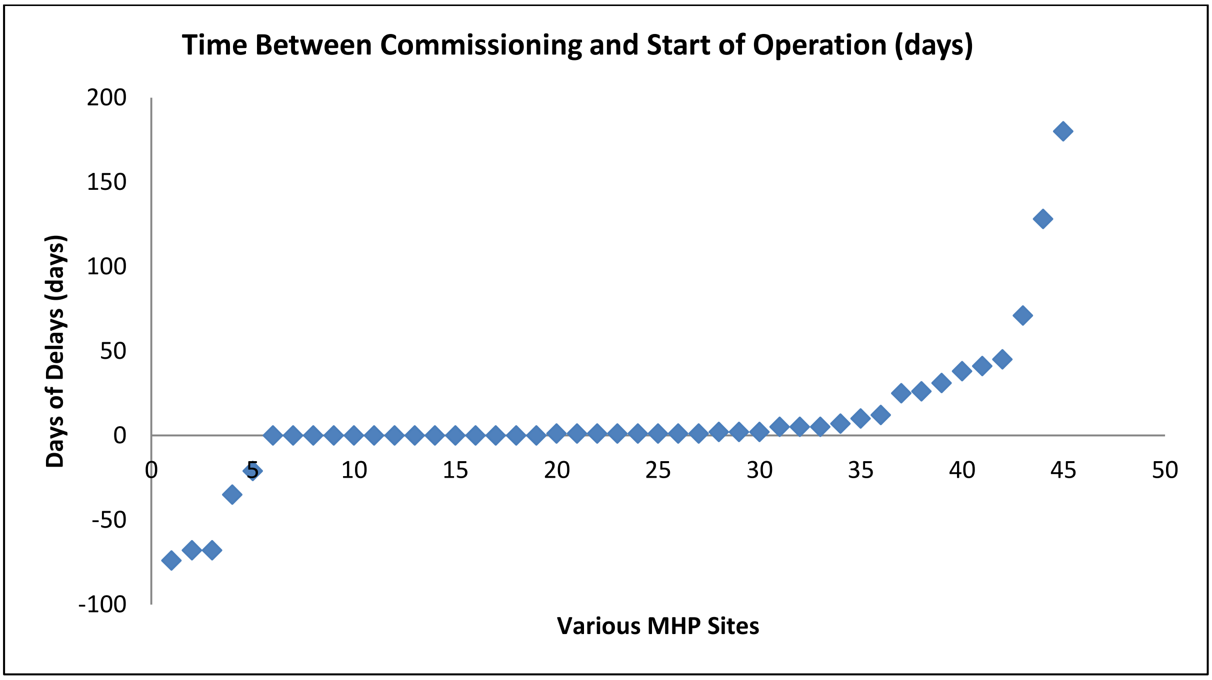
Figure 5-10: Technical Indicators - Days of Operation



Using 47 sites data, MHPs will have 213 days of operation in average, with median of 153 days. Standard deviation for days of operation is 177 days. This figure was calculated from the date of operation and did not consider weekly day off or maintenance day off (calendar day). Operating days vary because time of development process among sites is different.

The time lapse between commissioning and operation is important for impact measurement planning. Impact begins to be visible when MHP has been officially operated. Based on the KPI survey, the majority of sites commence with operation within 50 days of commissioning.

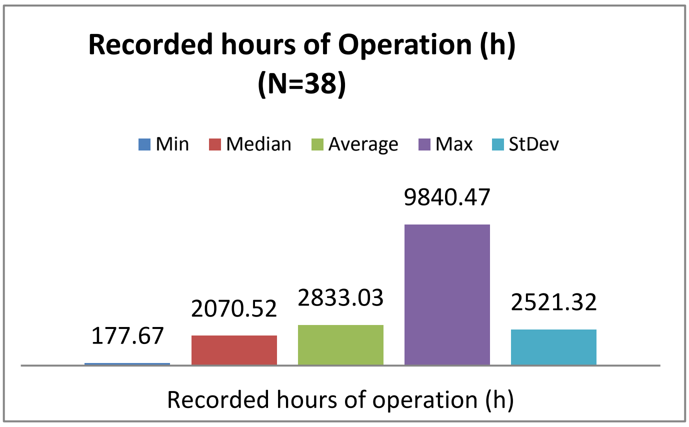
Figure 5-11: Technical Indicators - Time between commissioning and start of operation (days)



Commissioning involves the official technical hand-over of the infrastructure to the community. In instances where operation is significantly after commissioning, the reasons are mostly related to relevant management structures not being established yet and significant technical shortcomings discovered upon commissioning. In a few instances the operation commenced prior to commissioning by TSU, since a prior community/contractor commissioning took place.

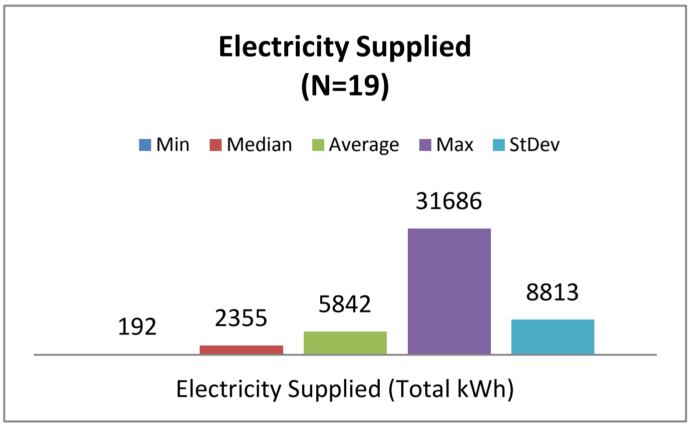
The operational hours of each site is affected by the time the MHP operation commenced, operational schedule, and maintenance schedule. The operational hour data was obtained from hour-meter reading.

Figure 5-12: Technical Indicators - MHP Recorded Hours of Operation



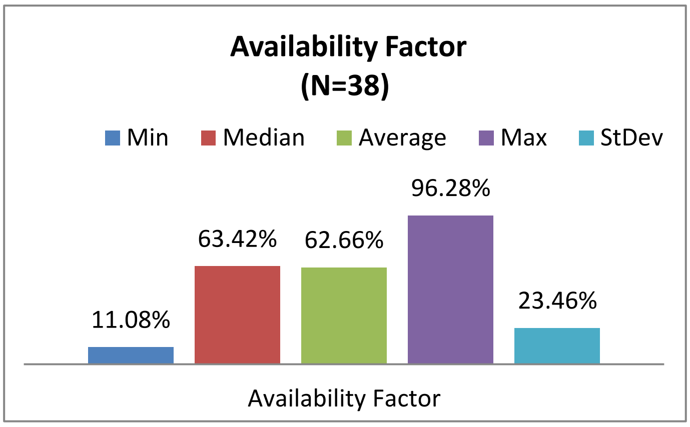
Based on data from 38 sites, the average hours of operation is 2,833 hours, with median of 2,071 hours. The longest hour of operation is 9,840 hours (506 days) from Mambuliling (SulBar028). The longest operation hours does not necessarily correspond to the longest day of operation. Salumokanan (SulBar033) that started earliest only has 8,583 hour (656 days) of operation.

Figure 5-13: Technical Indicators - Electricity supplied



Electricity supplied, which is measured by kWh meters, is affected by capacity of MHP, operating hours and daily load profile. The data does not include the electricity that was diverted to the ballast load, and thus does not indicate total electricity generated. For 21 sites with kWh meter, only 19 provide reliable data.

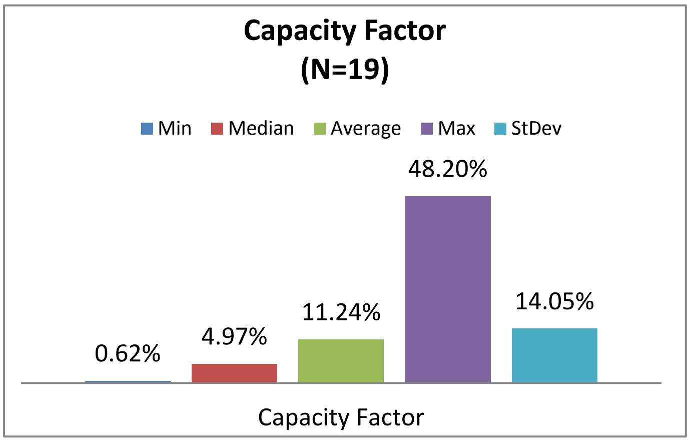
Figure 5-14: Technical Indicators - Availability factor



From 38 sites data, in average MHPs are available for 62.7% of the expected time with median of 63.4%. The highest availability factor is 96.3% from Bandar Mas (SumBar021) because they run the MHP for 24 hours per day, while the lowest availability factor is 11.1% from Kembung (Beng027) because it is affected by dry season. Actually the lowest availability factor occured in Duku, Mudiak (SumBar010) but it could be excluded since no households had been connected according to the KPI survey.

The capacity factor of MHP shows the proportion of effective capacity compared to installed capacity that is expected to be delivered by the MHP to the community. The calculation is by comparing the electricity generation (kWh) from MHP compared to total kWh that is expected to be generated from MHP plant which is working at full capacity continuously (100% availability factor).

Figure 5-15: Technical Indicators - Capacity factor

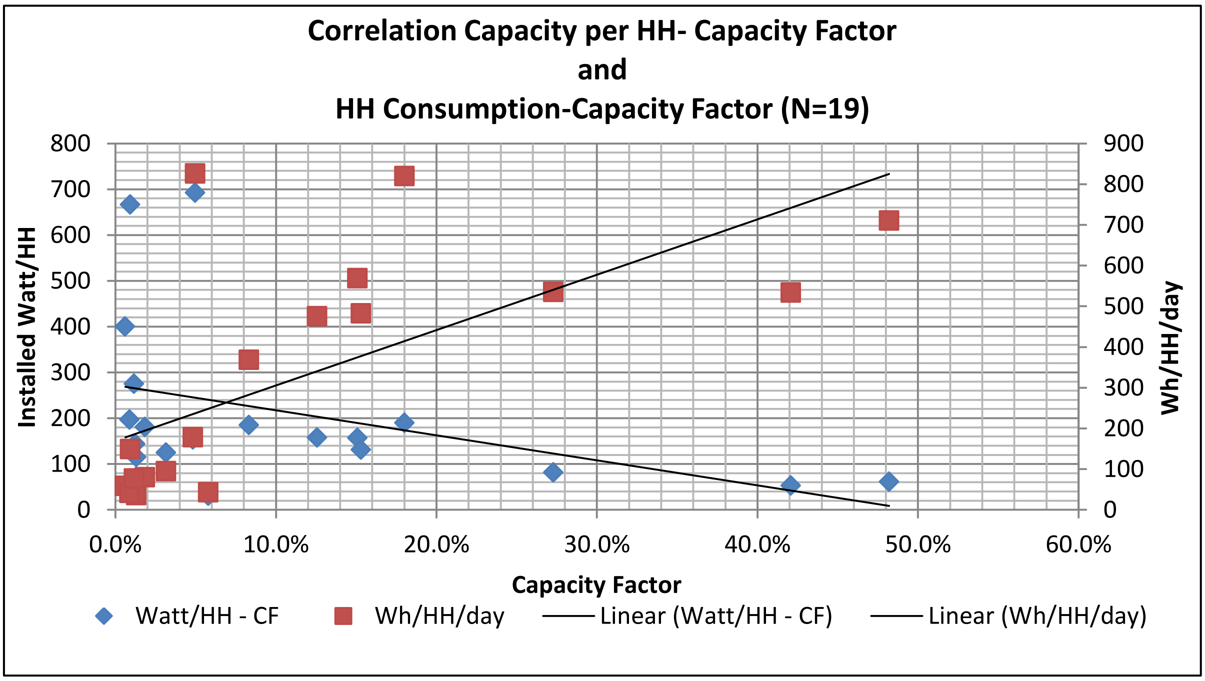


From 19 sites data, the average MHP capacity factor is 11.2%, with median of 5.0%. The low median value is caused by the majority of sites that are underutilized while only few sites had been highly utilized. This phenomenon might be affected by reduced water flow and minimal electricity consumption. The highest capacity factor is 48.2% in Bokin (SulSel023) while the lowest capacity factor is 0.6% in Osango (SulBar004).

The basis for calculating the capacity factor was data obtained from kWh meters at 19 sites where these were available. However, in some cases kWh meters were installed sometime after the commissioning of the system, which implies that the MHP actually operated for longer than the kWh meter data indicates.

The following graph displays the correlation of capacity factor and the installed capacity per connected household (blue), as well as the correlation between capacity factor and the daily energy consumption per household (red). Negative correlation is observable concerning the installed capacity per household. Consequently, a higher capacity factor is related to a lower installed capacity per household. On the other hand, a positive correlation can be drawn between capacity factor and supplied Wh per household per day. A higher daily consumption results in a higher capacity factor.

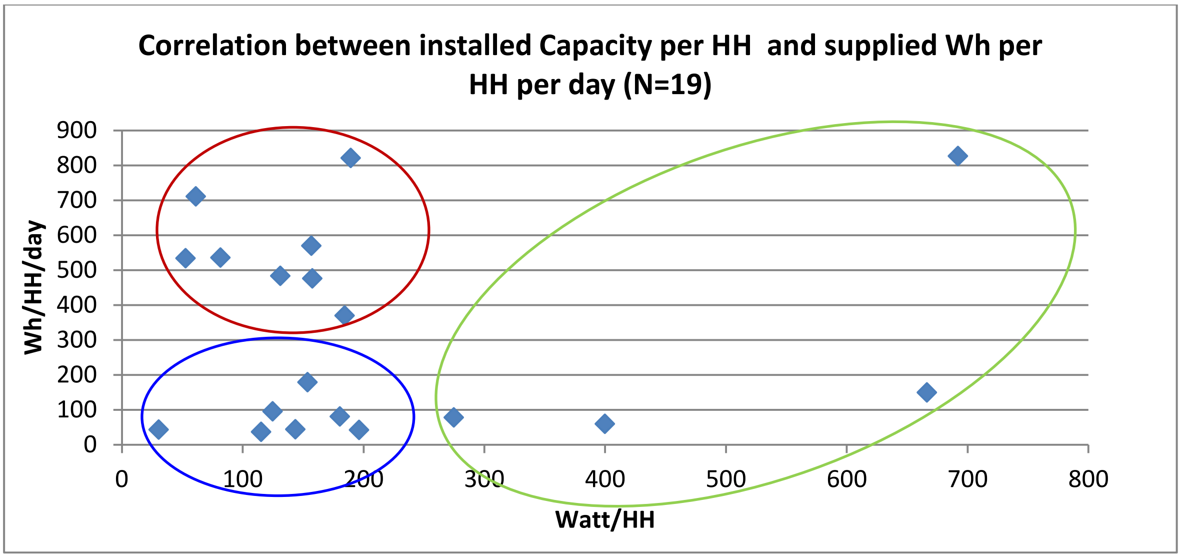
Figure 5-16: Technical Indicators - Capacity factor: installed capacity and supplied energy



This raises the question whether connecting more households and therefore decreasing the installed capacity per connected household would affect the household's energy consumption. Would less capacity result in less consumption? This question will be discussed in the next paragraph.

Then following graphic shows that there is no significant correlation between the installed Watt per household and the household's daily consumption based on the KPI data. Consequently, the capacity of the MHP per household is not a restricting factor for energy consumption in the 19 surveyed sites. However, decreasing capacity below a certain level of demand will influence consumption behavior.

Figure 5-17: Technical Indicators - Installed capacity and supplied energy



Although no correlation can be observed, the diagram displays clusters of sites. Firstly, the sites can be divided between a majority that has a capacity per household of 30 - 200 Watt/HH and a minority of sites (4) where a very high capacity/HH is observed (green). Moreover, the first group can be divided into a group with a relatively low energy consumption/HH (blue) between 36 Wh/HH/day and 178 Wh/HH/day and a group (red) with a consumption range of 369 - 820 Wh/HH/day. In order to understand what the reasons for higher consumption could be, key indicators of all three groups were compared and summarized in the table below.

Table 5.3: Clustering of households as per available daily energy consumption

	31- 196 W/HH		275-692 W/HH
	GROUP 1 36-178 Wh/HH/day	GROUP 2 369-820 Wh/HH/day	GROUP 3
Sample size (N)	7	8	4
Average Capacity Factor (CF)	3%	23%	2%
Average days of operation	166	303	128
Average connected HH	99	68	44
Electricity supplying cost (IDR)	31,870	3,814	36,734
Average supplied kWh per day	246	1,038	180
Average Watt/HH	135	127	508
Ratio connected HH to expected HH (%)	70%	63%	33%

As expected, the capacity factor (CF) of the second group is with 23% significantly higher than in the first groups (2%) due to higher consumption. Accordingly, the electricity supplying cost are lower in average in those sites. (Group 2: IDR 3,814; Group 1: IDR 31,870). Comparing the first two groups that show a similar capacity/HH in average, the following conclusions can be drawn:

- In average, more households had been connected within Group 1 (99) compared to 68 in Group 2. Therefore, connecting more households will not have a major impact on the overall electricity consumption
- In average, sites in Group 2 had been operating for almost twice as long as sites in Group 1. This indicates an increasing use of energy with time.
- A higher consumption/HH is correlated to a higher energy consumption in general.

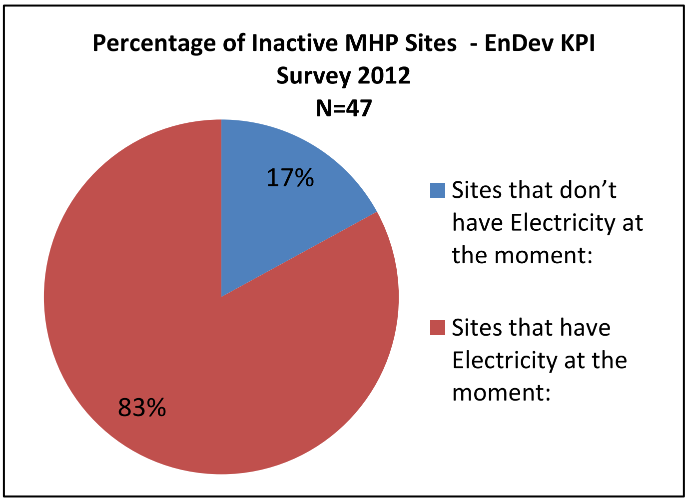
On the other hand, comparing Group 2 and Group 3 with different capacity/HH in average the following observations can be made

- The capacity factor of Group 3 is very low (2%) compared to Group 2 (23%). Consequently the electricity supplying costs are very high in Group 3.
- In average, sites in Group 2 had operated for more than twice as long as sites in Group 3. Therefore, the time factor plays a role in setting up the MHP and connecting the targeted households.
- High capacity (W)/HH does not result in a high overall consumption. The average supplied energy is 180 kWh/day in Group 3 whereas Group 2 supplies an average of 1,038 kWh/day. Indeed sites in Group 3 have a high capacity/HH because of a low number of connected households.
- This fact is also shown in the average number of connected households of 44 in Group 3 compared to 68 in Group 2. Moreover, only 33% of the expected household had actually been connected in the sites of Group 3, whereas 67% had been connected in the sites of Group 2.

