Improving Maintenance of Micro Hydropower Systems in Rural Nepal –

A qualitative study evaluating problems affecting micro hydropower maintenance and their possible solutions

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Abstract

Nepal is in a state of energy crisis. Even though the national power grid covers far from the whole country, the Nepalese government has been forced to introduce a load shedding system to prevent overload. At the same time, Nepal has one the world’s largest potential for hydropower due to the Himalayas that stretch across the whole northern part of the country. Seeing the inability of the country to produce electricity on a large scale, an abundance of NGOs and aid programs have engaged in developing local renewable energy solutions, to power Nepal’s rural population. Small hydropower plants producing up to 100kW, called micro hydropower (MHP), make out a substantial part of these renewable energy projects.

As a result of many successful systems for financing and organizing MHP projects, together with the development of a well-established domestic MHP industry, the rate of installation of MHP plants has increased much during the past decade. However, some aspects of MHP in Nepal still need to be improved, one very important aspect being the maintenance. Many professionals working in different areas of MHP in Nepal have observed that maintenance is lacking at a majority of the plants, with negative effects on the economy and the life of the plant, which in turn affects the MH-powered communities negatively.

This study investigates what problems there are in MHP maintenance, the cause for these problems and what solutions that could efficiently address them. One solution is investigated more thoroughly: the idea to establish a MHP repair and maintenance (R&M) center closer to the location of the MHP plants. Today, R&M services and sales of spare parts are mainly offered in the two locations of Kathmandu and Butwal, both far from the majority of Nepal’s MHP plants.

The study builds on qualitative interviews and quantitative surveys with people from different parts of the Nepalese MHP industry and Nepalese MHP organizations, as well as with MHP plant operators. It has been carried out with the help of Dhaulagiri Community Resource Development Center (DCRDC), a Nepalese NGO that facilitates MHP projects sponsored by the program Energy Sector Assistance Programme.

The results show that there are many different and interrelated causes for lacking maintenance, most being of a social character and most originating in the lack of motivation and/or lack of awareness of both the plant operator and the whole community. One important finding is that maintenance quality largely depends on the type of community. In places where the benefits of electricity are obvious to the whole community, such as in communities frequently visited by tourists, the plant operators operate and maintain the plants more responsibly, with the result that MHP plants have less faults and economic problems.

An important conclusion from the study is thus that measures to improve maintenance should focus on increasing awareness about electricity’s opportunities. It is also believed that this will require financial resources specifically aimed for solving maintenance issues.

Concerning the establishment of a MHP R&M center, it is a solution which does not address the original cause for lacking maintenance, but which is believed to benefit MHP plants with both good and bad maintenance quality by decreasing costs and increasing accessibility of R&M services.
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Keywords

Micro Hydropower, Maintenance, Issues, Nepal
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Acronyms and abbreviations

AEPC – Alternative Energy Promotion Center
CDM – Clean Development Mechanism
DANIDA – Danish International Development Agency
ESAP – Energy Sector Assistance Programme
ELC – Electric Load Controller
IEA – International Energy Agency
MCB – Miniature Circuit Breaker
MCCB – Moulded Case Circuit Breaker
MGSP – Mini-Grid Support Program
MHP – Micro hydropower
MH-powered – Micro hydro-powered
NGO – Non-governmental organization
NMHDA – Nepal Micro Hydropower Development Association
R&M – Repair and maintenance
UN – United Nations
1 Introduction

Electricity scarcity is a recognized problem in Nepal. Only 3 percent of the energy is supplied by electricity (IEA 2009) and even though the national grid far from covers the whole country, the Nepalese government has been forced to introduce a load shedding system to prevent overload. It is appreciated that the load shedding system causes the country to lose almost $1 billion in revenue every year and the scarcity is an obvious hinder to economic development and poverty reduction (Bisht 2010).

Due to the geology of Nepal, distinguished by the Himalayas stretching across the whole northern part of the country, it has a vast potential for hydropower; the economically feasible capacity is estimated to about 42000 MW (Bisht 2010). This is about three times the hydropower currently installed in Sweden. Being well aware of the potential hydropower poses, the Nepalese government has set up ambitious plans for hydropower development.

However, the progress of these large-scale projects is not fast enough to satisfy the needs of the population, and within the past few decades, many Nepalese and foreign NGOs, along with the Nepalese government, have realized the importance of micro hydropower (MHP), which is local production units of about 5-100kW. This has resulted in around 2,500 MHP schemes producing close to 20 MW of electricity for rural Nepal (NMHDA 2011), and in a well-established domestic MHP industry.

Figure 1: MHP plant Bhuji Khola 6th in Baribang VDC, Baglung district, Nepal.
The single largest supporter of MHP is the Energy Sector Assistance Programme (ESAP) (Kandel 2012), founded with Danish aid in 1999, and now working with several local NGOs throughout Nepal. This and the many others programs that support rural electrification have greatly increased both the number and the quality of MHP schemes, but some aspects are still not working perfectly.

According to many professionals in the Nepalese MHP sector, one of the major problems facing MHP projects is poor operation and maintenance of the plants. In many cases, maintenance is less thought of as a preventive action and more as something that is done when faults occur. However, without regular maintenance the life of the plant might be considerably shortened and the community might have to pay a lot more for repair services and spare parts than would be necessary.

Another problem that makes maintenance more difficult and that increases its’ costs for the communities, is the inaccessibility of maintenance services and spare parts. The MHP industry of Nepal is today centered in two cities: Butwal located in the Terai region in southern Nepal, and the capital Kathmandu, which is located in the middle of the country. Both places are far away from the hilly regions in Northern Nepal and in the far West and East, where the majority of Nepal’s MHP plants are located (see figure 2). Thus, plant operators have to travel many days to access services or spare parts, which is both costly and time-consuming. This often results in long shut-downs of the MHP plants which naturally causes inconvenience to consumers and which is especially harmful to commercial end-uses. One solution that has been suggested to address this problem is to establish repair and maintenance centers in decentralized locations much closer to the MHP sites. It is believed that such centers could relieve remote communities of much trouble and of some of the maintenance costs, thus supporting the success of electrification of these remote areas.
1.1 Scope of study
This study has been carried out in an area of Western Nepal where there are especially many MHP plants. It has been geographically confined to the districts of Baglung, Kaski and Myagdi, where the local NGO Dhaulagiri Community Resource Development Center (DCRDC) has worked for over ten years with the facilitation of ESAP-sponsored MHP projects. The study, which has been conducted with the help of DCRDC, aims to evaluate the quality of MHP maintenance, the reasons why maintenance falls short, as well as to investigate possible solutions to maintenance problems. Since staff members of DCRDC are very engaged in the idea of a decentralized R&M center, one part of the study (the 4th research question below) was dedicated to investigate the potential of this specific solution and to produce background information for a business plan concerning such a center.

1.2 Research questions
The main questions to be answered within this study are:

- What issues affecting maintenance quality do MHP plants face, what are the reasons behind these issues, and how can they be addressed?

- Related to the above question: What is the quality of maintenance performed at MHP plants in Nepal? Which parts of maintenance are working and which are not?

- Also related to the first question: What are the most frequently occurring failures and faults, and why are these the most common? Are they a result of lacking maintenance or are there other reasons?
Taking a closer look at one suggested solution: Assuming that a decentralized repair and maintenance (R&M) center located closer to the MHP sites would help to improve the maintenance situation: how would the business of the center be structured and financed, and is the solution economically viable?

1.3 Note on limitations of study

MHP projects and the system by which they are implemented differ somewhat throughout Nepal, mainly depending on the organization/program/financer that supports the project. Thus, it should firstly be noted that the conclusions in this study with certainty only concerns ESAP-sponsored MHP schemes facilitated by DCRDC in the districts of Baglung, Kaski and Myagdi. The results and conclusions are believed to be similar in other MHP schemes sponsored by other programs and in other geographical locations of Nepal, but only minor cross-checking with MHP professionals from other organizations and other regions of Nepal has been done to verify this, nothing of which is presented in this report due to lack of material. It would have been interesting to interview somebody working with MHP projects sponsored by other programs/organizations than ESAP and from other regions in Nepal, but there was no time for this.

While the above limitation can be said to be geographical, there are also limitations of the social kind. Since the maintenance situation is very much affected by social aspects these are important to consider for the full picture of why maintenance is lacking. However, the study is not large enough to include all of these aspects. One important social aspect that has not been investigated is the question of gender equality, which through informal interviews and observations during the study has been shown to affect the maintenance situation in different ways.

Another social aspect that has not been considered in this study is that of political stability. The unstable political situation that has been in Nepal in the past decades as well as the level of development of the country affects the maintenance situation indirectly in many ways. Examples that are mentioned in this report are bad infrastructure and low education level. However, the full extent of the effect of political instability has not been investigated. An interesting aspect is that with a stable political situation and a higher level of development, MHP might not have been such a big industry in Nepal, since it has grown as an effect of a insufficient national grid.
2 Background

The definition of a MHP plant in terms of capacity varies, but a common definition is 5-100 kW, and the electricity is supplied to a local grid. In Nepal, the majority of the power is used for residential end-uses, but consumers are encouraged to also utilize it for small-scale businesses. MHP offers various opportunities and advantages to the rural population, the most important being:

- The plants are so called Run-of-River systems that preserve the natural flow of the rivers, which gives minimal environmental effects.
- Many of the components can be locally manufactured and locally built, by local inhabitants, thus boosting employment and lowering costs.
- The supply of electricity in rural areas stimulates industry and economic activity. (INFORSE 2005)

In Nepal, the growing interest in MHP has resulted in a well-established domestic industry sector that offers a complete set of MHP products and services, and in many programs that facilitate the implementation of MHP projects. To understand the context in which MHP maintenance becomes a problem and thus the focus of this study, it is important to understand both the technical details of a MHP plant, as well as the system and the environment in which the projects are implemented. The following sections aim to give a brief description of this.

2.1 Technical details

2.1.1 Civil parts

Diversion weir
Weir is the construction that diverts water from the source stream through the intake and into the canal. Its purpose is to act as a barrier to bypassing water and sometimes it is possible to utilize natural features of the river as weirs. (ICIMOD 1997)

Many MHP projects initially construct temporary weirs out of stones and boulders, since permanent weirs made of concrete are very expensive.

Intake
The intake is where the water flows into the canal from the river. It should be equipped with a trash rack that prevents larger debris from entering the canal. Optionally, a gate construction (a so called sluice gate) can be added to regulate the flow. (ESAP, Mini-Grid Support Programme 2000)

Figure 3: The civil parts of a MHP plant. (Practical Action 2001)
**Headrace canal**
The canal leads the water from the intake to the forebay tank at the head of the penstock pipe. It can be open or covered depending on the susceptibility of debris falling into it. (ICIMOD 1997)

**Desilting basin**
The desilting basin (also sometimes referred to as gravel trap) is located some distance from the intake along the canal or combined with the forebay tank. It is constructed as a wider section of the canal, to allow gravel and coarse sand to settle at the bottom; particles that otherwise could cause rapid wear to turbine runner. To flush out the “silt load” that is deposited at the bottom, a flushing cone is added to the structure, that allows the basin to be regularly emptied. (ICIMOD 1997)

**Forebay tank**
The forebay tank is located at the end of the headrace and at the head of the penstock pipe. Its purpose is to ensure that the water enters the penstock pipe smoothly without turbulence. Since it is constructed as wider part of the canal, similar to the desilting basin, water slows down which again allows larger particles to settle, as well as entrapped air to escape. Thus, also the forebay tank is equipped with a flushing cone to flush out deposited silt. (ICIMOD 1997)

**Spillway**
The spillway is an outlet from the headrace canal or the forebay tank that diverts some of the water flow, in case the flow is too high. (Practical Action 2001)

**Penstock**
The penstock pipe conveys the water under pressure from the forebay tank to the turbine in the powerhouse. The pipe is wider and shorter at MHP plants with cross-flow turbines that demand a higher water flow, and they are thinner and longer at MHP with Pelton turbines that demand a lower flow, but a higher head. (Practical Action 2001)

![Figure 4: Forebay tank and spillway at Kut Khola 2nd, Baglung district.](image)

**Support piers and anchor blocks**
These are supporting structures that keep the penstock in place. (Practical Action 2001)
Powerhouse
The powerhouse is the building in which the electromechanical and controlling equipment is located and where power is generated. (Practical Action 2002)

Figure 5: Powerhouse of Kut Khola 2nd MHP plant, Baglung district. The penstock is seen behind the powerhouse.

2.1.2 Mechanical parts

Turbine
The turbine converts the energy in the water into mechanical (rotating) energy. In Nepal, the two most common types of turbines are cross-flow turbines and Pelton turbines (INFORSE 2005). Pelton turbines are impulse type turbines, which means that they utilize the force of one or more water jets striking the turbine blades to achieve rotational movement. Thus, Pelton turbines need low water flow, but high head. Cross-flow turbines have features of both impulse and reaction type turbines, the latter type utilizing the pressure of water to achieve rotational movement. Cross-flow turbines need higher water flow than Pelton turbines, but lower head. (Practical Action 2002)

Figure 6: A cross-flow and a Pelton turbine. (Micro Hydro Development 2004)
Butterfly valve
Valve at the end of the penstock used to regulate water flow into the turbine, or to disconnect the turbine from the flow completely when needed. (Energy Efficiency & Renewable Energy u.d.)