5.5.2. Technical Problem on MHP Sites

This section reviews the current condition of the MHP in terms of their ability in delivering electricity.

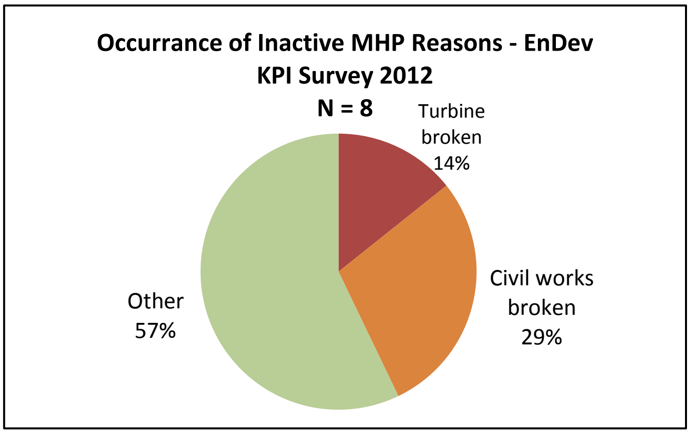
Figure 5-18: Technical Problems - Percentage of inactive MHP



From KPI Survey in September 2012, 83% of 47 surveyed MHP are delivering electricity and 17% of sites (8 sites) were not delivering electricity at the time of the survey.

For the 8 inactive MHP sites, the reasons were reduced water flow in dry season, civil works broken and turbine broken. The oldest inactive site operated for 391 days, the youngest inactive site for only 45, while the oldest active site has been operational for 656 days, and the youngest active site for 39 days.

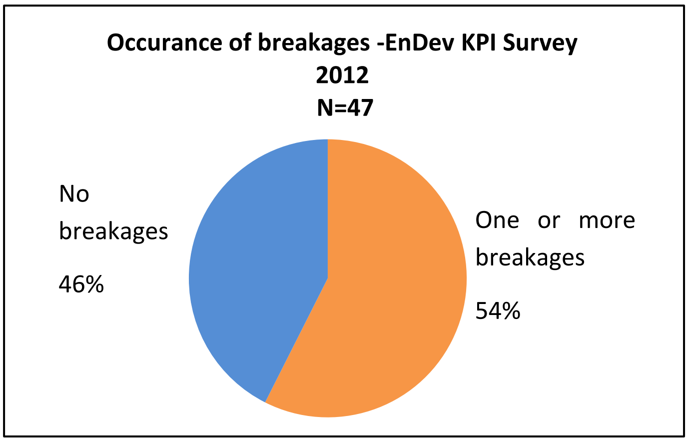
Figure 5-19: Technical Problems - Percentage of Reasons for Inactivity sites



The most common reasons were reduced water flow in dry season for 57%. From field observation we found that rapid deforestation might play significant role on lack of water supply.

Broken turbine occurred in 14% of the surveyed sites and civil works broken happened in 29% of the surveyed sites.

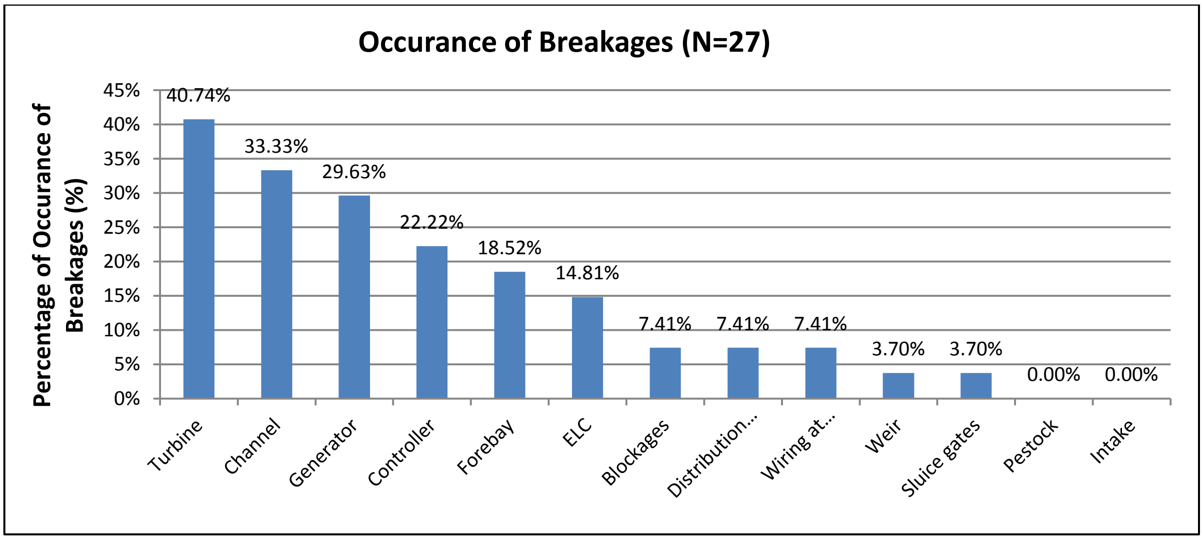
Figure 5-20: Technical Problems - Percentages sites where breakages occur



The number of inactive sites will change overtime due to repair initiative from the operator, more breakages, natural disaster etc. It is also important to look at long term occurrences of breakages.

The bar graph below highlights the types of breakages and their frequency from 27 of the surveyed sites which had experienced at least one breakage. The most common breakages are on turbines (40.74%) and channel construction (33.33%).

Figure 5-21: Technical Problems - Type of breakages

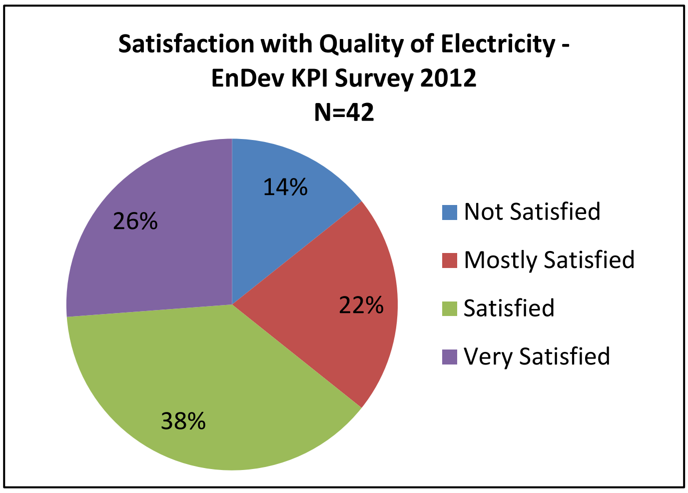


5.5.3. Correlation between Technical Indicator to Subjective Perception on Quality of Electricity

Quality of electricity depends on voltage and frequency of the electric power supply. However since none of the sites have data loggers installed to capture daily fluctuation in electricity supply, the quality of electricity is analysed by identifying occurrence of the disturbance symptoms such as light flickering or black outs, as reported by respondents. To overcome the reliability question regarding this question, an analysis of comparing the subjective assessments with available technical data was performed.

Electricity quality is described by occurrence of the disturbance symptom, and community satisfaction with the MHP electricity supply. Community satisfaction is measured by using scale of 1 to 4 which consists of "Very satisfied"; "Satisfied"; "Mostly satisfied"; and "Not satisfied". The respondents were senior, respected persons in the village such as village head.

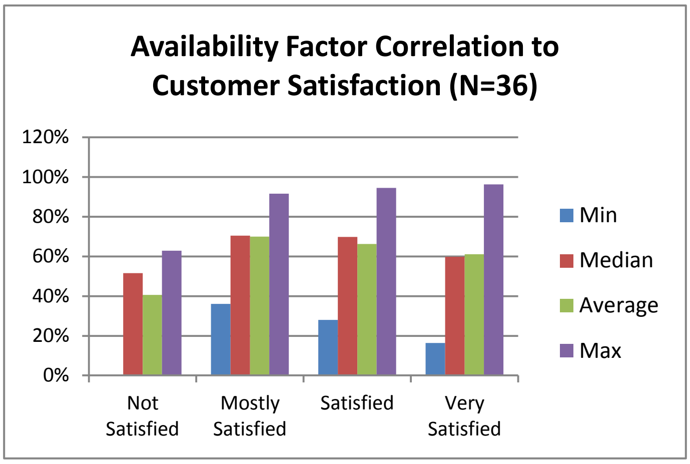
Figure 5-22: Satisfaction with quality of energy



From 42 sites data, 26% of respondents said that they are very satisfied with the quality of electricity. Respondent from Air Pawuak (Beng022) cited less black-out occurs compared to supply from PLN grid as their reason for "Very Satisfied".

There are 38% of respondents say that they are satisfied, 22% of respondents are mostly satisfied and 14% of respondents are not satisfied with the MHP electricity supply.

Figure 5-23: AF and customer satisfaction



Relation between availability factors (AF) and quality satisfaction of the electricity supply is identified by comparing the availability factor from each sites with their quality satisfaction answer. Availability factor (AF) of the non-satisfactory sites is lower than the other sites.

Meanwhile, the respondents cannot distinguish the answer between "Mostly satisfied", "Satisfied" and "Very Satisfied". The tendency is captured by the anomalous reduction on average value of the availability factor contrary with the satisfaction level when it increases.

The first possible explanation is that the "Not Satisfied" answer refers to the respondents which already had complained about the electricity service from the MHP and/or the scheme is already out-of-service for a significant period of time. Possible improvement in future survey can be done by making binary scale of satisfaction (satisfied/not satisfied) or three scale of satisfaction (bad, acceptable, good). The second explanation is that the AF values rely on the MHP operating schedule. There is also an indication that dissatisfied respondents are coming from the sites that are currently broken or not operating due to several reasons.

Availability factor affects community satisfaction of the MHP. From the KPI survey, inability of the respondents to distinguish the different level of satisfaction, except the “Not Satisfied”, means the correlation cannot be inferred clearly.

5.6. Commercial Indicators

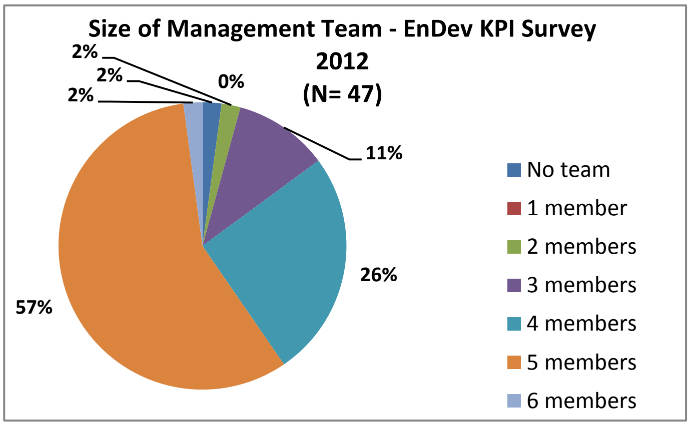
The commercial indicators highlight the managerial aspects of the MHP management team. Accountable and transparent management are pursued to embrace sustainability in managing MHP system. Monthly fee collection should be sufficient to cover overhead cost, salaries, system maintenance, and incidental costs. Indicators to measure commercial performance are based on the amount of tariff collected from customers.

In the KPI survey, two aspects had been surveyed to draw conclusions on sustainable management. These are the overall structure of the management team, the financial situation and tariff settings.

5.6.1. Structure of the Village Management Committee

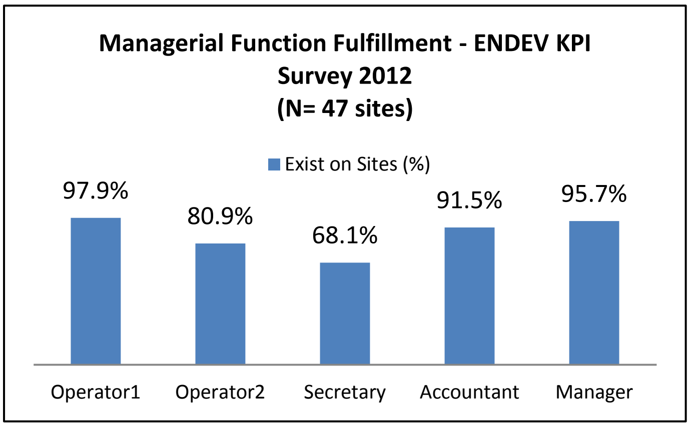
In order to maintain the MHP and keep the system running, a strong and reliable management team (i.e. village management committee [VMC]) is required.

Figure 5-24: Commercial Indicators- Size of Management Team



More than half of the surveyed sites (57%) had set up a team with five members according to the TSU recommendations, which comprise of two operators, a secretary, an accountant and a manager. A team of four members was managing the MHP in 26% of the sites.

Figure 5-25: Commercial Indicators - Managerial function fulfillment



Most sites have an operator (97% of the surveyed sites), a manager (95% of the surveyed sites) and an accountant (91% of the surveyed sites). The average percentage of women holding a position in each team is 10% of the surveyed sites.

In general, the initial management team was still in charge by the time of the survey. In only 6 out of 47 sites that the VMC had been reorganized and only one of these 6 sites reported that they did not provide any training for the new staff.

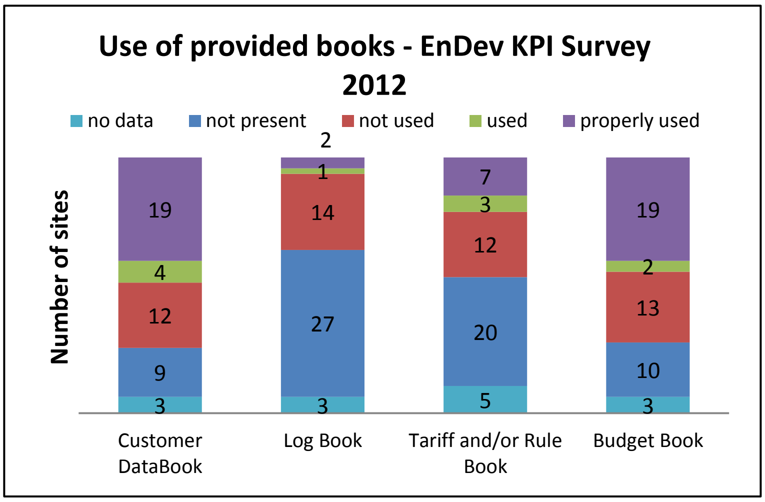
One indicator of how appreciated the management tasks are considered is the amount of salary. The following table shows the percentage of sites where the position was paid if it existed and their average salary. More than half of the sites paid their staff and typically the operator gets the highest average salary (this appears sensible, considering that the operator has the main responsibility of running the system in a daily basis). In the sites where both operators work voluntarily, the remaining team is not paid either.

Table 5.4: Commercial Indicators – Management Team Salary

Function	Number of sites with active position	Position receiving payment		Average Salary
	Number of sites	Number of sites	%	(IDR/month)
Operator1	46	30	65%	321,308.3
Operator2	38	25	66%	320,930.0
Secretary	32	17	53%	117,176.5
Accountant	43	24	56%	141,791.7
Manager	45	28	62%	161,035.7

To observe the quality of administrative work, the KPI survey posed a question about the condition of management books (log book, cash book, customer data book, etc.) which was provided by the TSU staff. Basis for a good administration is well-structured and maintained documentation on collected fee, budget and customers as well as a daily check of technical indicators and breakages. The survey found that the provided books have not been used to a satisfying extent. In 19 sites out of 47 sites, the *Customer Data* book and the *Budget book* had been properly used. In most of the surveyed sites, the provided *Log-book* and the *Tariff* book had not been used or is not even available at all. However, according to observations from the TSU surveyors, most of the sites established a customised way of documentation and used their own books. This self-initiative and customisation is a positive finding.

Figure 5-26: Commercial Indicators - Use of provided books



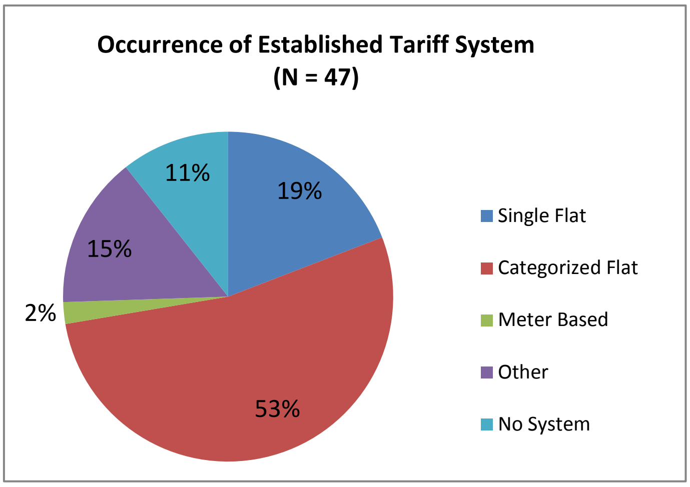
VMCs were established in almost all of the sites except in Duku-Mudiak Air village (SumBar010) and do provide consistent administration (albeit with room for improvement). Improvements have to be done in the field of monitoring and documentation. Clear objectives with simple and efficient method should be implemented to get an effective monitoring process towards achieving sustainability.

Prevalence of women involved in administration and management is very low (10%) and at present there is insufficient data to infer a correlation between gender balanced management team and system performance.

5.6.2. Financial Indicators

To run an MHP sustainably, the management team needs sufficient financial means to cover maintenance cost and management salary. Income for MHP management team is generated from the electricity tariff collected. The tariff system is also an indicator for community participation and their sense of appreciation and ownership.