Drive system
The drive system transfers rotational energy from the turbine to the generator and can be constructed in two different ways; either as direct coupling where the turbine and the generator are placed along the same rotating shaft, or by using a belt to transfer power from the turbine shaft to the generator shaft. (Practical Action 2002)

2.1.3 Electrical parts

Generator
The projects facilitated by DCRDC generally use the same type of generator; a brushless synchronous generator producing three phase alternating current from the Indian company Kerala Electrical & Allied Engineering Co. Ltd. (For a few MHP plants with power output lower than 5 kW, induction motors are used instead.)

Brushless means that the machine does not have slip rings or brushes, and is fitted with an independent exciter, generating an alternating current rectified by a set of rotating diodes. (Kerala Electrical & Allied Engineering Co. Ltd. u.d.)

Electric Load Controller (ELC)
The ELC keeps frequency and voltage at constant level (50 Hz and 230 V in Nepal). Though water flow can be regulated with the butterfly valve, the water flow is normally unchanged and thus the power produced by the generator is constant. However, village load fluctuates constantly and when the load decreases, the ELC controls power transfer to a ballast, which consumes the excess power. If the village load would exceed the produced power, the ELC can cut off the electricity supply to the village. (Practical Action 2002)

The ELC is also equipped with indicators that show load current and ballast load voltage of all three phases, as well as frequency, generator voltage and produced power.
Ballast load/heater
Any electricity-consuming element could act as a ballast load. In most Nepalese MHP plants, it consists of an electric heater made out of a water-filled tank with an electric coil passing through. To keep the water temperature down, there is a continuous flow passing through the ballast tank.

Energy meter
Energy meter is since some years back installed in all MHP plants, since the community can get credit for produced renewable energy from United Nations CDM-fund (Clean Development Mechanism) (Acharya 2012).

Switchboard with fuses
A panel equipped with fuses for each distribution line (each phase) to prevent overload of generator, and earth leakage trip switches.

Lightning arrestor
A lightning arrestor is a device that is connected in parallel with electric equipment, and that diverts high voltages caused by lightning. The arrestor is made from a material that acts as an insulator at normal voltages, thus not affecting normal operation, but that acts as a conductor at very high voltages. Due to the frequent thunderstorms in Nepal during monsoon season, especially in the hilly areas, lightning arrestors are very important protection equipment to MHP plants. (ArresterWorks.com 2011)

Moulded Case Circuit Breaker (MCCB)
The MCCBs are integrated in the ELC and protects the plant from overcurrent and short circuits. (Kunwor 2012)

Miniature Circuit Breaker (MCB)
MCBs are installed at the points of consumption i.e. the houses for over-current protection. (Gurung, Karna 2012)

2.1.4 Transmission and distribution
Description of the power transmission and distribution equipment are left out in this report, since they have not been confined in this study of MHP maintenance.

2.2 The system of MHP scheme installation and operation
There are many different sponsors of MHP schemes in Nepal and there are just as many ways in which the schemes are carried out. In the studied case, four main participants/participating groups take part in the process of providing a community with MHP; ESAP being the donor,
DCRDC being the facilitator, MHP manufacturing and installation companies, and very importantly, the community itself.

- **ESAP (Energy Sector Assistance Programme)** is a program under the governmental institution AEPC (Alternative Energy Promotion Center), set up by the Danish International Development Agency (DANIDA) in 1999. Its aim is to achieve ongoing sustainability in the rural/renewable energy sector in Nepal within a 20-year timeframe.

  Within ESAP, there are several programs supporting different sources of renewable energy, and the Mini-Grid Support Program (MGSP) is the one that promotes MHP for rural electrification and promotion of end-uses. Apart from providing subsidy, ESAP also provides a systematic framework for the implementation of MHP projects that assures the quality and the validity of the schemes. (AEPC 2008)

- **DCRDC** is an NGO started by the local inhabitants of Baglung in 1995. It is working in several fields to render basic services to people, with focus on poor, marginalized, and disadvantaged households in the district of Baglung and a number of adjoining districts (DCRDC 2011). 12 years ago DCRDC joined with ESAP’s Mini-Grid Support Program and DCRDC is now one of seven local NGOs in Nepal that facilitate ESAP-sponsored MHP projects for the rural population. In the years of DCRDC’s MHP activity, the organization has successfully completed 57 MHP projects (DCRDC 2012).

  DCRDC handles the communication between the community, the donors, and the MHP companies. This is facilitated by having a number of staff members in branch offices that are in close communication with remote communities.

- There is a relatively large number of **MHP manufacturing and installation companies** in Nepal, mainly located in the cities of Butwal and Kathmandu. Most of them both manufacture and install MHP equipment, and many of them also perform the feasibility studies preceding MHP schemes. Mechanical and civil parts such as turbines, penstock pipes, distribution poles are fully manufactured by the companies, and electrical parts such as ELCs and switchboards are assembled by them. Apart from the generators, butterfly valves and the ELC motherboards, all MHP equipment is manufactured or assembled in Nepal (Acharya 2012).

- **The community** in this matter is simply a number of households that together decide on investing in MHP. It can be made up of one or several neighboring villages.

### 2.2.1 Initiation of a MHP scheme

A new MHP scheme is initiated by a community that raises a request to DCRDC, or answers to a recommendation from the organization. When making the request, the community has to provide DCRDC with details about the estimated power demand, the number of households that would benefit from the power plant, as well as how much households are prepared to contribute financially and in terms of labor and the tariff they are prepared to pay for the electricity. DCRDC then arranges for a company to carry out a basic feasibility study of
potential sites around the village area, and if this study shows that the project seems viable, a more detailed feasibility study follows. The feasibility studies investigate the following requirements:

- That the interest and the capabilities of the community are sufficient.
- That the costs can adequately be covered by the community’s contribution and the support from donor.
- That the power demand matches the possible output of the planned MHP plant. (Junejo 1997)

The detailed feasibility study also includes a detailed design of the plant. If the study results are positive, a manufacturing and installation company is consulted and construction can begin.