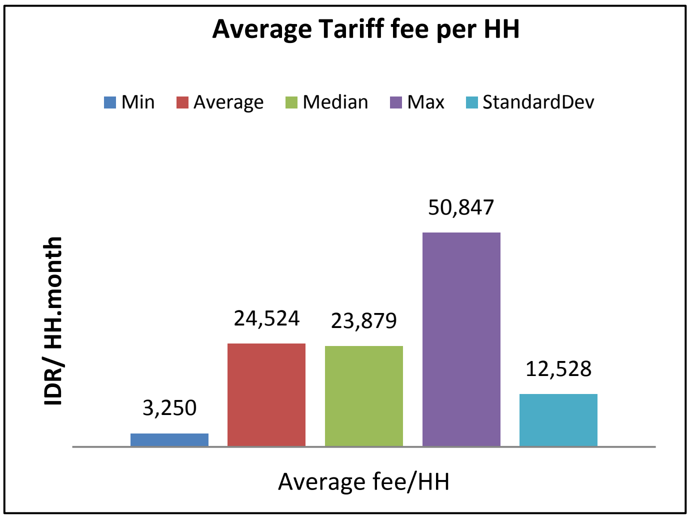
Figure 5-27: Commercial Indicators - Occurance of Tariff System



Sensitization and establishment of a tariff system was required to highlight community participation by paying for their MHP electricity. Challenges in observing this indicator in the KPI survey were that in 11% of the surveyed sites a tariff system had not been established yet or has not been running long enough to infer on its performance. Consequently, the available data is not always a reliable source and statistical results have to be looked at carefully.

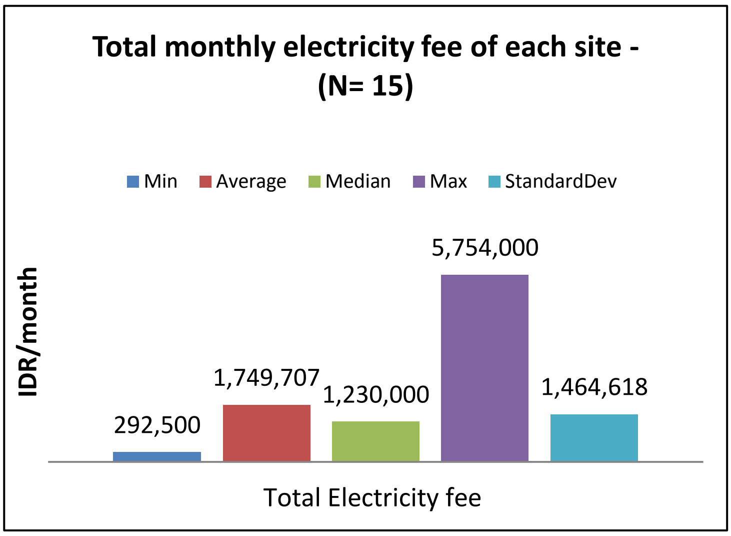
For the surveyed sites with an established tariff system, most apply a categorized Flat Tariff System. Although only 53% of the surveyed sites say that they use a categorized flat system, there are also sites who answered “other”, which have categorized flat systems in conjunction with other systems. This resulted in some data inconsistencies. Beside more than three categories in the categorized flat tariff, several sites base their categories on the number of appliances.

Figure 5-28: Commercial Indicators - Average Tariff fee per HH



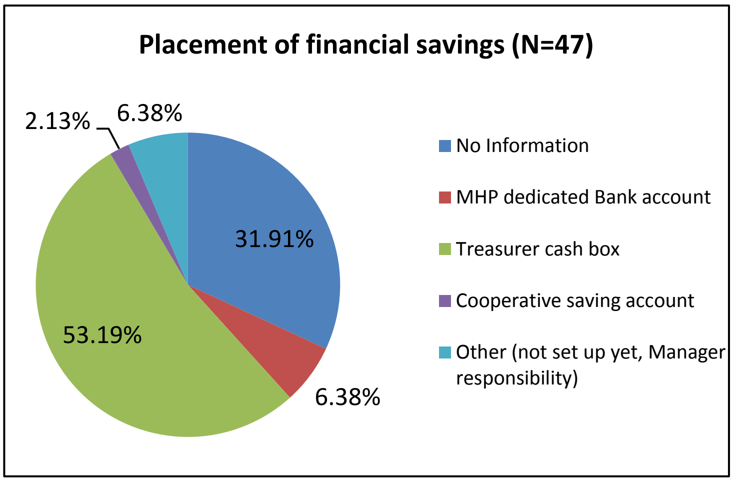
In order to compare the different tariff systems, the average fee per household was calculated. The data is based on information on how much income management expects each month and how many households had been connected. This analysis only uses 29 surveyed sites which can be considered as a reliable data source (section 0). The average tariff for the sample sites are IDR 24,524 per household per month. Lower tariffs are paid in those sites where it is based on the use of appliances. Higher average tariff per household are observed in the sites with Ampere-based tariff.

Figure 5-29: Commercial Indicators - Total monthly electricity fee of each site



Calculation on monthly expected income from electricity tariff is using the data of the expected tariff income not the actually collected income. Higher income indicates higher number of customers since the average tariff amount is quite similar. The graph, while only based on 15 sites, serves as an indicator of the amount of cash the management team has to handle on a regular basis, which bears a certain risk where the site is far from banking and/or cash deposit facilities.

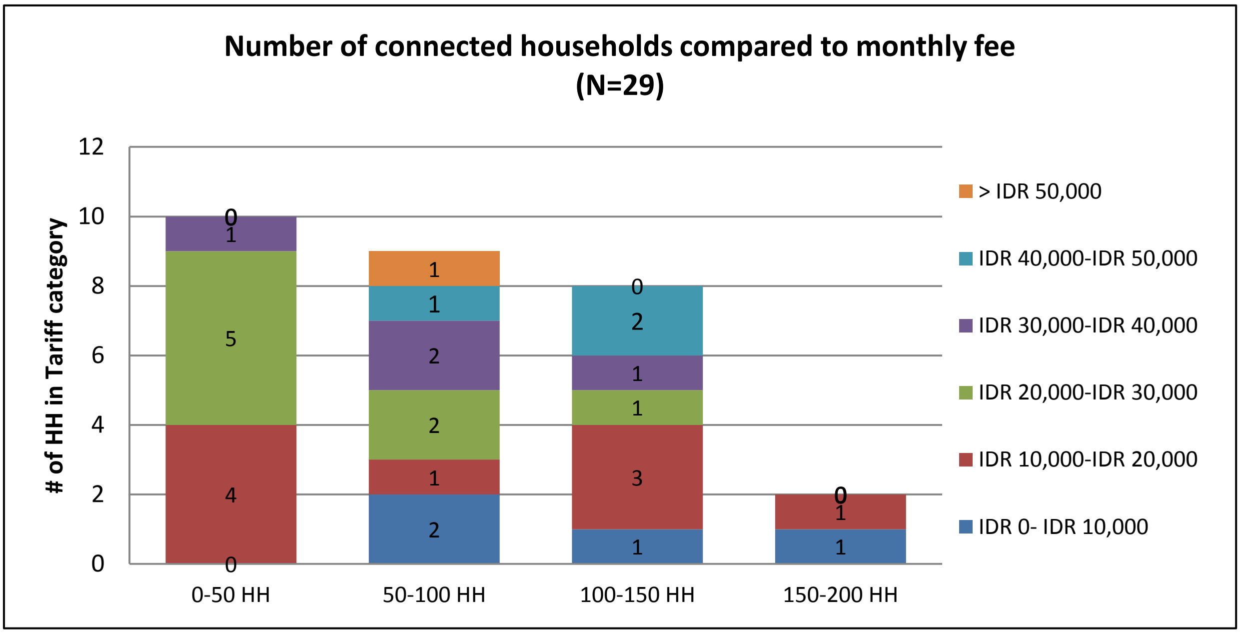
Figure 5-30: Commercial Indicators - Placement of financial savings



Out of the 47 surveyed sites, 32 submitted information on where the revenue and savings are placed. Almost 80% out of those (53% of all surveyed sits) keep their savings in a treasurer cash box. Only one site had a cooperative saving account (that also had the highest amount of savings amonst 15 sites of reliable financial data) and only 3 sites had a MHP dedicated bank acount. In one site the responsibility of the savings rests with the teams manager and 2 sites had no rule established yet.

The figure below shows that among the surveyed sites, the sites with less connected households tend to have lower fees. The finding raises a question on how can the management team cover the operational expenditure with their small income. Several management teams mentioned that they prefer to collect additional money to cover their major maintenance or repairs.

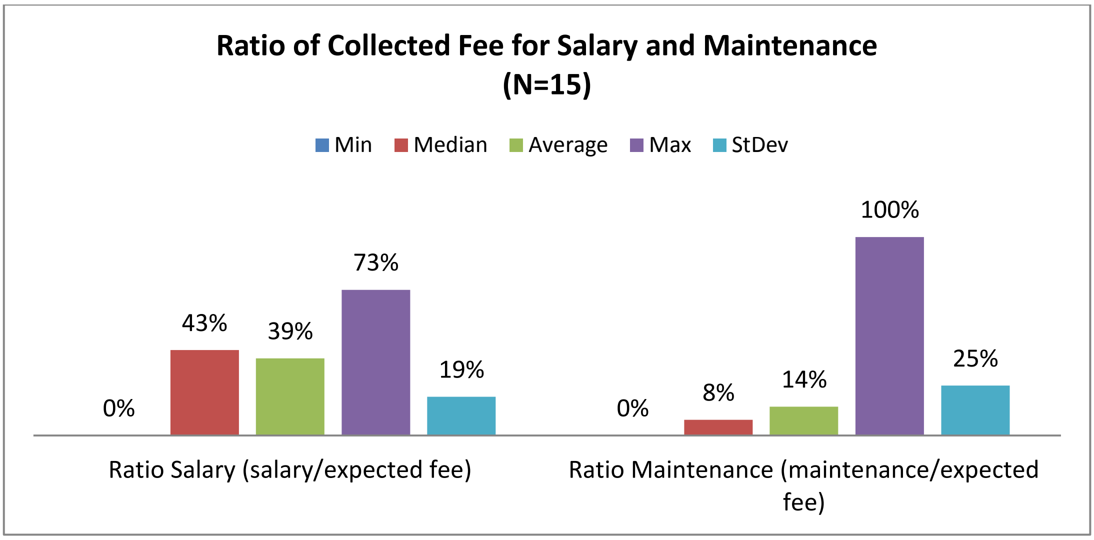
Figure 5-31: Commercial Indicators - Number of connected HH compared to monthly fee



5.6.2.1. Operational Expenditure

The management team spending on salaries and maintenance was assessed during the KPI survey. The ratio of salary was calculated by dividing the total monthly salary by the expected fee income. In terms of maintenance cost, both the monthly and total maintenance costs had been considered (section 5.6.2). The ratio for maintenance cost was calculated by calculating the average monthly maintenance cost among the 15 surveyed sites which had reliable data.

Figure 5-32: Commercial Indicators - Ratio of Collected Fee for Salary and Maintenance



5.6.2.2. Savings

To calculate the financial savings in terms of supplied kWh, the total savings data and the consumed electricity (kWh) are necessary.

Figure 5-33: Commercial Indicators - Savings per kWh

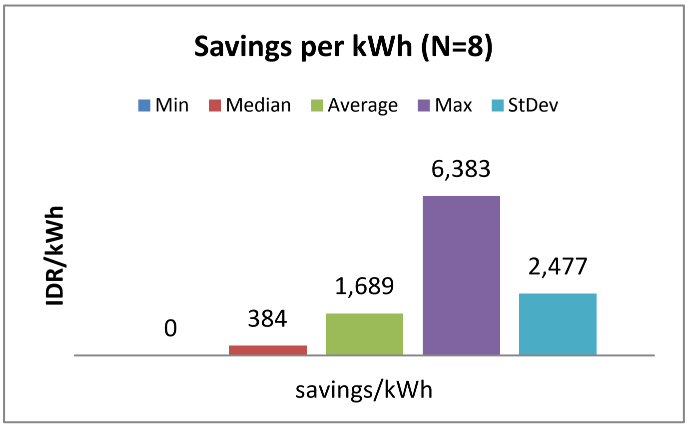


Figure 5-34: Commercial Indicators - Total Savings

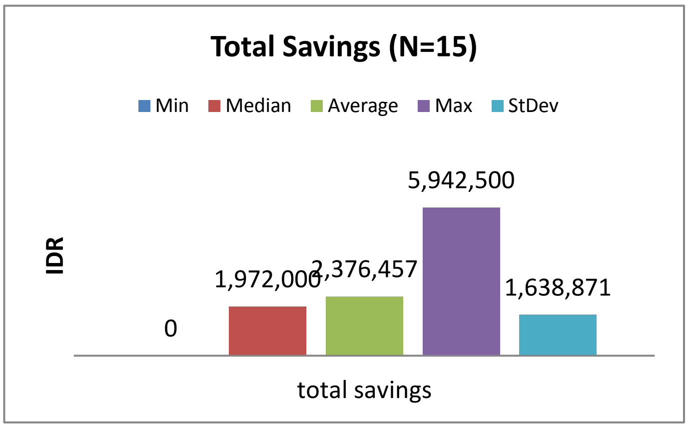
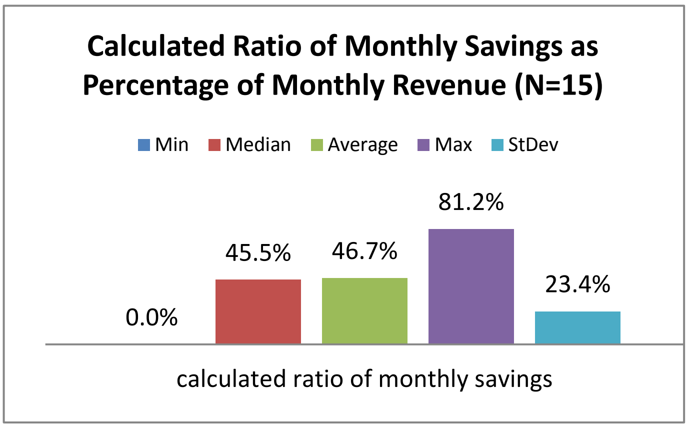


Figure 5-35: Commercial Indicators-revenue/saving ratio



Up until the KPI survey was conducted, only 21 of the surveyed sites were installed with kWh meters, while only 8 of them provide sufficient information on the saving account situation. The indicator for savings per kWh only represents the 8 data and no clear conclusions can be inferred due to the small size of data (17% of the surveyed sites). Savings per kWh supplied indicator vary from 6,383 IDR to 0 IDR.

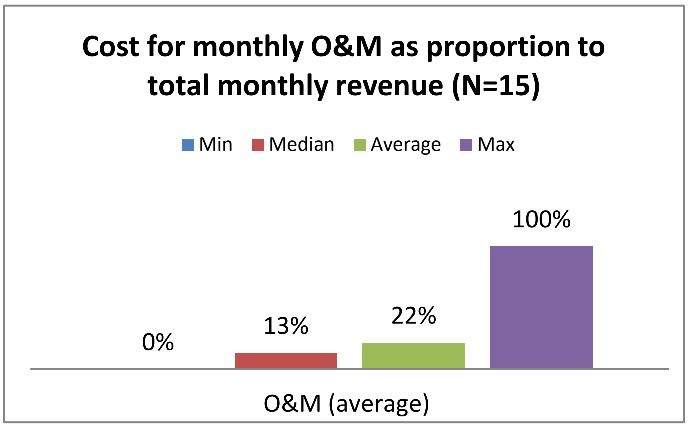
While savings per kWh indicates the future expected amount of savings, the total amount of available savings give information on the availability of funds to overcome any unexpected breakages. A median of almost IDR 2,000,000 in savings ensures that future costs for maintenance, repairs as well as the salary for a reliable management team can be paid.

There are 15 total saving data and only one site without savings. No saving occurred as a consequence of their tariff policy to exclude the maintenance cost from tariff system and collect additional money if maintenances had to be done instead. This system works as long as every customer is prepared to pay a different amount each time, but may be difficult to maintain, when larger investments have to be done.

In order to ensure the MHP's sustainability, revenue is collected from connected households, which is used to pay the VMC members and save funds for maintenance and future replacement. VMC training is conducted under MHP-TSU and the proportion between savings and operational overheads is an indication of how well a VMC accommodates future expenditures.

Of the 47 sites surveyed, only 15 sites maintain sufficiently concise financial records to determine whether the community will have sufficient resources, by saving an average of 45% of total revenue for future expenses.

Figure 5-36: Commercial Indicators - monthly O&M costs



The figure serves as an indication of the proportion of funds, out of total revenue collected, which is spent on monthly operation and maintenance expenses. In average, about a quarter of total revenue is spent on consumables and smaller replacement parts.

For the site indicating a maximum of 100% no regular revenue collection is done and maintenance expenses are covered collectively by the community as and when they occur. Thus the VMC does not have direct access to its own financial resources and needs to routinely liaise with the community.

5.6.2.3. Electricity supplying cost

The electricity supplying cost indicator aims to give an indication about the amount of money that was spent to provide the electricity as demanded by the customer. Since there are a number of elements that affect the supply cost, various scenarios were tested and compared and are reported on in more detail in **Appendix A: Scenarios for electricity supply costs**.

Equation 1 – Electricity supply costs

$$Electricity\ supplying\ \ cost = \frac{COST_{Capital}}{CAPACITY_{measured}\ \times\ CF\ \times\ 8760\ \times\ 10}$$

Equation above explains that the electricity supplying cost indicator is affected by development budget, the MHP capacity which was measured during commissioning[3], and capacity factor. By defining a period of analysis of 10 years, the operating cost projection is negligible compared to capital cost.

Equation 2 – Capacity factor

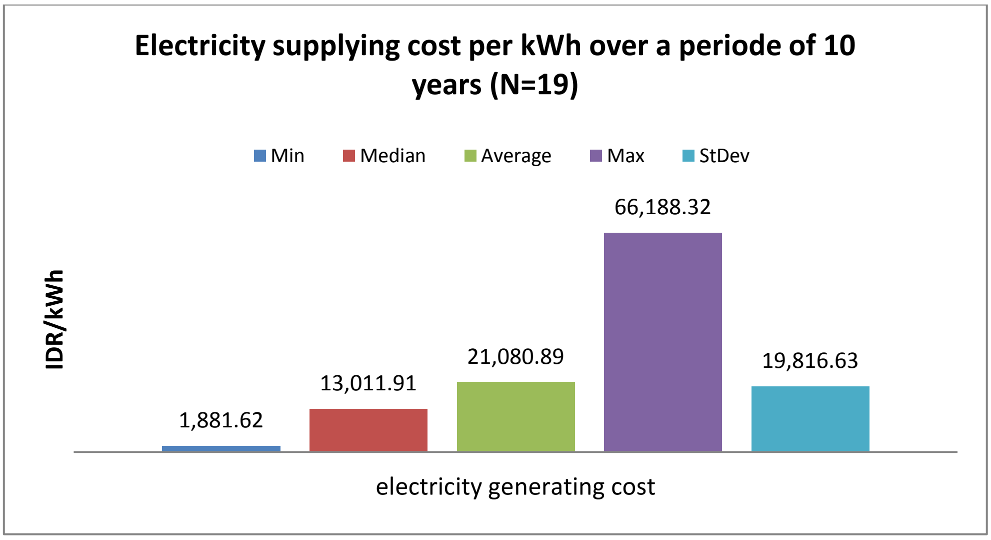
$$Capacity\ Factor = \frac{KWH_{MainLoad}}{CAPACITY_{measured}\ \times OPERATION_{days}\ \times\ 24}$$

KWh main load means the electricity that is supplied to the grid and measured by the kWh meter in the power house. Operation days describes the time between initial operation of the MHP and the date of KPI survey in the particular MHP.

[3] Commissioning is a process to ensure readiness and safety of an electrical system and to validate amount of power that can be produced by the MHP scheme at maximum capacity.

The figure below shows that the electricity supplying cost of the 19 surveyed sites is within the range of IDR 1,900 /kWh to IDR 66,000 /kWh. Nevertheless, the average of the electricity supplying cost is 21,000 IDR/kWh with median of 13,000 IDR/kWh.

Figure 5-37: Electricity supplying cost per kWh



The value of the indicator is varying among the surveyed sites. It is caused by its dependency on the capacity factor and capital cost (development budget) as explained in the graph of dependency analysis.

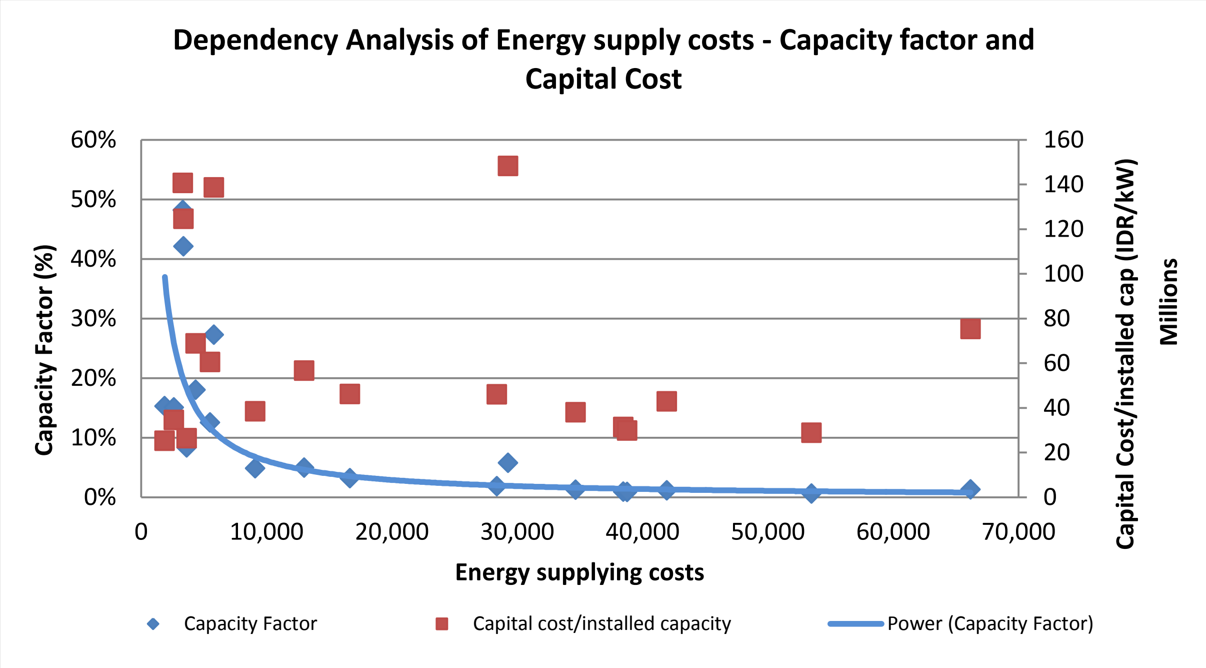
From the graph, we can see that the capacity factor has the power[4] function which has stronger influence to the electricity supplying cost than the capital cost with its linear function. Increasing the capacity factor in each sites to 50% results in an electricity supplying cost average of IDR 1,400/kWh.

Meanwhile, keeping the actual capacity factor and decreasing the capital cost by 50% result in an electricity supplying cost average of 10,540 IDR/kWh[5].

Influence of the capacity factor is thus significantly higher than the influence of capital cost. In addition to that, for the sites that had been running for longer period tend to have higher capacity factor. The tendency is considered as a consequence of community adaptation to the MHP and increasing usage of electricity appliances (hence greater demand for the MHP electricity), while previously unconnected houses also receive access.

[4] Power function is defined as $y = ax^n$ where *a,n* – constants
[5] Scenario analysis of the electricity generating cost can be found in the appendix.

Figure 5-38: Dependency analysis



The above graph shows the capacity factors (blue diamond) and the capital cost per kW (red square) calculated for 19 MHP sites. The two data sets are vertically aligned for each site, which thus allows for a comparison between a certain site's power factor and capital cost/kW. The blue trend line shows the correlation between the energy supplying costs (IDR/kWh) and capacity factor. The former improving (i.e. energy supplying cost) markedly once a capacity factor exceeding 10% is achieved.

In the other hand, capacity factor of the surveyed MHP sites are increasing over time. The sites which had been running longer have higher capacity factor (see **Appendix A: Scenarios for electricity supply costs**). It takes time for the community to climb their learning curve on using electricity and getting more use out of it. Indications that were found during the survey showed that less houses were connected in the initial operation period and more houses were connected afterwards coincide with more appliances being used. In conclusion, enforcing a reliable energy production and connect more customers, PUE and appliances will have positive influence on the cost of energy supply by the MHP scheme.

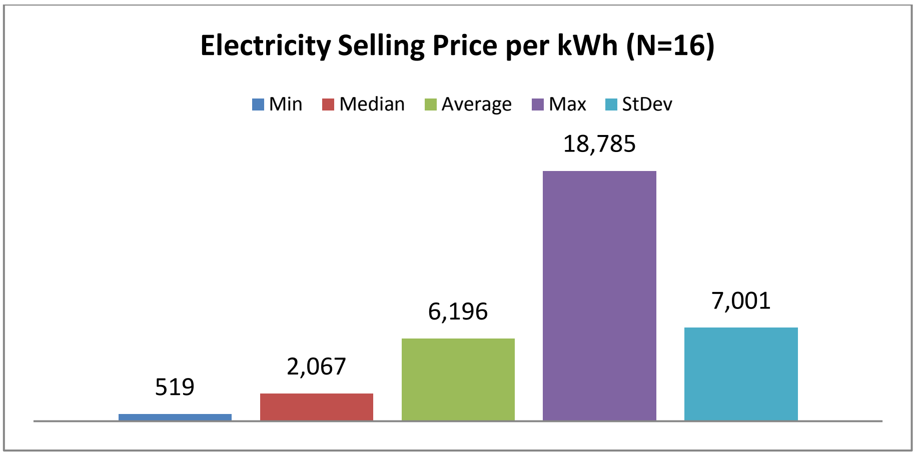
5.6.2.4. Electricity selling price

The electricity selling price per kWh aims to give an indication of the electricity price for each kWh supplied from the MHP. Using the kWh unit makes the indicator comparable to other electricity prices such as from PLN, diesel generators or other renewable energies.

$$Electricity\ selling\ price = \frac{FeeMonth_{exp}}{CAPACITY_{measured} \times CF \times 24 \times 30}$$

Expected monthly electricity fee ($FeeMonth_{exp}$) is the sum of the electricity fee from all the connected houses according to the tariff. The high deviation between the selling prices of different sites is mainly a result of different scales of electricity production. Sites that produce less kWh than other sites tend to have a higher selling price which results from the tariff concept of paying a monthly flat fee.

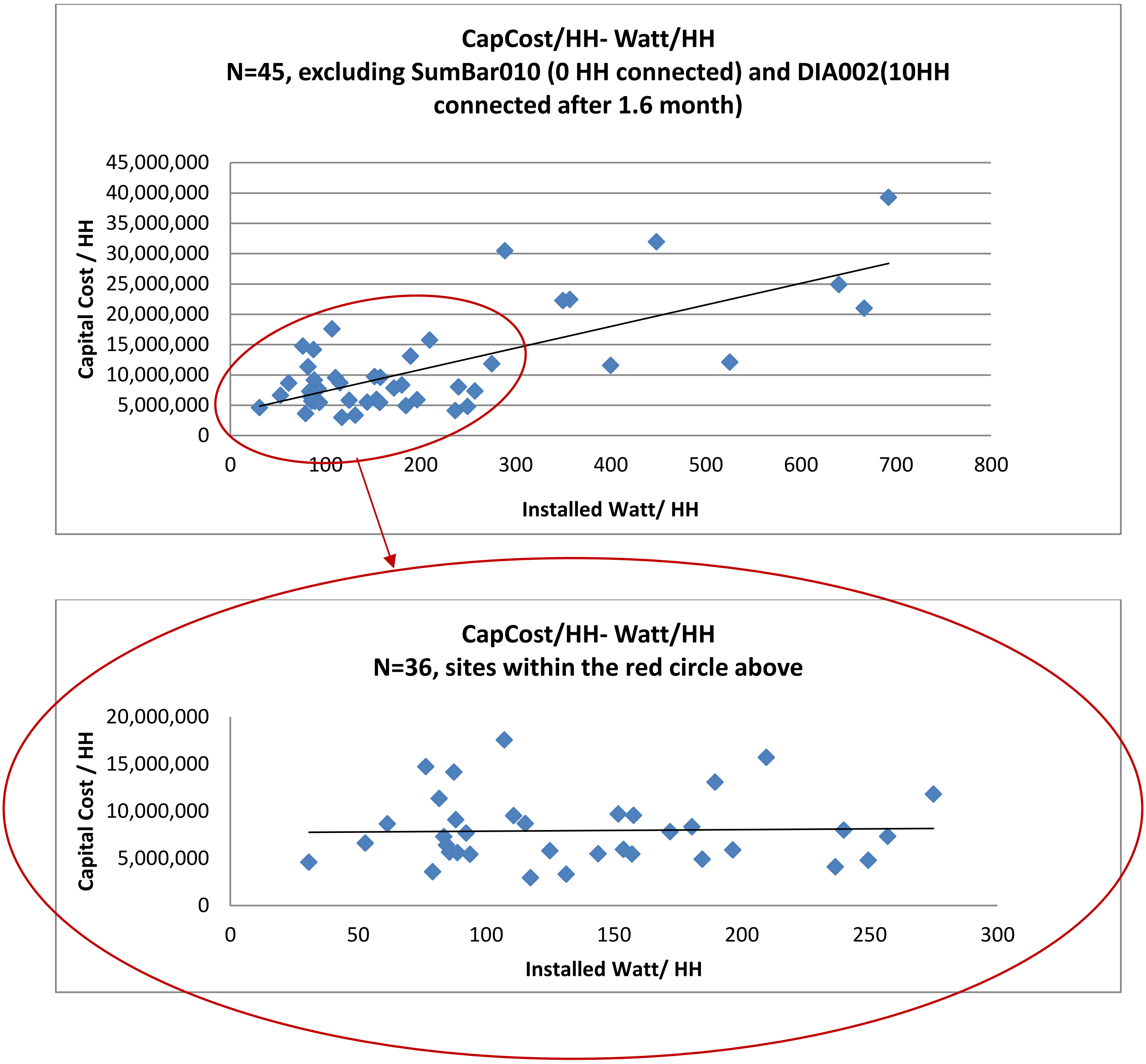
Figure 5-39: Commercial Indicators - Electricity selling price per kWh



5.6.2.5. Capital Cost/HH - Installed Watt/HH

The following graph visualizes the correlation between capital cost per connected household and installed Watt per connected household. It shows a positive correlation, although 80% of the considered sites (45) are clustered in a range of 31-275 installed W/HH and a Capital Cost between IDR 2,943,095/HH and IDR 17,544,393 IDR/HH. A closer look on the 80% of sites shows, that within this group there is only a small positive relationship. Moreover, the 9 sites with a higher Watt/HH had only connected 39% (min 7%, max 83%) of the targeted households, whereas sites with the lower Watt/HH had already 67% (min 16% , max 116%) of the targeted households connected. In conclusion, sites with high capital cost and high installed capacity per household were originally designed to connect more household and it is thus likely that the installed capacity (W/HH) would decrease, as additional households are connected.

Figure 5-40: Commercial Indicators - Capital cost/household and installed Watt/household



5.7. Performance Indicators and Status Quo of MHP

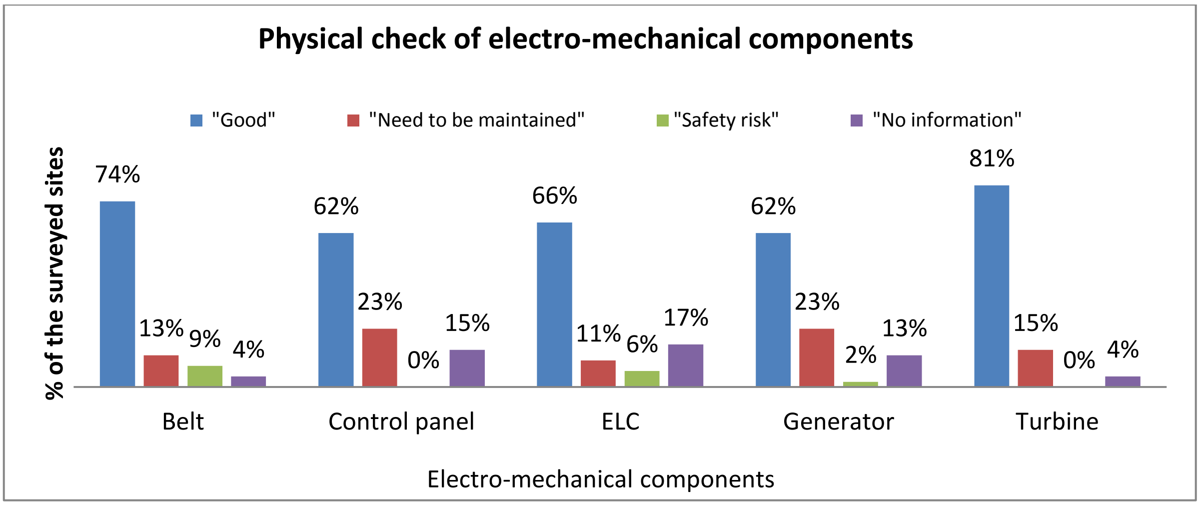
The KPI questionnaire not only covered topics on financial and operational status. The field staff additionally assessed the physical condition of the MHP. A total of 55 criteria for 15 components had to be checked whether they are in a good condition or not. The criteria for "good condition" for each of the components were pre-defined. Through the verification process the surveyor had to decide whether the good condition is fulfilled (F), not fulfilled (NF) or the question is not necessary (NN) for each of the criteria in every component. Furthermore the surveyor had to infer whether the component working good (G), had to be maintained (M) or whether there is a severe risk to the safety of the MHP environment (SR) based on their findings, by checking through the pre-defined criteria. Blank tick boxes are considered to contain no information (NI).

Table 5.5: Example of Physical Condition Check

Component	Criteria	Fulfilled (F)	Not fulfilled (NF)	Not necessary (NN)	No information (NI)
Turbine	Good condition of welding	100.0%	0.0%	0.0%	0.0%
Belt	Good condition of belt	97.9%	2.1%	0.0%	0.0%
Generator	Good cable condition	95.7%	2.1%	0.0%	2.1%

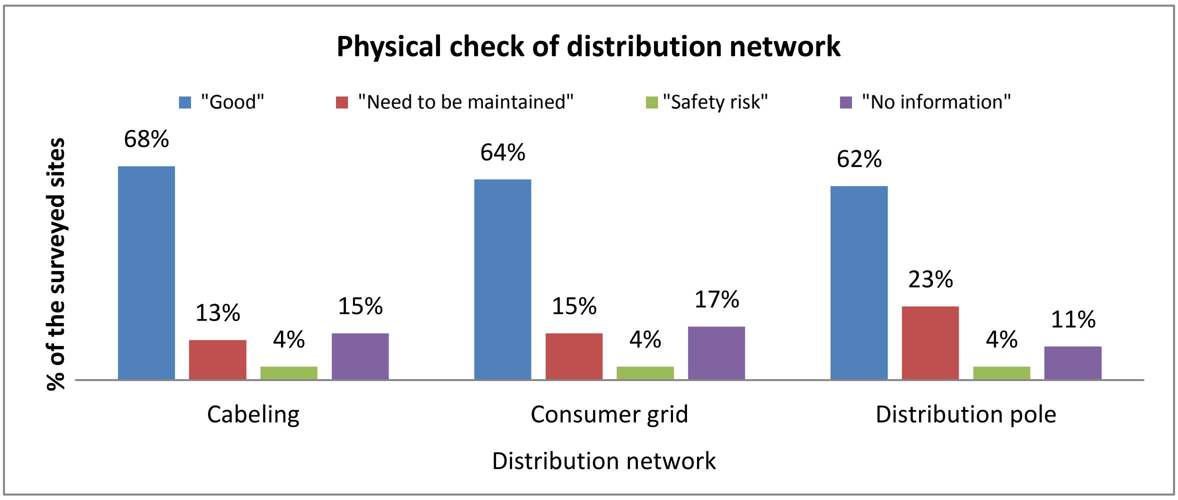
As we can see from the table of physical check for electro-mechanical component, 100% of the surveyed sites were in a good condition of welding, a good condition of the belt (in 98% of them) and good conditions of the cables connected to the generator (96% of the surveyed sites).The condition of electro-mechanical components is shown in Figure 5-41, where most of the components are in good condition. There are 9% of the surveyed sites have safety issues in their belt component. It is mostly because of the belt not being caged.