2.2.2 Funding and quality control
If the results of the feasibility studies are positive, subsidy will be provided by ESAP. The ESAP subsidy usually covers around 40% of the project cost and the rest is paid for by the community members, in cash and in labor, and by bank loans. The subsidy is not given as a one-time donation; it is granted in rounds as the project moves on and can prove that it has achieved the required quality. ESAP is careful to secure that the constructed MHP plant is actually fulfilling the design requirements such as power capacity and number of households benefited, since the amount of subsidy given is based on these parameters. Thus, there are several quality checks when the plant starts operating and when it has operated for some time, at which times the company receives remaining parts of the subsidy amount.

Throughout the first year of operation, the installation company is obliged to repair any damage and replace any broken parts, to guarantee a correctly manufactured and installed plant. When one year has passed, it is time for the one-year guarantee check, which marks the time when the company’s responsibility ends, and the community gets the lone responsibility of managing the plant. After this, ESAP has completed its work and is no longer involved in the managing and operation of the MHP plant.
2.2.3 Community participation

For MHP schemes to succeed, it is vital that the community is actively participating in the project from the very beginning. After all, they are the owners and the main investors in the plant. To manage the process of the project from initiation to continued operation, a users’ committee is created consisting of around 7-13 community members. Members of this committee take care of collection of tariffs, spreading of information, communication with DCRDC, and other management issues. However, all larger decisions are taken in mass meetings that are open to everybody in the community, and these mass meetings are often facilitated by DCRDC staff.
Throughout the process, DCRDC also plays an important part by raising awareness on how electricity can be used for residential and commercial end-uses. One has to remember that though electricity is a natural and indispensable part of everyday life in the developed world, these remote communities have never before had access to it, and need support and information to learn about how to best utilize this new resource.

For a plant to work continuously and smoothly the community naturally has to pay tariffs as decided, and to contribute labor in case of damage to civil parts of the plant. Most communities seem to be proud and happy about their MHP plants, and are willing to contribute what is asked for. However, most communities also live hand-to-mouth without a subsistent income, and a problem that sometimes occurs is that consumers are unable to pay the agreed tariff, which naturally causes a problem to the plant’s economy. On the other hand, if the plant is well managed and operated, it can even generate income to the community that can be invested in other projects benefitting the community members.

2.2.4 Maintenance
The plant is operated and maintained by one or sometimes two plant operators, who are chosen from the community and by the community, via the users’ committee. Anybody can candidate to become plant operator: young or old, woman or man, but they should preferably have completed 8th grade in school (Khatiwada 2012). However, plant operators can be chosen on completely different basis. An example is a plant operator who had only completed 3rd grade in school, but was chosen since he had donated the land where the plant was built. The age distribution among plant operators in Nepal today seems even (Ranjitkar 2012), but there are few women working as plant operators.
Once a plant operator is chosen, he or she is given a 22-day long “basic plant operator training”. The training is paid for by ESAP, which contracts the actual training to individual organizations or companies that can offer a suitable curriculum. So far, most plant operators have been trained by Nepal Micro Hydropower Development Association (NMHDA) in Kathmandu, but some MHP manufacturing and installation companies in Butwal have also conducted this training.

The training includes theoretical and practical demonstrations of all the different parts of the MHP plant (civil, mechanical and electrical) and of all the tools and materials that will be used while operating. It includes R&M, fault identification and trouble-shooting, and plant operators should be able to replace bearings and various electrical components after the training. Furthermore, plant operators are taught safety and first aid, basic management concepts, the importance of keeping the logbook, the importance and possibility of commercial end-uses, and they are also taught wiring techniques, since operators are responsible for all the wiring from distribution level to consumers. One day is spent at an operating MHP plant. Companies in Butwal have until now been able to provide more practical items in their curriculum, since they have access to their own manufacturing facilities and sometimes even demonstration plants. However, NMHDA is currently building a MHP demonstration plant close to their office in Kathmandu, which will benefit the attendants of the plant operator training (Ranjitkar 2012). (NMHDA, Oshin Power Services Pvt. Ltd. 2012)

At training, plant operators are given a book published by ESAP that contains the content of the 22-day training, as well as a maintenance schedule and a trouble-shooting manual. The maintenance schedule (attached in appendix A) is very thorough and lists what should be checked and at what time intervals for civil, electrical, and mechanical parts of the plant, as well as for distribution equipment. Despite the training, the book and the maintenance schedule, maintenance is lacking at many plants, due to many different reasons that will be discussed in this report. However, both NMHDA and MHP companies that conduct the training agree that the basic plant operator training contains a lot of knowledge in a short
period of time and that plant operators, who generally have little school experience to begin with, forget much of what they learn in training (Ranjitkar 2012) (Kafle 2012).

Sometimes plant operators are given an additional 7-day training after some time of operating, called “advanced operator training”. The same structure concerning financing and organizing applies to this training as to the basic plant operator training. DCRDC usually recommends advanced plant operator training to plant operators of very remote plants that have difficulties accessing R&M services and spare parts. (Acharya 2012)

After the first year, when the installation company provides R&M, the community itself is responsible for paying for services and parts, and the plant operator is responsible for seeing to that the plant is being maintained and repaired properly, either by him-/herself or by technicians from the installation company. Since the MHP industry of Nepal is centered in Kathmandu and Butwal, this is where plant operators have to travel to buy spare parts or to bring parts in need of repair services.

2.3 Maintenance issues
Most experts in Nepal agree on that MHP maintenance is not performed regularly and that this causes problems to both the continuous power supply and the economy of the plant. In the previous section, the system of choosing and training plant operators is described, and even though this it is a well worked out system, it does not seem to be sufficient to create a stable maintenance situation. Its extent is limited by budget and time, and it has to deal with social aspects, such as the low education level of plant operators when they come to training.

Maintenance issues in Nepal are generally related to social aspects. Lack of education, lack of awareness and lack of motivation are all contributing to irregular and faulty maintenance. Another, but related, problem is the high turn-over rate of plant operators, which among DCRDC’s projects is around 25-30 % (Kandel 2012). (This means that 25-30 % of the chosen plant operators leave their position within a year.)

Social aspects are hard to address and this study will investigate nature of the social problems and potential solutions to these. In comparison, it is easier to find potential solutions to concrete problems, such as the long distance from the MHP plants to R&M providers. The solution suggested by DCRDC, which is also investigated in this study, is to build a MHP R&M center closer to the cluster of MHP plants that DCRDC have facilitated. This way, villagers would not have to travel so far to access R&M services or spare parts, which would lower both costs and outage time. However, even thought most experts in the MHP sector in Nepal agree that such a solution would be beneficial to the MH-powered communities, the details of the potential R&M business have not been investigated until this study, which is why this is one of the study’s main goals.