Figure 5-41: Physical check of electro-mechanical components



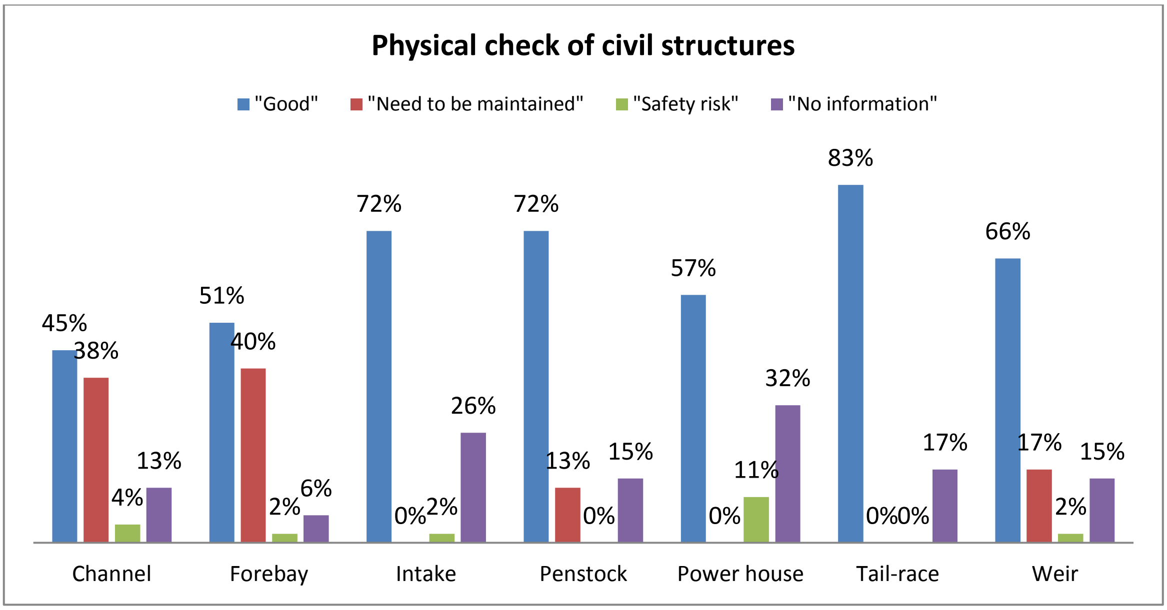
Regarding the distribution network, more than half of the surveyed sites have good distribution network facilities. The community should pay attention to maintain the network since there are 23% of the surveyed sites where distribution faults were detected.

Figure 5-42: Physical check of distribution network



Regarding civil works, forebay and channel are the components that need to be maintained in almost half of the surveyed sites. Channels are often broken because of the vegetation near the channel, sedimentation, and landslides and in some areas the MHP operation was disrupted because of these. More regular forebay and channel maintenance could significantly reduce problems from occurring.

Figure 5-43: Physical check of civil structures



Concerning an overall technical assessment, two interpretations are possible that complement each other. Firstly, the average fulfilment rate of all criteria related to one component and in addition, the overall assessment of this component.

Table 5.6: Components with good physical condition

Component	Average fulfilment rate	Overall assessment: Good
Turbine	92%	81%
Intake	89%	72%
Belt	89%	74%
Tail-Race	86%	83%

In conclusion, **Turbine, Intake, Belt and Tail-race** were generally found to be in the best condition. Although the overall assessment gives a more qualitative analysis, average fulfilment rate shows, that a good assessment can be based on a high rate of fulfilled criteria.

On the other hand critical assessment is more complex. A high average "non-fulfilment" does not necessarily indicate a safety risk. In addition, "no information" was given more frequently in the overall assessment compared to the specified criteria. For example the **consumer grid** showed the highest rate of "non-fulfilled" criteria because grid expansion was still running during the time of the survey and some sites had already run out of budget for the MHP grid. Therefore the overall assessment was nevertheless positive. Components that mostly had to be maintained were **forebay** and **channel** and the highest safety risk were observed at the **power house**. Moreover, the same phenomenon of correlation between "no information" and critical assessment is prevalent in terms of overall assessment as well.

Table 5.7: Components with poor physical condition

Component	Average "non-fulfilment" rate	Overall assessment: Maintained (M)	Overall assessment: Safety risk (SR)	Overall assessment: No information (NI)
Fore bay	13%	40%	2%	6%
Channel	18%	38%	4%	13%
Powerhouse	18%	0%	11%	32%
Consumer Grid	23%	15%	4%	17%

Out of 47 sites, 16 claimed that at least one of the components threatens the MHP's safety. The main reasons behind is that the belt is not covered and no lightening-protection rod is grounded in the power house.

6. Survey Challenges and Solution

Several challenges were identified while conducting the KPI survey on the field as well as during data processing. The following chapter highlights major problems that occurred during the survey.

6.1. Motivation of Surveyor and the Survey's Purpose

A challenge on conducting the KPI survey was dealing with various perceptions among field surveyors on the purpose of the survey and ensuring motivation to undertake the survey diligently and with prudence. The KPI survey was not adequately considered during initial project planning, and field staff regarded the activity as an additional burden and add-on to their work load. There are two types of main motivation problems that arise in the field: a lack of motivation and unrealistic expectations.

6.1.1. Lack of Motivation

6.1.1.1. Irrelevant Question

KPI survey is a very comprehensive survey including technical, financial, consumer and management aspect. However, since the sites are mostly in their early stage of operation (a few months old) many questions were viewed as irrelevant by both respondents and surveyor. Asking perceptively irrelevant questions influenced willingness to provide better, more detailed answers (even for important question).

For example, in one particular site Sebayur (Beng025) Sebayur, they had not established any village rules regarding fee collection, had a serious social conflict regarding electricity and their turbine is only capable of supplying electricity to one electric phase at a time. Power interruptions and fluctuations are thus a constant nuisance. Some villagers declined to cooperate during the survey because of their prior dissatisfaction with MHP service. Although some people were still cooperative, the survey was not conclusive on many issues and aspects such as productive use of energy (PUE) and types of appliances were considered irrelevant by the respondents. Surveyor confronted with such a frustrated site, were most tempted to cut interviews short and avoid lengthy discussions.

The MHP managerial aspects, which involved interaction and coordination with the village head was perceived beyond the technician's more technical responsibilities. They maintain that MHP management success is highly dependent on socio-cultural aspects of MHP community, rather than proper training and social setup. While there is no doubt that human psychology and behaviour are playing a big role on effective MHP management (therefore sometimes result of all the community preparations and trainings differ among sites) an assessment of managerial issues is essential in order to define wider managerial short-comings.

6.1.1.2. Misperception

There was a perception that the purpose of KPI survey was to evaluate the work quality of all the field technicians, who also acted as surveyors. Rather than perceiving the KPI survey as an opportunity for reflection through objective data collection, there was a temptation to be biased. Communication between the coordinating MHP specialist and their field technicians/surveyors in a particular region should be improved especially in explaining the purpose of the mission before it is performed.

6.1.1.3. Work Priorities

Most of the field surveyors are TSU technicians that had urgent missions to support construction and commissioning of the remaining MHP sites in parallel with KPI survey. TSU support will conclude by end 2012 and there are approximately 45% of Green PNPM – MHP sites still under construction and need to be commissioned within this period. Supporting technical aspects for these sites are MHP-TSU main priority. Understanding this, several of the KPI surveys were conducted by the authors of this study themselves. Nonetheless TSU technicians were required to undertake the surveys as well, which conflicted with their work load.

6.1.2. High Expectation

High expectation often occurred when there is an irregular visit from an institution, including GIZ. Since August 2012, several sites in Sumatera Barat have become village pilots for Productive Use of Energy initiatives who were provided with several appliances for income generating activities. The information caused high expectation regarding irregular survey visit from GIZ for the KPI assessment. During survey in Bengkulu, some TSU technicians had mistakenly believed that the KPI survey will be used as a basis for another PUE appliances support initiative. Clear purpose and communication before and during the visit should be maintained to explain carefully the objective of the KPI survey.

6.2. Defining the MHP target area

An MHP sites does not necessarily supply electricity for the all houses in a village. Some MHP only supply a few house clusters or hamlets in the same village or nearby village. In order to handle this confusion, clarifying the MHP target area is essential.

The MHP target area is a defined area consisting of HH, PUE, and SI which is intended to be connected to the MHP according to the management team plan and as a basis for making *Detailed Engineering Design* (DED) from TSU. Therefore the KPI survey was restricted to the MHP target area.

Figure 6-2: MHP Target Area as part of one village

Figure 6-1: MHP Target Area as part of two villages

Different terminologies distinguish the different data sources and are summarised in the following table.

Table 6.1: Terminology for connected and targeted households

Terminology	Record	Data Source
Actual Connected Household	MHP Fee Collection Books	KPI Survey
Total Households in Target Area (MHP, diesel +PV, PLN, not connected)	MHP Management Team Data or retention	KPI Survey
Targeted Households to be connected	TSU data during site verification	Form-B Demographic/Field Survey
Expected Households to be connected	PNPM data	Form-A/ Proposal

The KPI survey compared data between the "Total Households in Target Area" obtained from KPI Survey and "Targeted Households to be connected" from Form-B in the proposal verification stage. The "Actual Connected Household" can be different due to technical or financial problems in the field.

However, KPI survey data shows that the number of "Total Households in Target Area" differs significantly from the number of "Expected Connected Household". This fact indicates that several data might not have been verified properly. "Actual Connected Household" data was easily verified by checking on the management administration book either in Customer Register Book or Fee Collection Book. These books clearly display the name of the head of each household and the amount of money they had paid, and this data is considered more reliable than other data.

Figure 6-3: Verification of the number of "Actual Connected Household" during KPI Survey a) interview with management team b) photo of fee collection book record

It should be emphasized that the Registration Book often lists customers based on number of connected houses, whereas in some village in Indonesia more than one household can live in a same house. Discrepancies between these two numbers occured several times.

There is no easy way to verify whether the number of "Total Household in Target Area" is accurate other than counting the houses manually (considering the houses may be widely scattered). This was a major challenge since the concept of "MHP Target Area" has no clear physical boundary and there was no record of planned data on the management team. Management team members only remembered which houses still needed to be connected to the MHP and which were connected to another another source. There are also several caases that the inhibitants had left the village. Clear definition and perception among surveyor need to be improved.

6.3. Measurement of Technical Performance

Measurement of the condition of technical performance faces five kinds of problems:

a. Lack of metering equipment
b. Unclear time of meter installation
c. Mistakes on meter reading by field technician
d. Display is not working properly
e. Different Perception on the question

To anticipate mistakes in meter reading, each field surveyor was obliged to take pictures of the kWh-meter and hour-meter reading. Since kWh-meter and hour-meter reading is cumulative data, it is not sensitive to daily or weekly load cycle unlike volt-meter, ampere-meter and frequency-meter.

Figure 6-4: Measuring MHP Technical Performance a) meter reading on KPI Survey b) photo of various installed electrical meters installed on the control panel

Mistakes often happen in reading the kWh-meter and hour-meter display. Most common mistake on kWh-meter and hour-meter reading is when reading the decimal values. This mistake could lead to 10 times higher value of kWh-meter and hour-meter reading than actually is the case.

Most of the sites were equipped by volt--meter, ampere-meter and frequency-meter but most of the sites are not equipped with kWh-meter and hour-meter. Therefore, field surveyors could only record data during the time they visited the site.

6.4. Assessment of MHP Team Financial Condition

Five common challenges on MHP financial conditions assessment are:

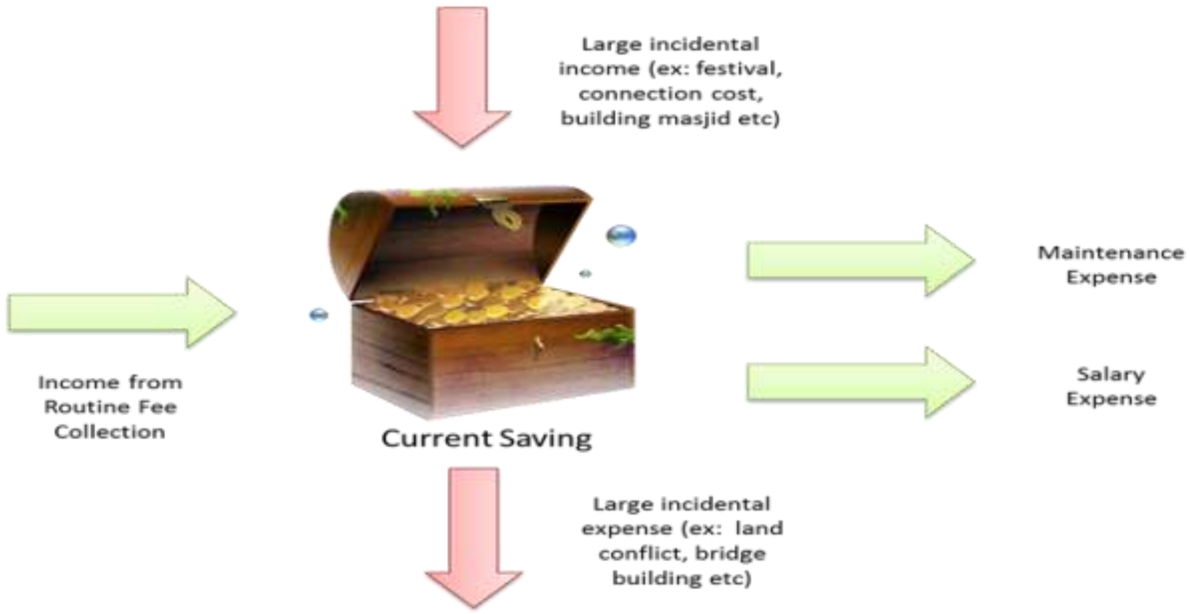
a. The villages have not established village rules and tariff system yet
b. Operation of the MHP is not settled yet
c. Survey questions were vulnerable to misinterpretation and did not cater for incidental expenditure and income

d. Various tariff schemes
e. Some targeted customers houses are not connected yet

In some sites, MHP management cannot collect any fee from the customers since the village regulation is not established yet, as a result of social circumstances and the only recently commissioned MHP.

Since most sites have been operational for only few months, the MHP management and system operation is not stable yet. Maintenance expenses data for example, show zero maintenance expenses in most sites since the components are still very new and have not experienced any breakdowns yet. The following cash flow diagram visualizes another challenge in collecting financial data. The survey aims to capture routine income and expense (green arrows) in order to predict current and future savings. However, especially new systems show large incidental income and expenses that have significant effect on the current financial status.

Figure 6-5: Cash Flow Diagram on MHP Management Financial Condition



In addition to incidental expenses, calculation on routine income and expenses in some survey data show inconsistency. This might result from misunderstanding the exact nature of data that was needed to be collected. As an example, collection ratio defines the proportion of income that is actually collected with the total expected income collected according to the tariff rule. According to this definition, collection ratio should range from 0% to 100% as higher number shows higher payment morality.

Figure 6-6: Definition of Fee Collection Ratio: Actual Fee Collection divided by Expected Fee to collect

Several questionnaires from the surveyed sites mentioned that the actual fee collected can be more than 100% of expected fee collected. It might be due to confusing income derived from regular collection fee, which is mentioned in the tariff scheme, with income from an initial once-off connection fee. To connect the houses to the MHP grid, several sites apply additional cost for initial connection to the requested houses. In few surveyed sites, the initial connection cost had included kWh meter for the customers.

6.5. PUE Definition Problem

The terminology and definition of Productive Use of Energy (PUE) posed significant challenges in the field. The definition required thorough explanation to avoid misunderstanding. The table below describes terminologies that are used in the survey.

Table 6.2: Common misinterpretation on definition

Terminologies	Common Misinterpretation	Solution
Productive Use of Energy	It has to be related to big capacity electricity appliances using MHP (ex: rice huller, welding machine) Manual appliances do not count toward PUE.	Get preliminary information about livelihood Give examples, mention small business that is often overlooked Ask for diesel machinery Look around the villages
Warung	Smaller *warung* (kiosk) does not count	Look around the villages for small kiosk Make it clear that kiosk, using electric light or other appliances, count as *warung* If surveyor was in doubt, they can make list of small businesses which can be double-checked during data entry to avoid wrong categorisation
Small Business	Concept not clear, interviewee does not remember examples mentioned in the manual	Give more examples of businesses with small number of staff (about 2 staff, excluding the owner)
Community Business	No misunderstandings recorded , due to familiarity with cooperatives in Indonesia	
Workshop	Common perception on automotive workshop and neglected carpentry or furniture workshop.	Give examples If surveyor in doubt, they can list it in "other" then it can be checked during data entry to avoid wrong categorisation

There are cases, Sebayur (Beng025) as an example, the community situation was not conducive due to inadequate service of the MHP. Therefor questions regarding PUE were considered irrelevant, since the basic service for household lighting had not even been fulfilled because of dry season.

7. Conclusion and lessons learned

The KPI Survey was conducted in September 2012 which had successfully collected data from the 47 sites which had been supported by the MHP-TSU. The purpose of the survey was to measure performance of the TSU supported sites using Key Performance Indicators (KPI) in terms of sustainability. Apart from verifying the number of connected and non-connected households, three topics related to sustainability had been covered

a. Operational status: Reliability of the MHP operation and observe their challenges
b. Financial status: Accountability of administration and financial aspects of the management team to guarantee sustainability of the MHP schemes
c. Physical site check: Current condition of the MHP.

During the planning phase effort was taken to formulate the questions as simple and as clear as possible, while still being able to collect a broad variety of data. However, questions had been interpreted differently especially in the financial section.

Field surveyors experienced several challenges ranging from difficult accessibility of the MHP site to misinterpretation of the survey questions. There are several improvements that should be implemented in the next KPI survey, such as clearer formulation of questions and describing the purpose of questions; avoiding misinterpretations of definitions and incomplete technical measurements on site; and considering mechanisms to accommodate unaccountable financial documentation; more pictures have to be taken of all relevant objects on site to allow cross-checking; and data evaluation requires systematic cross-checking, verification and classification to select reliable and representative data sets.

The KPI survey evaluation presents a diverse-angle of 47 sites in Sumatra and Sulawesi. Data evaluation uses spreadsheet-based software which is flexible for both quantitative and qualitative analyses.