2.4 Site/area of study
The study has been carried out on several sites within a larger geographical area, why it is more feasible to call the location of the study the area of the study. Both the varying character of the individual sites, as well as the overall features of the area of study are important to understand the results.
The studied MHP plants are located in the districts of Baglung, Myagdi and Kaski in the Western Nepal.

![Figure 12: Baglung, Myagdi and Kaski districts are colored green.](image)

The landscape in Baglung, Myagdi and Kaski is hilly and apart from a few larger towns, most land is used for agriculture by rural population living in small villages on the hillsides and in valleys. Rivers of varying sizes run through the landscape and pose excellent possibilities for MHP. The climate is dry during most of the year, but in June through August, rainy season sets in with heavy rains and thunder storms, which causes problems for MHP plants, both because of the high frequency of land slides damaging civil parts and because of the damage lightning does to electric components. Because of the hilly landscape, the frequent landslides, and an unstable government, the infrastructure is mostly bad or non-existent and many villages can only be reached by many hours of walking.
Thanks to the increased focus on MHP from foreign donors, the Nepalese government and from local NGOs (in this area primarily DCRDC), the number of MHP plants in the study area has grown quickly within the past ten years. The number of DCRDC-facilitated MHP projects completed each year since 2003 can be seen in Error! Reference source not found. and the number of projects per district is depicted in Error! Reference source not found.. Baglung is the district with the most MHP plants of Nepal’s all 75 districts (AEPC/ESAP, Community Awareness Development Centre 2006) and is sometimes referred to as “the Energy District of Nepal”.

Even though the geographical features are similar throughout the area, the conditions of the individual sites vary, much because of the different possibilities of economical activity. Some of the areas in the Kaski district closer to the Himalayas are visited by an increasing amount
of tourists, which has led to new business opportunities and improved infrastructure. This has led to an increased utilization of the electricity produced by MHP, since tourists demand services such as cell-phone charging, WiFi, and hot showers. Most Nepalese people in these areas are engaged in tourism, and have a higher standard of living than the population in agricultural, hard-to-access villages in other parts other parts of Kaski, Baglung and Myagdi.

3 Method

Material for this study was collected during a two months visit to the study area in Nepal (April – May 2012). The study builds mainly on interviews and surveys, with own observations as a complement to this. Some quantitative data was also gained from studying documents at DCRDC concerning their MHP projects. To answer the research questions of this study, different aspects and observations of the maintenance situation were investigated by collecting information from people involved in all stages of a MHP project, from decision-makers of governmental support programs, to MHP plant operators. Both qualitative and quantitative information was collected, with the purpose of the quantitative surveys to verify (or possibly contradict) the information gained through qualitative interviews, as well as to illustrate the general maintenance situation. The three methods of gathering information for this study are listed below:

1. Survey for MHP plant operators about maintenance routines and fault frequency.
2. Survey for MHP installation and manufacturing companies about their maintenance recommendations, fault frequency, and information concerning a possible decentralized R&M center.
3. A large number of interviews with professionals in the MHP sector, to gain various information about maintenance quality, fault frequency, observed maintenance issues, and possible solutions to the observed issues.

In the following three sections the above methods of gathering information are described in further detail; how the survey/interview questions were chosen, how the surveys/interviews were carried out, and how the interviewees were chosen.

3.1 Survey for plant operators about maintenance routines and fault frequency
A draft of this survey was prepared before reaching Nepal, mainly by using information about maintenance learnt from Peter Ruyter at Cargo & Kraft Turbin Sverige AB’s. After consulting with MHP professionals at site in Nepal, the survey was somewhat changed, the largest change being that it went from focusing almost exclusively on technical aspects to including more personal questions about the plant operator. This was done to address the social factors affecting maintenance quality. The technical questions focus on the work done in and around the powerhouse and the civil parts, and the maintenance on distribution lines has been excluded in this study. Throughout the report, the survey is referred to as the Plant operator survey, and the included questions are listed in textbox 1.
### Plant operator survey questions

1. Do you still have the book that is given at training? If so, do you use the maintenance schedule that is included there? If not, do you have some other maintenance schedule?

2. How often do you grease bearings in turbine and generator?

3. How often do you check the temperature of the generator and the bearings in turbine and generator?

4. How often do you listen to sounds and vibrations of the machine?

5. How often do you clean the powerhouse?

6. Do you check tension of the belt between shafts of turbine and generator? If yes, how often?

7. Do you make planned turbine shut-downs to do maintenance inside it or is turbine only stopped if there is a problem?

8. Do you write down energy meter values in the logbook daily?

9. Do you write down values of current, voltage, and frequency daily?

10. How often do you check civil parts?

11. Is there somebody in the community who knows skilled labor and knows how to fix civil parts if they brake?

12. Do you have all the material needed to fix civil parts in the village, for example cement, wire etc?

13. What faults have occurred (big and small) since the plant started operating? For example replaced bearings, belts, fuses etc. Everything you can remember.

14. Where do you go to get spare parts?

15. How long have you been working as plant operator of this plant?

16. How much training have you had?

17. Do you think the training should have been more practical or was there enough practical exercise?

18. What are the plant’s hours of operation?

19. Do you have another job apart from being plant operator?

20. Are you happy to work as a plant operator?

21. What is your salary?

22. Are you satisfied with this salary?

23. Why did you want to become plant operator?
The survey was carried out as interviews with plant operators when visiting MHP sites. Since none of the plant operators visited spoke English fluently, the interviews were conducted with help of an interpreter, which in all cases except one was a DCRDC staff member. (One interview was interpreted by an engineer consulted by ESAP to do the a power output verification (POV) of the visited MHP plant.) None of the interviews were recorded and answers were instead noted in written form.

The visited MHP sites were not selected with any particular strategy. The opportunities to visit plants were given when DCRDC staff travelled to field for other reasons and thus the selection of plants included in this study is completely unintentional: some plants have been operating for many years and some were just completed; some plants are in very remote areas and some are in more urbanized areas; most plants are in Baglung district, but one is in Myagdi district and one is in Kaski district. Altogether, the Plant operator survey was conducted at six plants, all facilitated by DCRDC. The names of the plant operators and dates of the interviews are listed under “Personal communications” in References. In addition, some observations could be made at MHP sites where it was not possible to conduct the whole survey due to different reasons such as lack of interpreter, lack of time, bad weather etc.

3.2 Survey for MHP manufacturing and installation companies
The survey for MHP installation and manufacturing companies was created at site in Nepal, after having gained a greater insight in the maintenance situation. The objectives of this survey were 1) to investigate what maintenance recommendations the companies provide to plant operators at installation, to clarify what information operators have access to, 2) to investigate the companies’ apprehension about fault frequency to compare with the fault frequency information received from plant operators in the Plant operator survey, and 3) to gain information that could be used to evaluate the possible business of a decentralized R&M center.