The following are the summarised lessons learned from the KPI survey result

a. 3,211 households, 253 productive uses of energy and 129 social institutions had been connected to MHPs in 47 sites.
b. Construction on MHP consumer grid had not been completed in some sites and is the main reasons for high numbers of non-connected households.
c. A significant number discrepancy between targeted and total connected households had been observed. Data which was used in planning phase should be verified carefully which require clear definition or boundary of target area. The planning should consider PLN grid expansion within 2-5 years from the planning phase. .
d. With median of 63% for availability factor and 6.1% for capacity factor, the ratios are considered extremely low.
e. Low capacity factor implies that the electricity usage was low due to few households connected or less appliances being used. There is thus a potential for additional consumer or productive use of energy to connect to the MHP.
f. Low availability factor indicates two aspects, comprise low operating hours that MHP did not operate for 24 hours, 7 days a week; and the operation experienced significant technical problems which could be caused by natural forces or inadequate maintenance.

g. While both the capacity factor and availability factor can improve by encouraging more consumer demand, it should be done in tandem with an increased electricity tariff (preferable consumption based). This should maintain the balance between service provided and revenue collected.
h. Measurement tools, especially for technical parameters such as kWh-meters, have to be installed. The value of panel indicators and urgency for replacing broken indicators in the panel should be communicated with the management team.
i. Electricity supply cost can be significantly reduced by increasing the capacity factor of the MHP scheme. If the capacity of the MHP is used effectively by connecting more houses and productive appliances, the cost will be decreased.
j. The physical site check reveals that though the overall condition of the surveyed sites in general is good, 16 out of 47 sites stated that at least one of their components poses a safety risk. Main risks are absence of grounding cable for lightning rod in powerhouse and exposed drive belt.
k. The most common breakages of electrical-mechanical equipment occurred on turbine, generator and controller. From civil structures, most common problems are reported on channel, forebay and blockages.
l. Though several criteria had been mentioned in the questionnaires to help field surveyors in making judgment on the overall condition of each component, bias still needs to be reduced to make the physical site check more comparable among the surveyed sites. There is still room for improvement to guarantee a more objective result.
m. MHP administration needs time to properly set up the managerial system, in order to become more accountable and provide comparable financial data.
n. In some surveyed sites, the tariff setting was not yet finalised by the time of the survey. The surveyed sites with existing and settled management team mostly run well.
o. Though generally speaking the provided books had not been used properly, some management team had made their own record books, which should be reviewed as means to improve on a new documentation approach.
p. Payment morality is satisfying in those sites which are able to provide reliable data.
q. Financial data is complex due to varying tariff systems with incidental income and expenses.
r. Dry season significantly affected water availability to the inactive sites the situation is higher than previously estimated. This should be considered as research question for the next survey.
s. Deforestation appears to be the root-cause for poor MHP performance at several sites. Incidences of flooding, landslides and consequential damage to infrastructure are more prevalent at sites with a high rate of observed deforestation. While this could not be quantified during the KPI survey, mitigation measures to counter the effects of deforestation are highly recommended.
t. The availability of spare parts for routine maintenance activities seems to be of little concern, as operators have reported that they have no trouble sourcing consumables (e.g. grease) and wear and tear parts (e.g. belts).

Appendix A: Scenarios for the electricity supply cost

Introduction

The Electricity Supply Cost or Electricity Generation Cost indicator refers to the amount of money that is spent to supply the electricity. It is defined as "supply" cost because it considers the kilo-Watt hours needed, and supplied, to satisfy the main load, i.e. actually consumed by the customers. It does not consider the amount of energy generated, of which a varying proportion may be dissipated through a ballast or dump load. According to the formula, capital cost (IDR), measured capacity of the MHP (kW) and the capacity factor (%CF) determine the electricity supply cost.

The underlying data sources and formulae used to for electricity supply cost calculations are presented in **Appendix B**.

$$Electricity\ Supply\ Cost = \frac{COST_{Capital}}{CAPACITY_{meassured} \ * \ CF \ * \ 8760 \ * \ 10}$$

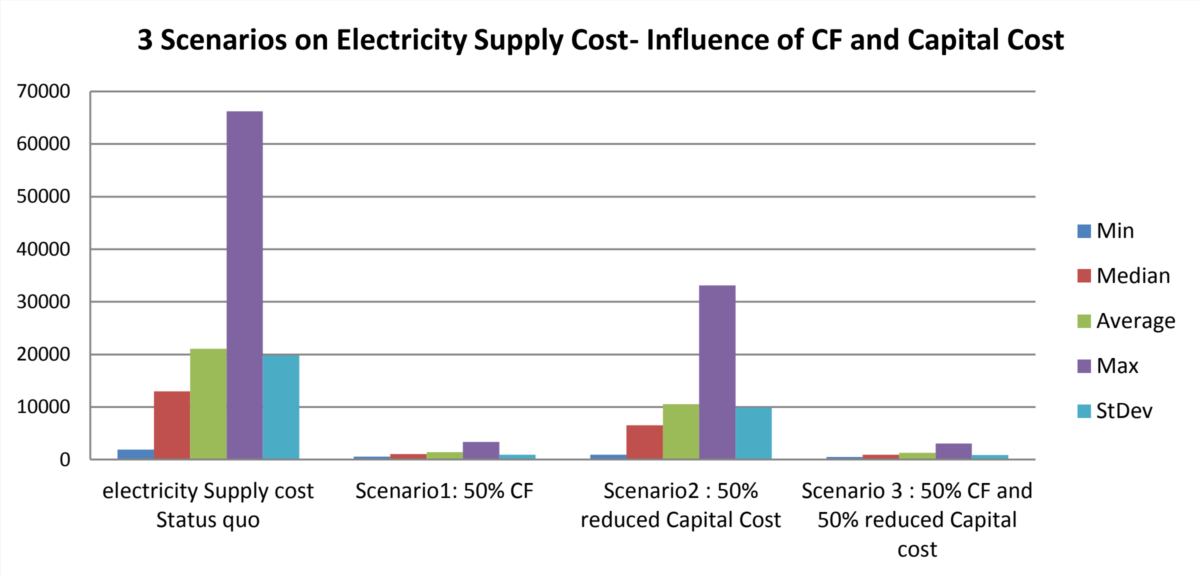
Three scenarios had been analysed and compared in order to show the influence of capacity factor and capital cost. The first scenario assumes that each of the 19 sites produce electricity with a capacity factor of 50%. Second scenario keeps the current capacity factor and assumes a reduction of 50% capital cost. A third scenario combines the other scenario and assumes reduction of capital cost as well as an increased capacity factor. Table A.1: Description of scenarios for Electricity Supply Cost below summarises the scenarios.

Table A.1: Description of scenarios for Electricity Supply Cost

Scenario	Capacity Factor (CF)	Capital Cost
Status quo	Status quo	Status quo
Scenario 1	50% Capacity Factor in each site	Status quo
Scenario 2	Status quo	50% reduction of Capital Cost
Scenario 3	50% Capacity Factor in each site	50% reduction of Capital Cost

According to the scenario assumptions, the results in Table A.2 show the impact of an improved capacity factor. Using the MHP with a capacity factor of 50% in each site, results in average electricity supply cost of **1,444 IDR/kWh**, whereas only reducing the capital cost by 50% results in average electricity supply cost of **10,540 IDR/kWH.**

Figure A-1: Three scenarios for Electricity Supply Cost



The scenario selection clearly indicates that the most effort should be put in increasing the capacity factor to improve the electricity supply costs instead of decreasing the capital cost.

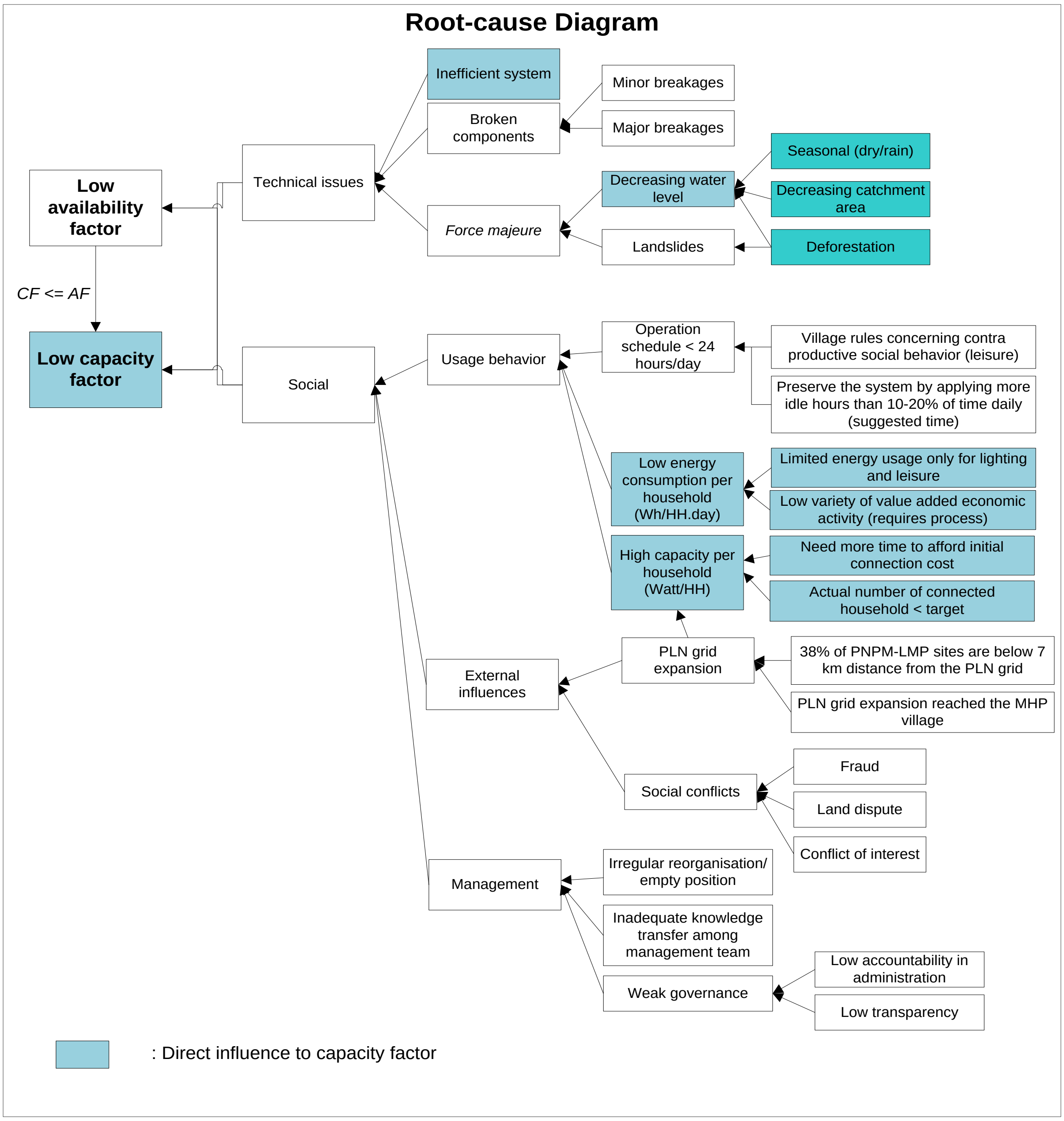
Table A.2: Scenarios analysis of electricity supply cost

	Min	Average	Median	Max	STDEV	N
Status quo	1,881.62	21,080.89	13,011.91	53,497.83	17,062.35	19
Scenario1	**576.05**	**1,444.09**	**1,051.65**	**3,385.22**	**964.08**	19
Scenario2	940.81	10,540.44	6,505.96	33,094.16	9,908.32	19
Scenario 3	518.44	1,299.68	946.48	3,046.70	867.67	19

Root cause analysis

In order to understand the variables that affect the capacity factor, a basic root cause analysis was performed. The value of capacity factor is always equal or less than availability factor, and there is strong relation between them. However, while reasons for low availability factors also affect the capacity factor, this is not a reciprocal relationship and there are causes which particularly affect the capacity factor, but not the availability factor. The figure below shows a root-cause diagram, with blue text boxes specifically indicating the causes that affect the capacity factor.

Figure A-2: CF and AF root-cause diagram



Technical aspects, like an inefficient system, particularly causes low capacity factor. Power output from MHP system is influenced by reduced head, low efficiency turbine, fault in construction and frequency of broken components. Broken components are differentiated between "minor", which can be repaired timely at a cost less than IDR 1 million, and "major" that incur costs above IDR 1 million. Force majeure, forces beyond immediate human control caused by nature or entities that have greater authorities, also influences technical performance.

For **Social aspects**, three categories are differentiated: electricity usage behaviour, external influences, and management. Limited schedule of operation which is often only 10 – 16 hours per day causes low system availability and consequently low capacity factor. Most of the surveyed sites apply a night-time only operating schedule to avoid counter-productive impacts of electricity (such as children watching television in the mornings, rather than going to school) and since there is limited productive use of energy demand during daytime. In fact several village regulations prohibit the use of electricity for productive use of energy out of concerns that this would affect night-time electricity supply. Economic activities in most sites are farming and trading their unprocessed agricultural products therefore few processing activities exist in villages.

Energy consumption per household (Watt-hour/household/day) is also very low since electricity demand is generally limited to lighting and television. Average capacity per household for the surveyed sites is 207W/HH while for rural electrification each household generally has 110W/HH.

Low number of connected households is caused by low affordability for initial connection cost to the MHP grid or options to connect to the PLN grid. Low affordability implies that it takes time for potential customers to save money and pay the initial cost.

PLN grid expansion is considered an external influence which the project has no control over. Together with PLN grid expansion, social conflicts are frequent at MHP sites, ranging from fraud to land dispute.

In terms of managerial aspects, there are several issues which are considered to be the causes of low availability and capacity factor. Those causes are the absence of management team position, inadequate knowledge transfer during reorganisation, and poor governance, as reflected in low accountability and transparency on administration.

Increasing the Capacity Factor

The capacity factor is the result of dividing the total supplied kWh by the total possible annual amount of energy generation.

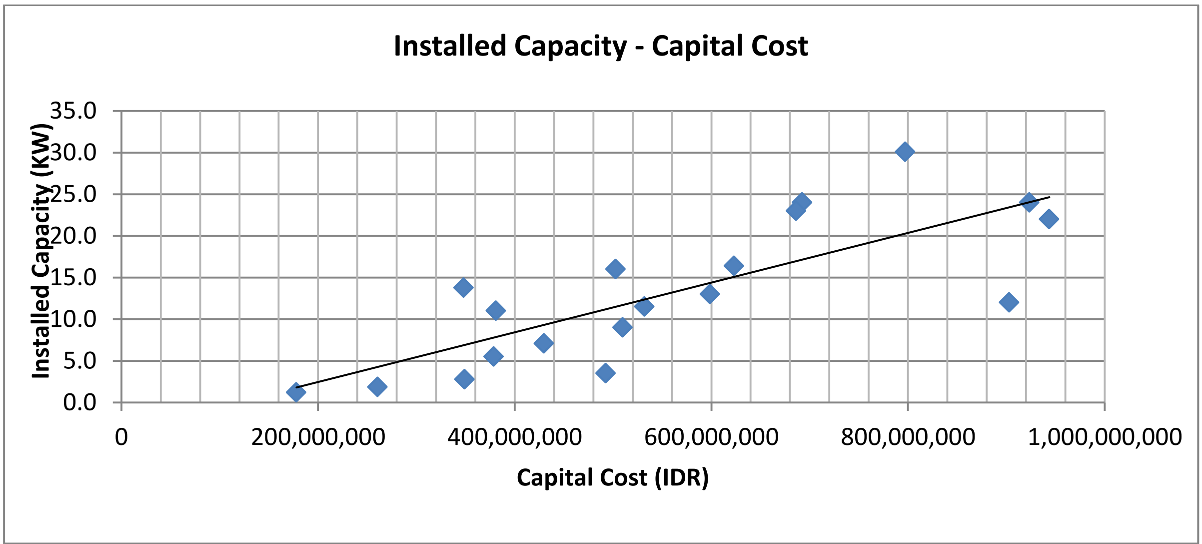
$$CF = \frac{kWh_{MainLoad}}{CAPACITY_{measured} \ * \ OpCal_{days} \ * \ 24}$$

Therefore, it is influenced by the measured capacity as well as the supplied kWh. The capacity factor can be raised by decreasing the measured capacity or by increasing the supplied kilo-Watt hour.

1. Decreasing the measured capacity

This approach will result in an increased CF, however its impact on decreasing the electricity supply cost will not produce a desired outcome. The reason lies in the calculation of the electricity supply cost, where the total generated kWh projected to the period of 10 years depends on the measured capacity. **Consequently, decreasing the design capacity will not have any effects on the electricity supply cost.** However, an indirect impact is observable because MHP capacity has a linear relation with capital cost.

Figure A-3: Installed Capacity and Capital Cost - Correlation



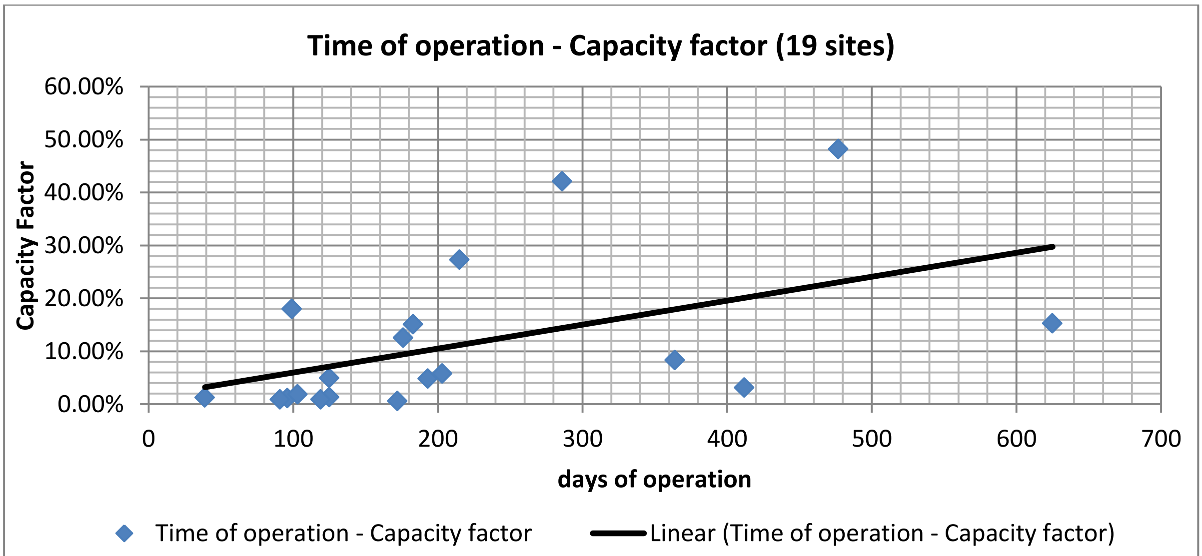
2. Increasing the supplied kWh

Increasing supplied electricity results in a higher capacity factor. The above calculation of scenario 1 and 3 assumed that the capacity factor of 50% is a result of higher energy generation produced by the fixed measured capacity of the respective sites. **Consequently, increasing the capacity factor by rising the annual energy generation has a significant impact on the electricity supply cost**. Increasing the the amount of supplied energy will be achieved by a) increasing the running time of the MHP (i.e. the availability factor) and/or b) ensuring that the MHP operates at its maximum, with fully opened guide vane and no losses through the ballast. The latter can be achieved by increasing electricity demand to a point near equal to maximum electricity generation capacity.

3. Capacity Factor increases over time

Analysis of the existing data from the surveyed sites reveals an increasing capacity factor for sites that had been running for a longer period of time.