The survey is referred to as the MHP company survey and the included questions are listed in textbox 2.
### MHP company survey questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Details</th>
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<tbody>
<tr>
<td>1. What equipment do you supply to MHP plants?</td>
<td></td>
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<tr>
<td>2. At installation, do you provide plant operator with maintenance recommendations for your equipment?</td>
<td></td>
</tr>
<tr>
<td>3. What maintenance recommendations do you give for your equipment?</td>
<td></td>
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<tr>
<td>4. Do you recommend the plant operators to open the turbine sometimes, to do maintenance inside the turbine?</td>
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<tr>
<td>5. What are the most common repair services you perform on MHP equipment?</td>
<td></td>
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<tr>
<td>6. Why do you think are these the most common?</td>
<td></td>
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<tr>
<td>7. Do you test your equipment before you sell it, and if so, how often?</td>
<td></td>
</tr>
<tr>
<td>8. What parts of your equipment have to be replaced by you, and could not be provided by an individual R&amp;M center?</td>
<td></td>
</tr>
<tr>
<td>9. Do you also sell general spare parts such as fuses, MCCBs etc?</td>
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<tr>
<td>10. Can you give a price example of a repair service, for example replacing the turbine bearings? If a technician has to travel a longer distance to the MHP site, how much does this add to the cost of the repair service?</td>
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The survey was carried out as interviews with representatives from the companies, and since all representatives spoke good English there was no need for an interpreter. The surveyed companies were suggested by the supervisor of the study, Mr. Shambhu Raj Kandel, as companies that are frequently consulted in DCRDC’s MHP projects. A list of the companies visited, the representatives that were interviewed, and the dates of the interviews can be found under “Personal communications” in References.

### 3.3 Interviews with MHP professionals

Many professionals from the MHP sector were interviewed to provide their point of view on different aspects of MHP maintenance, and the questions asked varied depending on the interviewee. Therefore, the questions are not listed here. Furthermore, in many cases the interviews turned into an interactive discussion rather than a strict interview. None of the interviews were recorded and answers were instead noted in written form. The interviewed people/institutions and the main purpose of the interview are described below, and a full list of names and dates of interviews can be found under “Personal communications” in References.

- Staff members from DCRDC’s MHP section were interviewed about their opinions and observations of the quality of maintenance work, the problems affecting maintenance work, and the viability of different solutions to the discussed problems.
The information provided by these interviews/discussions could then be matched with the outcome of the surveys, as well as own observations in field.

- **Staff members at Oshin Power Services Pvt. Ltd.** were interviewed about the plant operator training in order to investigate what knowledge plant operators are given. They were also providing opinions concerning the establishment of a R&M center in Burtibang, since the company has been engaged in the idea for some time. As one of the largest MHP manufacturing and installation companies in Nepal, they could also contribute price information used to plan the finances of the R&M center.

- **A representative from Nepal Micro Hydropower Development Association (NMHDA),** an umbrella organization for MHP companies was interviewed about the plant operator training that NMHDA conducts in order to investigate what knowledge plant operators are given, and to see if the content of NMHDA’s curriculum was different from the curriculum of Oshin Power Services’ training. As an organization working with many different stakeholders of Nepal’s MHP industry it was also interesting to inquire about their observations and opinions on the maintenance situation and to hear their point of view on different suggested solutions.

- **The component manager of AEPC/ESAP’s MHP section was interviewed with the main purpose to hear his opinion on the solution of decentralized R&M centers to improve the maintenance situation. The interview was also done to research what the apprehension of maintenance is at the decision-making level, and to see if this apprehension differed from that of people involved in other levels of a MHP project.**

- **Two staff members of DCRDC’s branch office in Burtibang** who will be responsible for the establishing the decentralized R&M center if the idea seems viable, were interviewed about details of that project.

- **Independent engineers** working as consultants for ESAP were interviewed about their apprehension of MHP maintenance. This provided objective opinions on the subject, since the engineers were employed neither by DCRDC nor by AEPC/ESAP.

- Additionally, a number of plant operators and chairpersons of MHP plants, met randomly during the field trips and not included in the *Plant operator survey,* contributed with their view on different aspects of maintenance.

### 3.4 Sources of error

- Generally, the major limitation and source of error in this study was language. Since the study builds more or less exclusively on interviews, making sure that the questions were correctly understood by interviewees and that the answers in turn were correctly understood by the interviewer (i.e. the report-writer) was obviously very important for the results. Even though most interviewees such as DCRDC staff, MHP engineers, other MHP professionals, and policy workers spoke good English, some language difficulties remained, and thus a reservation is made against minor misunderstandings.

Concerning the *Plant operator survey,* which had to be conducted with help of an interpreter, the language barrier can have affected the answers in several ways. Firstly because of minor misunderstandings between interviewer and interpreter, as mentioned above. Secondly, the interpreter was always a professional in the MHP sector, which unintentionally can have made him communicate the answers in an un-objective way. The reasonableness of the answers could be checked by comparing
them to the question asked, but the content might have been slightly changed because of translation. However, this is not believed to have any considerable impact on the results of the study.

- One factor that is believed to have affected the answers of the Plant operator survey, is the situation in which the interviews were carried out: The plant operators were in all cases interviewed in the presence of many other people, consisting of fellow community members, DCRDC staff and sometimes representatives from MHP companies. This is believed to have put pressure on the operators, since both community members and MHP professionals have a high interest in seeing that the plant is well maintained. Thus, it is believed that the result of the Plant operator survey might show a situation that seems better than the actual reality is.

- The amount of time in field and the possibility of travelling to MHP sites limited the amount of data that could be collected. Travelling even short distances takes much time in Nepal and visits to the MHP sites could only be done by accompanying DCRDC staff on their scheduled trips, much because of the report-writer’s inability to speak fluent Nepali. The six plants included in the quantitative part of this study should give a fair view of the general maintenance situation, but since the visited plants were randomly chosen there is a chance that trends have been missed. Optimally, more plants in the Myagdi and Kaski districts would have been visited to include a larger variety of communities and plants. Also, more older plants should have been visited, to observe the quality of maintenance after several years of operation.

- The MHP company survey is listed as a quantitative source of information, even though only three companies answered its questions. Initially, it was planned for four companies to contribute to the survey, but one company in Butwal could not be visited due to banda (road strike). However, the answers given by the three questioned companies are so similar that they are believed provide information that accurately represents the viewpoint of MHP companies in general.

- The fact that all interviewees were involved and had certain interests in the MHP sector makes their answers subjective and some interviewees might even have interests to protect by answering questions in a certain way. Thus, one has to be critical when interpreting the opinions of interviewees.
4 Results

The aim of this chapter is to answer the research questions stated in section 1.2, and results will be presented in the same order as the questions. The results come from both qualitative and quantitative interviews, and the former will be presented in flowing texts, while the latter will be illustrated by means of statistics and short paragraphs. Quantitative data is meant to serve as a comparison to the situation as it is apprehended by MHP professionals, i.e. the results from the qualitative interviews.

The interviewees contributing to the qualitative information are referred to in this section by their title and last name, and their full names, details and the dates of the interviews can be found under “Personal communications” in the references.

Since the fourth research question was investigated to produce background information for a business plan, the research work was more interactive and results presented here comes from questions and answers, discussions and reasoning with the interviewees, as well as from own conclusions. Thus, this research question is presented after the other three (in section 6), in a way where pure results (i.e. answers from interviews) and discussion are not strictly separated.
4.1 What issues affecting maintenance quality do MHP plants face, what are the reasons behind these issues, and how can they be addressed?

The general impression is that maintenance is not done regularly at a large number of plants, due to many different and often interrelated reasons.

4.1.1 High turn-over rate of plant operators
A major issue is the high turn-over rate of plant operators, which is approximated to 25-30% by Mr. Kandel, former regional coordinator at DCRDC. This means that 25-30% of the plant operators appointed by the communities leave their new job within a year. Thus, many MHP plants are left without trained operators until a new one can be trained, which leads to that the plant is either stopped or runs without proper maintenance and supervision, both cases being very harmful to the plant’s economy. Error! Reference source not found. shows that two out of the 10 visited MHP plants are operated by persons with no training. AEPC/ESAP has limits on the number of plant operators that can be trained every year, which causes waiting times for training, and Mr. Khatiwada and Mr. Acharya says that DCRDC currently has over 30 people waiting to get trained. Mr. Devendra Adhikari at AEPC/ESAP means that the limits to the number of operators given training each year is not a budgetary restraint – it is rather a question of the justification of giving training: ESAP wants to give training to people at the right time, that is, not too long before the plant will start operating, due to that the choice of operator might be changed or knowledge might be forgotten if training is given too early. The training is obviously necessary, but a lot of what is learnt there is forgotten. Mr. Devendra Adhikari says that everybody wants training whether they need it or not, but ESAP needs to set limits.

The high turnover rate probably depends on a number of different reasons, but two interrelated reasons that many of the interviewed experts think affect this number, is the low salary of plant operators and the popularity among Nepalese men to move to foreign countries to work. Discussing the salary level, Mr. Khatiwada, mini-grid engineer at DCRDC, means that most plant operators are dissatisfied with their salary, which varies from around NPR 3,000-6,000 per month depending on plant size and the economic situation of the community. (This can be put in relation to the life expenditures for a rural inhabitant, which are tentatively estimated by Mr. Kandel to about NPR 5,000 per month.)

Figure 17: Out of 10 visited plants, 8 had trained plant operators and 2 had untrained plant operators.

Two questions from the Plant operator survey confirm Mr. Khatiwada’s observations, and these are shown in table 1 and 2.
Table 1: Plant operator survey results: What is your salary?

<table>
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<tr>
<th>What is your salary?</th>
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<tbody>
<tr>
<td>1. 3000 NRs per month.</td>
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<tr>
<td>2. 4400 NRs per month. During the first 2-3 months the operator worked without salary, to gain experience.</td>
</tr>
<tr>
<td>3. 2500 NRs per month for the visited plant, but operator also operates a private plant that is adjoined to the visited one and for this he gets 4000 NRs and food, so he is very happy with that deal.</td>
</tr>
<tr>
<td>4. 5500 NRs per month.</td>
</tr>
<tr>
<td>5. 4000 NRs per month.</td>
</tr>
<tr>
<td>6. 5000 NRs per month.</td>
</tr>
</tbody>
</table>

Table 2: Plant operator survey results: Are you satisfied with this salary? (The accuracy of these answers ought to be questioned due to that interviewees were in a pressed situation with many community members and DCRDC staff present.)

<table>
<thead>
<tr>
<th>Are you satisfied with this salary?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Question not asked.</td>
</tr>
<tr>
<td>2. No, he is not really satisfied with this amount.</td>
</tr>
<tr>
<td>3. Yes. (See above question)</td>
</tr>
<tr>
<td>4. Question not asked.</td>
</tr>
<tr>
<td>5. Yes.</td>
</tr>
<tr>
<td>6. It is not enough, but it’s OK.</td>
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</tbody>
</table>

According to Mr. Khatiwada, the low salary especially becomes a problem when plant operators compare the income with the money that could be earned abroad. In Nepal, there is a clear trend for people to move abroad to work or study, because of the limited opportunities in the country, caused in large by the unstable political climate during the past two decades. It is very common for young men with low education level to move to the Gulf countries and work in construction, at restaurants etc. These jobs can give an income corresponding to NPR 15,000-20,000 or even higher, and thus many men choose to support their families from abroad for some years to save up money.

According to both Mr. Khatiwada and Mr. Acharya, who is sub-engineer at DCRDC, the certificate given at the basic plant operator training makes it easier for plant operators to get jobs in the construction business in Gulf countries, since it is a proof of technical education. Thus, Mr. Khatiwada and Mr. Acharya means that the training that is given to plant operators and which is inevitable for the operation of the MHP plant, is also in itself contributing to plant operators leaving their jobs. Even if they do not go abroad, the training certificate can help them find jobs with higher pay in bigger cities. As in most countries, more education tends to make people move from rural remote areas to urban areas with more opportunities.

Naturally, the training cannot be taken away for such a reason, but it is an observed problem that is noted not only by DCRDC staff. Mr. Kharel, consultant engineer working for AEPC/ESAP, also observed the likely connection between the technical training given to operators and the high turn-over rate. Mr. Kandel however, does not believe that the training and certificate contributes notably to the possibility of plant operators to get jobs in the Gulf.
countries. In his opinion, leaving or staying in the village, is more a question of age. The trend is for young people to move from remote areas, and so the community could make a more secure choice of plant operator by choosing somebody who is older. Mr. Ranjitkar at NMHDA noted that mostly young men go to Gulf countries, and the age distribution among plant operators is very even, ranging from 16 to 60.