Figure A-4: Correlation between capacity factor and operation period



There are possible reasons, namely:

1. The network grid has not been established by the time of commissioning in most of the sites. Consequently, the number of connected households will increase over time which affects kWh meter counting.
2. The exact date of the MHP operation commencement is not documented and is given by a vague time interval. This fact has an impact especially for sites in early stage where the capacity factor for a month operation time is twice as high as the capacity factor for two month operation time.
3. The consumers get used to electricity over time and start to connect more appliances, or new customers are attracted.
4. Dry season and rainy season influence energy generation. Therefore, considering the generation of both seasons will result in a more representative and higher overall consumption.

Data on MHPs with an operation time of more than one year are sparse within the KPI. Therefore, an in-depth analysis on the development of the capacity factor over time is recommended but exceeds the scope of this report.

Recommendations

The most common problem is low energy usage. Boosting the community learning curve in using productive use of energy needs a comprehensive approach. Facilitating the acquisition of electrical appliances for processing, manufacturing and repair activities is one strategy, but it needs to be complemented by mentorship support towards establishing economic activities. Ideally this is done in collaboration with the relevant ministries e.g. Ministry of Cooperative and SME (Small and Medium Scale Enterprise).

Mitigating the vulnerability of MHPs to natural forces needs more efforts and particular catchment area management and conservation and other forms of flood and erosion control must be pursued.

Managerial aspects can be strengthened by providing refresher training and peer group-based knowledge exchange (e.g. through benchmarking) among different management teams. A benchmarking initiative needs facilitators for initial meetings and to supervise the continuity of the group, until such time as the benefit of knowledge experience is internalised by the community.

In conclusion, the improvement of the capacity factor can be summarised as follows:

1. Electricity Supply Cost can be reduced by increasing energy generation and consumption.
2. Decreasing Capital Cost is not recommended as indicator to decrease Electricity Supply Cost.
3. Capital Cost and installed Capacity should be subject to the local requirement and not used to decrease Electricity Supply Cost.
4. Future designs can include grid connection after 10 years of generation within the economic analysis of MHPs in rural communities.

Appendix B: KPI Formulas

Variable	Source	Description	Unit
$CAPACITY_{measured}$	Commissioning Report	The maximum power output from the MHP during commissioning	kW
HH_{Con}	KPI Survey	Connected HH according to KPI	--
HH_{exp}	Form B – ENDEV Indonesia Database	Expected HH to be connected according to Form B (MHP TSU)	--
$DATE_{Survey}$	KPI Survey	Date of the KPI Survey	Date
$DATE_{Operation}$	Commissioning Report	Date when operation starts	Date
$CAPACITY_{design}$	Commissioning Report	Designed Capacity of the MHP	kW
$OPERATION_{Hours}$	KPI Survey	Operation hours according to hour meter	h
$FeeMonth_{coll}$	KPI survey	Total collected fee per month	IDR/month
$FeeMonth_{exp}$	KPI Survey	Total expected fee per month, that should be paid by customers	IDR/month
$COST_{Maintenance}$	KPI Survey	Total cost for maintenance	IDR
$COST_{Salary}$	KPI Survey	Cost for monthly salary	IDR/month
$SAVINGS_{Total}$	KPI Survey	Total Savings at time of the survey	IDR
$COST_{Capital}$	ENDEV Indonesia Database – Bill of Quantity Budget	Budget allocation for MHP construction	IDR
NB	KPI Survey	Number of breakages	--
$kWh_{MainLoad}$	KPI Survey	The total amount of electricity that is being supplied to the grid according to the kWh-meter if exist	kWh
$WATT_{HHact}$	$\frac{CAPACITY_{measured} \times 1000}{HH_{con}}$	Measured Watt per household that had already been connected	W/HH
$WATT_{HHexp}$	$\frac{CAPACITY_{measured} \times 1000}{HH_{exp}}$	Measured Watt per household related to the number of targeted households.	W/HH
$WATT_{HHdes}$	$\frac{CAPACITY_{design} \times 1000}{HH_{exp}}$	Designed Watt per targeted household	W/HH
$OPCal_{Days}$	$DATE_{Survey} - DATE_{Operation}$	Calender days since the date of starting operation until the date of the KPI survey	Days
$OPCalender_{month}$	$\frac{OPCal_{days}}{30}$	Calender month since start of operation until the day of	Month

Variable	Source	Description	Unit
		survey	
$FeeMonthHH_{exp}$	$\frac{FeeMonth_{exp}}{HH_{con}}$	Expected fee per month for each connected household	IDR/month (perHH)
$RATIO_{coll}$	$\frac{FeeMonth_{coll}}{FeeMonth_{exp}}$	Ratio between collected monthly fee and expected monthly fee (to identify payment morality)	--
$RATIO_{Salary}$	$\frac{COST_{Salary}}{FeeMonth_{exp}}$	Ratio of expected monthly fee that is used for Salary	--
$RATIO_{Maintenance}$	$\frac{COST_{Maintenance}}{FeeMonth_{exo} \times OPCal_{month}}$	Ratio of expected monthly fee that is used for Maintenance	--
$SAVINGS_{Month}$	$\frac{SAVINGS_{Total}}{OPCal_{month}}$	Total actual savings per month	IDR/month
$SAVINGS_{kWh}$	$\frac{SAVINGS_{Total}}{kWh_{MainLoad}}$	Savings per kWh	IDR/kWH
$E\_PRICE_{Selling}$	$\frac{FeeMonth_{exp}}{\mathrm{CAPACITY}_{\mathrm{measured}} \times CF \times 24 \times 30)}$ $= \frac{FeeMonth_{exp} \times OPCal_{days}}{kWh_{MainLoad} \times 30}$	Electricity selling price per kWh	IDR/kWh
$E\_PRICE_{generating}$	$\frac{COST_{Capital}}{CAPACITY_{measured} \times CF \times 8760 \times 10}$ $= \frac{COST_{Capital} \times OPCal_{days}}{kWh_{MainLoad} \times 356 \times 10}$	Electricity generation price per kWh when assumed, that the MHP is running for 10 years and neglecting the M&O cost during that period.	IDR/kWh
AF	$\frac{OPERATION_{hours}}{OPCal_{days} \times 24}$	Availability Factor: Ratio of actual operation time with the expected time of operation	--
CF	$\frac{kWh_{MainLoad}}{CAPACITY_{meassured} \times OPCal_{days} \times 24}$	Capacity Factor: Ratio of the amount of energy that was supplied to the MHP grid with the expected annual energy production, if the MHP had been running with full capacity 24/7 since the start of operation	--
BF	$\frac{NB}{OPCal_{days}}$	Breakage factor. How much breakages occured related to the Calendar days since the start of operation.	--

Appendix C: Comparison between KPI Survey and World Bank MHP Cost Effectiveness Analysis

Introduction

In mid-2012 The World Bank Group (WBG) commissioned an independent study on the feasibility of the MHP sites supported under GreenPNPM. The study also incorporated a comparison between TSU-supported MHP sites and non-TSU supported MHP sites. The WBG study reflects directly on the work conducted under EnDev Indonesia (through MHP-TSU) and since similar data was captured during the KPI survey, it is prudent to dedicate an appendix to the study that briefly summarises the WBG findings and compares them with the KPI results.

Comparative summary between KPI and WBG studies

The table below provides an comparative overview of the key information collected during both the KPI and WBG assessments, with synchronise well in terms of timing (both studies were conducted in 2012).

Table C.1: Comparative overall analysis between KPI and WBG studies

Data type	WBG results	KPI results
Sample size	15 sites (10 TSU-supported sites 5 non-TSU supported sites)	47 TSU-supported sites
Average installed capacity	22 kW With maximum 78kW and minimum 6 kW	12.6 kW (measured) With maximum 31kW and minimum 1.2 kW
Average capital cost/installed capacity	IDR 33.6million / kW Unit capital cost of TSU sites are higher (23%) than non-TSU sites (the report maintains this due to higher quality material and capacity building activities to ensure sustainability)	IDR 66.7 million / kW
Average number of connected households	59 HH With maximum 185 HH and minimum 1 HH	68 HH With maximum 163 HH and minimum 0 HH
Average difference between actually connected HH versus planned connected HH as proportion of	61% In average, there is a 37% difference between planned vs actual HH connected, with 90% as the maximum difference and -3% as the minimum difference (i.e. more	54% In average, there is a 41% difference between planned vs actual HH connected, with 100 % (i.e. no households connected yet) as the maximum difference and -16% as

planned connected HH	households connected than planned)	the minimum difference (i.e. more households connected than planned)
Capacity factor	38% Calculation “only based on instantaneous Amperemeter and Voltmeter reading” (page 25); data range from 93% to 1%	13% Calculation based on kWh reading at selected sites
Data recording awareness	High awareness for financial record keeping; low awareness (7%) on technical record keeping	Customer Databook and Budget Book are more properly used, but Operator Logbook is generally not used or not even present
Operational status of MHP	“The majority of schemes appears to be working well” (page 24) “..no significant operational problems are evident in most of the communities surveyed...” (page 38) Issues identified though include: Number of connected HH fail to reach planned number; Mismatch of design and actual water output capacity; Lack of monitoring and recording of technical performance; Lack of maintenance	While 83% of MHP sites were operational during the survey, 54% had reported breakages during their period of operation Of the 27 sites that reported breakages, 40% reported breakages of the turbine and 29% breakages of the generator
Average HH electricity consumption per month	64kWh/month/HH With maximum 152 kWh/month/HH and minimum 7 kWh/month/HH	10kWh/month/HH With maximum 25kWh/month/HH, and minimum 1kWh/month/HH
Average O&M costs as proportion of total revenue	13% With maximum 38% and minimum 3%; turbine and generator replacements not included Note: the report also states 20% as O&M costs as proportion of total revenue	22% With maximum of 100% and minimum of 0%. Sites with 100% O&M cost collect money only when it is needed for repair and maintenance. KPI data incluces all repair and replacement cost within the maintenance costs.
Monitoring equipment	26% (4 sites) of sites had kWh metering All kWh meter sites were TSU-	40% (19 sites) of sites had functioning kWh meters

	supported sites	
Control equipment	"In few sites, the control panel was in failure due to insects or technical failure (damage of fuse), and these are found in Non- TSU sites." (page 25)	Of the 27 sites that reported breakages, 29% reported breakages of the controller and 14% breakages of the electronic load control (ELC)
Civil works	"Civil constructions at TSU-supported sites are generally in better quality compared to non-TSU supported sites." (page 25)	Of the 27 sites that reported breakages, 33%reported breakages of the channel and 18% breakages of the forebay
Average monthly savings as proportion to total revenue collected	36% With maximum 56% and minimum 21%	Average: 47%, maximum 82%, minimum 0% (Figure 5)
Design failures	10% of TSU-supported sites (10), and 25% of non-TSU sites (4) had design failure at initial stage	27 sites had a difference in designed and installed capacity of more than 5% (as percentage of designed capacity). Of those with more than 5% the average discrepancy is 14.3% with maximum of 50.8% and minimum of -39.5% (i.e. installed capacity is higher than designed capacity)
Average monthly revenue per household	IDR 18,076 With maximum IDR 37,000 and minimum IDR 5,944	IDR 24,524 With maximum IDR 50,847 and minimum IDR 3,250
Average electricity supply cost	IDR 561/kWh With maximum IDR 2,256/kWh and minimum IDR 84/kWh Based on " total revenue collected per month divided by average [not measured] output produced per month and is therefore a rough proxy for a per kWh tariff" (page 28)	IDR 21,080/kWh With maximum IDR 66,188/kWh and minimum IDR 1,881/kWh Based on calculated capacity factor (including availability factor) as per kWh meter data

Site comparison between KPI and WBG studies

The table below serves to illustrate the deviations between actual number of connected households as per surveyed sites. The main reasons for discrepancies are a) the WBG survey was conducted a few months before the KPI survey and additional households might have been connected or disconnected during this period and b) the exact number of connected households is not always available from the village management committee.

Table C.2: Household connections between KPI and WBG studies

	Site Code	Village	WBG		KPI and TSU database	
			HH connected	HH planned	HH connected	HH planned
1	DIA009	Alur Kejrun	50	85	45	87
2	SumBar030	Marapan	70	80	70	82
3	SumBar062	Batu Basa	10	100	13	70
4	Not Found	Mesakada	316	501	not found	not found
5	SulBar031	Masoso	89	86	90	84
6	SulBar013	Salutambun Barat	111	117	117	117
7	SulBar016	Orobua Selatan	103	158	105	117
8	SulSel023	Bokin	46	100	57	100
9	SulSel022	Buangin	misprint	misprint	not KPI'ed	98
10	SulSel047	Kare Penanian	20	120	not KPI'ed	150

MHP financial analysis of WBG study

Summarized from Exhibit 2.12 (page 30) from the WBG Study, the table compares the net present value (NPV) between TSU-supported and non-TSU supported sites. The NPV "considering fuel saving" refers to funds previously spent of kerosene for lighting. The NPV calculation is based on the following assumptions:

1. Discount rate 10%
2. Inflation rate on operational cost for 15%
3. Annual increase on tariff and fuel cost 7%
4. 20 years project lifetime
5. No turbine/generator replacement cost is assumed on calculation

From this analysis it appears that a positive NPV over 20 years for off-grid MHPs is unlikely, unless savings on kerosene fuel is considered. TSU-supported sites perform worse in terms of NPV than non-TSU sites, because of higher quality, and hence more expensive, components.

Table C.3: Comparative financial analysis between TSU and Non-TSU sites

NPV (IDR)	TSU sites (10 sites sample)	Non – TSU sites (4 sites sample)	All Sites (14 sites sample)	Comment on relative financial performance
NPV – not considering fuel saving (IDR)				
Average	-541,838,959	-140,429,677	- 391,951,624	Non TSU > TSU
Max	-250,305,589	+87,105,763	+87,105,763	Non TSU > TSU
Min	-1,466,476,391	-319,763,775	-1,466,476,391	Non TSU > TSU
NPV – considering fuel saving (IDR)				
Average	8,858,985,885	1,263,995,453	5,145,436,246	**TSU > Non TSU**
Max	52,470,968,990	2,691,041,278	52,470,968,990	**TSU > Non TSU**
Min	-339,707,337	625,350,256	-389,263,636	Non TSU > TSU

MHP environmental analysis of WBG study

Summarized from Exhibit 3.4 (page 35) the below table compares the environmental impacts, in terms of greenhouse gas (GHG) emissions, between TSU and Non-TSU sites.

Table C.4: Comparative environmental analysis between TSU and Non-TSU sites

	TSU sites (10 sites sample)	Non – TSU sites (4 sites sample)	Comment on relative environmental benefit
Annual GHG Reduction (kgCO2/year)			
Average	2144	565	**TSU > Non TSU**
Max	3901	969	**TSU > Non TSU**
Min	32	161	**Non TSU > TSU**

In general, TSU sites have higher environmental benefit from fossil fuel saving except in Orobua Selatan (only 32 kg CO2/year). This also explains why, for the fuel saving consideration, TSU-supported sites had better a financial performance.

Appendix D: Summary of Used Electricity vs. Generated Electricity Potential Analysis

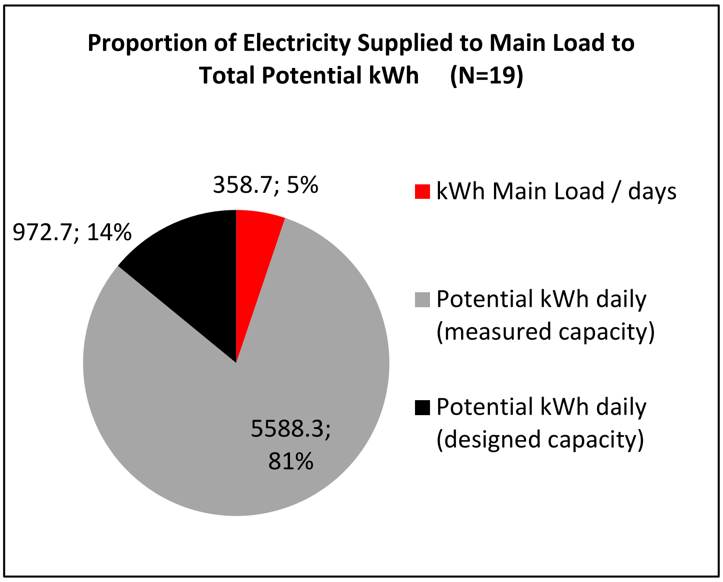
Introduction

Purpose of this analysis is to gain a deeper understanding of the relationship between actually consumed electricity at the MHP installations and the availability of surplus electricity for other uses. These uses may include connecting additional households, expanding the appliance types in connected households (beyond lighting and television, in order to increase household energy consumption) and, most ideally expanding the use of electrical appliances for productive use. Need for this analysis resulted from the low availability factors and capacity factors recorded during the KPI survey and this analysis is based on the 19 MHP sites equipped with kWh meters.

Analysis overview

From the data of 19 metered MHP sites, only 5% (358.7 kWh/days) of electricity is used to supply main load. Another 81% (5,588.3 kWh/days) is estimated to be wasted through the ballast via the electronic load control (ELC), according measured capacity assumption.

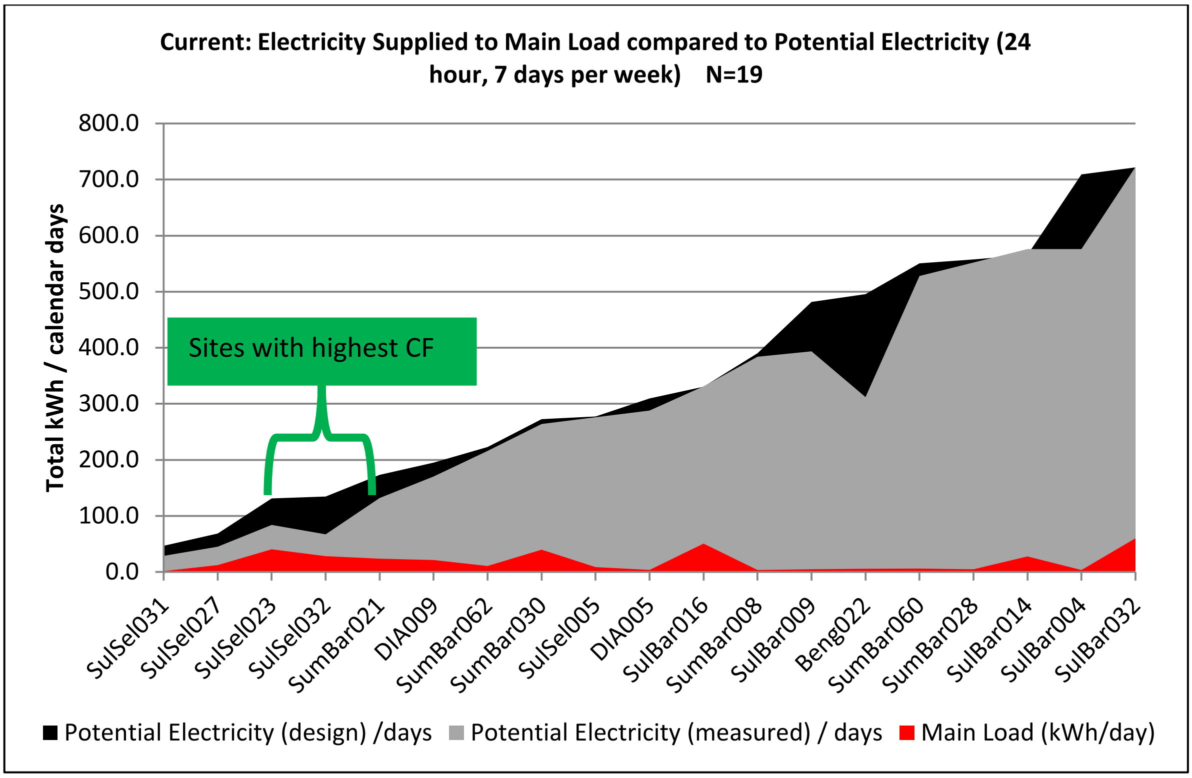
Figure D-1: Proportion of electricity supply and potential



The remaining 14% (972.7 kWh/days), “potential kWh daily as per designed capacity”, may or may not be recoverable since in most sites, measured capacities are smaller than designed capacity due to change in head (m). Some sites had slightly higher measured capacity compared to installed capacity but this effect is practically negligible on 19 sites considered. Thus efforts in terms of the recovery of the “lost” 81% of capacity should be prioritised.

Assuming an operating time of 24 hrs per calendar day, the relationship between main load, potential kWh daily (measured) and potential kWh daily (design capacity) for each site is presented in the following figure.

Figure D-2: Current: Main load and potential energy per site (24/7)

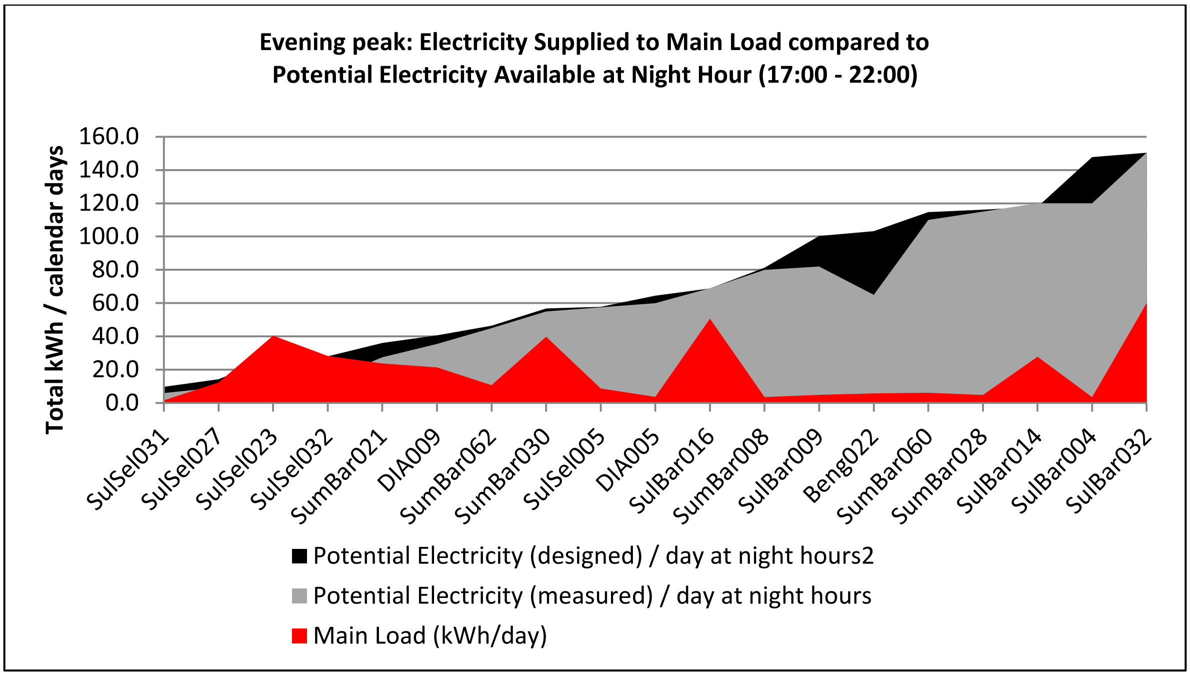


"*Main load*" (colour code **RED**) refers to the electricity supplied to the distribution grid, as measured from each site's kWh meter. "*Potential electricity (design)*" (colour code **BLACK**) refers to possible design and or construction failures, mostly as a consequence to a reduced total head (meters). To correct such failures might require modifications to infrastructure. "*Potential electricity (measured)*" (colour code **GREY**) refers to the maximum amount of electricity that can be generated if the MHP plant worked 24 hours and 7 days per week (i.e. at 100% availability factor) at full installed capacity (i.e. with a maximum allowable load and no losses through the ballast). The figure lists the sites from smallest installed capacity (SulSel031 - 1.95 kVA) to highest installed capacity (SulBar032 - 30.07 kVA).

As can be observed, most sites have significant unused electricity and regardless the generated electricity potential (up to 700 kWh/days on SulBar032), none of the sites had used more than 61 kWh/day. Sites with the highest capacity factors (CF) also had the lowest installed capacity, leading to the conclusion that high capacity sites do not automatically lead to higher household consumption. This implies that household energy needs are fairly similar across all sites, regardless of geographic, demographic or cultural differences.

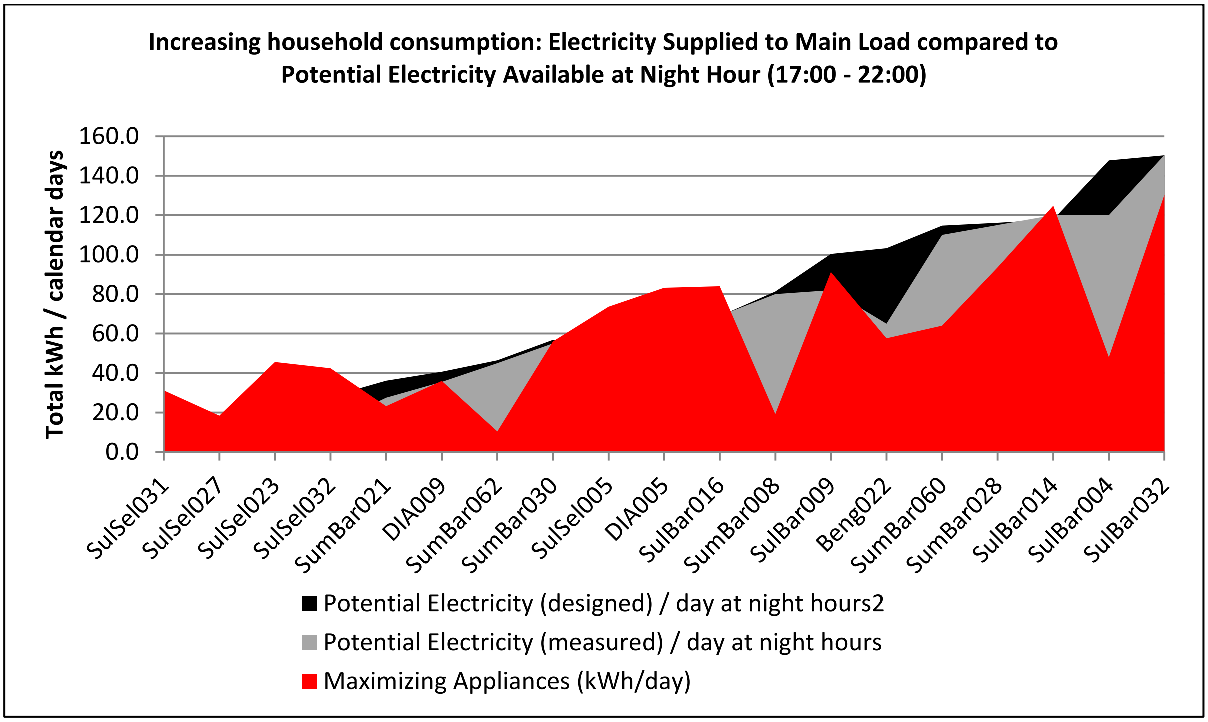
However, it must be stressed that not all "lost" potential electricity can be simply recovered by increasing household electricity consumption, since this consumption occurs mostly during peak times (early evening and morning), and might exceed the capacity of the MHP. A more viable option is to encourage PUE activities which operate during day time. Also, electricity demand during the night (between 22:00 and 06:00) will likely remain minimal with few options to increase this night-time consumption (apart from possibly refrigeration, water pumping, security lighting or few other). It is this latter consideration that is reflected in the next figure.

Figure D-3: Evening peak: main load and potential energy per site



Since currently most MHP generated electricity is mainly used by households during the evenings (17:00 – 22:00), they thus constitute the dominant load. For most sites however, a lot of energy is still lost ("potential energy (measured)") during the evening though. Only some sites, like SulSel023, SulSel032, and SulSel027 had already maximized their use of electricity during night. This implies that additional household connections and/or increased household consumption is not feasible and will likely outstrip the capacity of the MHPs. The effect of this strategy (i.e. increasing household consumption through additional appliances) for all sites is illustrated in the figure below.

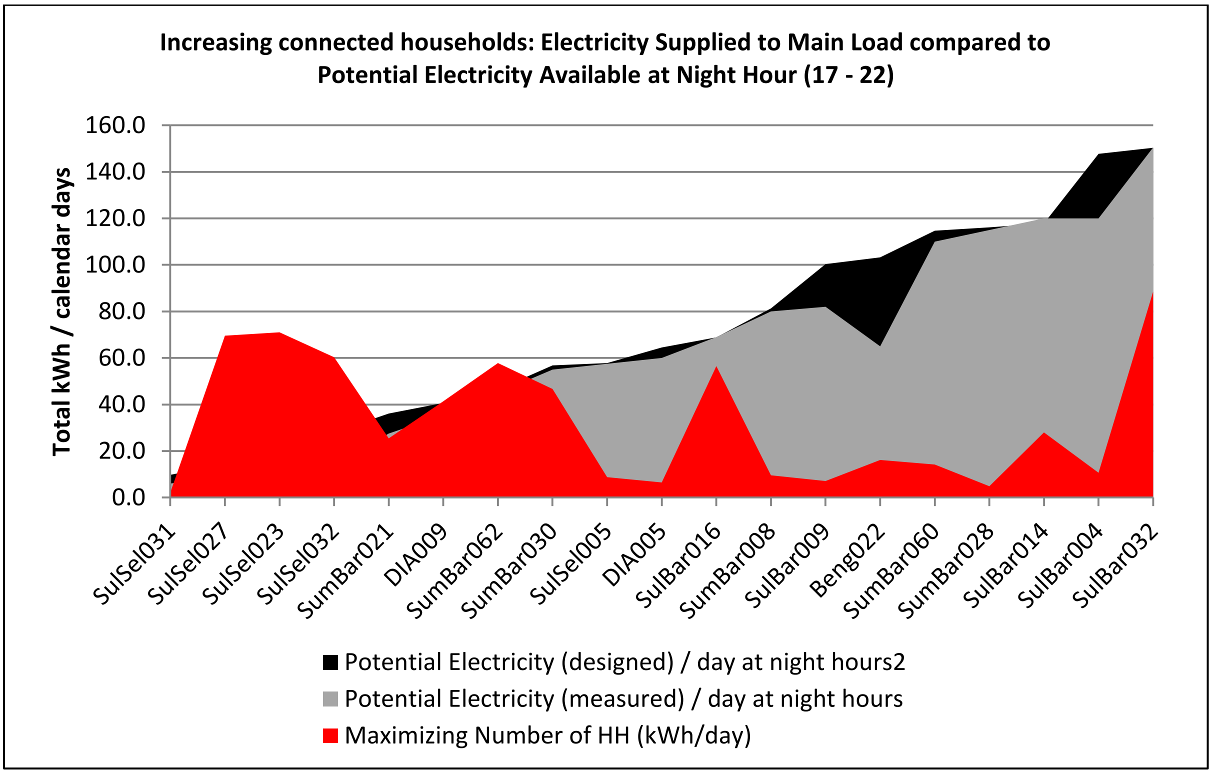
Figure D-4: Scenario: increasing household consumption



Assuming **currently connected household** increase their daily electricity consumption to 0.8kWh (using television, lighting, rice cooker and other) per household, electricity usage would increase substantially, to a point of near optimum utilisation for most sites (except SumBar062, SumBar008, SumBar069 and SulBar004). This strategy poses significant risk though, in terms of exceeding the MHPs capacity, as can be observed with several sites (SulSel031, SulSel027, SulSel023 and SulSel032).

Another strategy is **increasing the number of connected households**, but maintaining the current consumption. The KPI survey indicated that only an average of 60% of households was actually connected compared to the plan. The figure below shows the effect of maximising the number of households per site on the evening peak (17:00 – 22:00).

Figure D-5: Scenario: increasing connected households



While for some sites (SulSel027, SulSel023, SulSel032, DIA009 and SulSel062) an increase in number of connected households is not feasible (the MHP already operates at near optimum capacity), many other sites can easily accommodate additional households.

As indicated previously, encouraging productive use of electricity (PUE) during day hours is one of the most promising strategies towards harnessing the lost electricity potential. Using the scenario of increasing the level of current household consumption (through additional appliances) during evening peak (Figure D-4), several sites show significant potential for PUE during work time (08:00 – 17:00).

Table D.1: KPI MHP sites with PUE potential

Sites	Highest Estimate of Potential Electricity for PUE (kWh/day)	Lowest Estimate of Potential Electricity for PUE (kWh/day)	Current capacity factor (CF)	Improved capacity factor by increasing household consumption (CF) - based on lowest estimate
SumBar021	44.0	20.2	18%	18%
DIA009	56.8	35.4	13%	24%
SumBar062	72.0	61.3	5%	5%
SumBar030	88.0	48.2	15%	24%
SulSel005	92.0	83.3	3%	30%
DIA005	96.0	92.3	1%	33%
SulBar016	110.4	59.7	15%	29%
SumBar008	128.0	124.4	1%	6%
SulBar009	131.2	126.3	1%	26%
Beng022	104.0	98.2	2%	21%
SumBar060	176.0	169.8	1%	14%
SumBar028	184.0	179.2	1%	19%
SulBar014	192.0	164.2	5%	24%
SulBar004	192.0	188.5	1%	9%
SulBar032	240.8	180.7	8%	20%

As reflected in the table above, substantial electricity is available during day time for PUE activities at the sites with capacity factors below 20%. Allowing PUE activities by simply switching on the MHP during day time is not always an easy matter. Some VMC regulations do not permit PUE activities out of concern that it may compromise electricity supply for households, the extra operating times would increase maintenance expenses, and access to electricity during the morning may dissuade children from going to school and villagers to tend the rice fields since they might be tempted to watch television instead. In addition, operating the MHP for longer times each day does not automatically increase revenue, since households might not be able or willing to pay more for electricity (even if they were to consume more).

Conclusion

In conclusion it can be stated that the majority of the electricity generation potential from installed MHPs is lost due to low electricity demand and consumption for most of the day. Household use of appliances, even during evening peak is still very low (except in 3 sites). As summarised in the table below, the currently highest total estimated demand for electricity for evening use (17:00 – 22:00) by all households for the 19 surveyed sites is 318.3 kWh/day while generated electricity potential is 1,238.9 kWh/day.

Table D.2: KPI MHP sites electricity use and potential

Time of day	Electricity consumed (kWh/day)	Generated electricity potential (according to measured capacity)	Estimation of recoverable electricity waste (kWh/day)	Assumption on Scenario of Electricity Waste Recovery
24 hours	358.5 kWh/day	5,588.3 kWh/day	2,603.8 kWh/day	HH appliances usage improvement and PUE
Evening peak only (17:00 - 22:00)	318.3 kWh/day (maximum)	1,238.9 kWh/day	972.3 kWh/day	Maximizing appliances usage up to 0.8 kWh/HH/day (lighting, TV, rice cooker use)
PUE time (8:00 - 17:00) -1 hour of lunch	40.2 kWh/day (minimum)	1,982.2 kWh/day	1,631.5 kWh/day	Considering PUE at sites which clearly had not yet utilized energy available outside night time
Night time (22:00 - 06:00) + 2 hour of morning time + 1 hour of lunch		2367.2 kWh/day	Not quantifiable	Only minimal opportunities, possibly through refrigeration, security lighting, water pumping, hatchery and few other

The table below shows the effect of different electricity consumption scenarios in terms of total electricity consumed across all 19 sites.

Table D.3: Scenarios for harnessing household electricity potential

		Maximizing Use of Appliances	
Maximizing Number of households connected		Current household electricity consumption	Increased consumption of current households (0.8 kWh/HH/day)
	Actual Number of Connected households (KPI Survey)	Scenario - Business as usual: **318.3 kWh/day**	Scenario - Increase during evening peak: **972.3 kWh/day**
	Increased number of connected households (as planned) (TSU site verification)	Scenario – Increase connected households: **446.3 kWh/day**	Scenario – increase connected households and household consumption: **1,186.1 kWh/day***

***While the total amount of potential electricity is about 5,588.3 kWh/day, the potential electricity available during the evening peak (17:00 – 22:00) is only 1,238.9 kWh/days**

For about 50% of MHP sites, household energy consumption is very low (<300 Wh/household/day). While increasing household energy consumption amongst currently connected households is a viable strategy in terms of reducing energy losses, this should only be considered if a) it is accompanied with an increase in electricity tariffs and b) does not induce client-based energy wastage and c) does not result in exceeding the MHP's capacity in the short to medium term.

Increasing the number of connected households would certainly spread the benefits of electricity access, but for most sites does not have a substantial impact on reducing electricity losses. A strategy of combining increased household connections with increased household consumption can be considered, but must be cautiously managed (consumption could increase by an estimated 1,186.1 kWh/day, but the total amount of potential electricity available during the evening peak (17:00 – 22:00) is only 1,238.9 kWh/days). Particularly since electricity consumption focuses primarily on the evening peak.

Regardless of how household electricity usage during the evening peak might increase, 15 out of 19 MHP sites have significant energy potential (total of 1,631.5 kWh/day) available for PUE activities during daytime (08:00 - 17:00). Thus extensive PUE support is the most promising approach towards reducing electricity losses, increasing the MHP capacity factor and improving the overall economic performance of rural electrification using MHP. The fact that PUE activities in rural areas bring a whole range of other socio-economic benefits should not be ignored either.