4.1.2 Lack of awareness

Mr. Kandel, and many more with him, considers lack of awareness to be one of the largest hindlers to good maintenance. He means that to achieve sustainable operation of the MHP plants, it is equally important to give plant operators awareness about why they perform maintenance, what could happen if a plant is wrongly operated for a longer time, and maybe to achieve an even greater understanding: why energy is important and how it can be used to help develop their life and their community. Even if plant operators know the maintenance routines, it is unreasonable to expect them to perform their tasks properly if they do not know the importance of these tasks or the consequences of not performing them.

The basic plant operator training held by both NMHDA and Oshin Power Services include some sessions about awareness, but the topic is only given 1-1.5 days out of the 22 days of training (NMHDA, Oshin Power Services Pvt. Ltd. 2012). Both Mr. Ranjitkar at NMHDA and Mr. Kafle at Oshin Power Services seem to think that they provide sufficient discussion about awareness in their training programs.

The MHP industry in Nepal works to increase the commercial use of electricity from MHP and it is equally important to raise awareness about the possibility of commercial end-uses of electricity, and the even greater importance of smooth and continuous operation for the success of these end-uses. (It has to be remembered that plant operators come from remote areas without much economical activity, and the concept of business, budgets, costs and profits are probably not well known to the majority of them.) Commercial end-uses are also important to the economy of the plant, and Mr. Ranjitkar pointed out that NMHDA is careful to inform becoming plant operators that commercial end-uses can raise the income of the plant, since commercial end-users pay more per kWh than residential users, and that this eventually could benefit the plant operator him-/herself through raised salary.

Mr. Devendra Adhikari at AEPC/ESAP points out that the level of awareness depends on the location of the community and the type of people inhabiting it. In very remote areas, education and awareness about the possibilities electricity offers is low, and the maintenance situation is similar to what it was like 10 years ago, whereas in areas closer to large villages and cities, the awareness and maintenance quality has increased notably.

Mr. Adhikari means that the ambition and the interest of the plant operator affects the quality of the MHP plant from day one; if the plant operators are ready to learn during the installation phase, much valuable knowledge can be gained, and if not, some quality is lost already before the plant has started operating. Mr. Kafle at Oshin Power Services also tells about how the communities in areas dependent on tourism are very concerned about the smoothness of the power supply. Proving the validity of this statement, Mr. Karna Gurung, who is operating a MHP plant in Ghandruk VDC, which is one of Nepal’s most visited tourist destinations, says that he has a great responsibility, since most other community members engage in tourism.
and are thus very dependent on continuous supply of electricity for their income. Mr. Gurung tells that if the line to the village goes off, he instantly receives upset calls from stressed villagers who want the line back. In this area, turnover of plant operators is not a problem either. Mr. Gurung has operated the plant since it was installed 7 years ago, and another plant operator in the area, Mr. Man Prasad Gurung, has operated “his” plant for 10 years.

In the remote villages in Baglung district, Mr. Kafle says, the communities are not as concerned about the power supply, since it is mainly used for lighting. Also, the literacy and level of education is lower in Baglung, which leaves the community with less awareness of the importance of continuous power supply and the uses of power.

4.1.3 Lack of motivation
Closely related to lack of awareness is lack of motivation. Mr. Ranjitkar at NMHDA sees motivation as the single most important factor for making plant operators stay in service. He means that whereas low salary contributes to plant operators leaving their jobs, a reason just as important might be that they are bored. DCRDC staff member Mr. Khatiwada also tells about this problem: how many plant operators initially are proud and excited about their job, but that they become disappointed after a while, since it is lonely (the powerhouse is usually located some distance from the village) and does not always keep them busy throughout the day. Mr. Khatiwada also believes that some people might become plant operators only to get the chance of going to Kathmandu or Butwal, and that they are less interested in the actual work that follows.

4.1.4 Lack of practical training
The basic plant operator training includes fairly many practical sessions. Oshin Power Services conduct the training next to their manufacturing premises, and thus they can easily integrate practical training with theoretical lectures. Mr. Kafle, who is responsible for the trainings at Oshin, states that out of the 22 days of training only few are purely theoretical, and days are generally divided into a theoretical part followed by corresponding practical practice or demonstration. NMHDA conducts their training at their office in Kathmandu and does not have the opportunity to arrange the training program like the MHP manufacturing companies. NMHDA instead spends whole days at manufacturing premises in Kathmandu, alternated with full days of theoretical learning (NMHDA, Oshin Power Services Pvt. Ltd. 2012) (NMHDA, Oshin Power Services Pvt. Ltd. 2012). Mr. Ranjitkar at NMHDA says that he would definitely like to include more practical training, but with the time, money and facilities given, they currently include as much practical items as possible. However, he mentions that NMHDA plans to build a MHP demonstration plant close to their office in Kathmandu, which would be used at plant operator trainings. Both Oshin Power Services’ and NMHDA’s training includes only one day at an operating MHP plant.

The Plant operator survey included the question: “Would you have liked the training to be more practical?” but unfortunately only 3 of 6 plant operators were asked the question due to various reasons. Two of these three plant operators said that they would have wanted to have more practical training, and one of them said that the training had been good as it was.
Both Mr. Ranjitkar and Mr. Kafle state that the problem with the plant operator training is that much of what is learnt there is soon forgotten. It is important that plant operators keep practicing when back at the MHP plant, which many operators probably do not do. Plant operators actually have plenty of time to gain practical knowledge during the installation period, when a technician from the manufacturing company stays at the MHP site for several months. Mr. Devendra Adhikari’s opinion on plant operator awareness is valid when it comes to practical knowledge as well: the ambition and the interest of the plant operator affects the quality of the MHP plant from the day the operator is chosen, since so much valuable knowledge can be gained already during the installation phase.

4.1.5 Low education level
Mr. Ranjitkar at NMDHA states the low education level of the people becoming plant operators as one of the largest problems for well-functioning MHP maintenance. Plant operators should, according to Mr. Khatiwada and Mr. Acharya, have completed at least 8th grade of elementary school, but there are exceptions to this and since the age of plant operators ranges all the way from 16 to 60 years, some plant operators have obviously lived many years since their school days. Mr. Khatiwada mentioned that even if a plant operator studied technical subjects in high school, the concept of power and power generation is hard to grasp within the 22 days of basic training. Mr. Ranjitkar means that the low education level of becoming plant operators affects the amount of knowledge that can be gained at the plant operator training. However, he also observes that it is hard to find people with higher education level who candidates for the plant operator job, since people with higher education level tend to search for higher paid jobs.

Mr. Kharel brings up another aspect of the low education level: He means that low education level can be related with a lack of organizations skills and knowledge about the importance of organization. A great problem according to him is that tools are not kept in order - that they are damaged and lost, which is a bad start for good maintenance.

4.1.6 Economy of MHP schemes
One very important factor affecting maintenance quality, mentioned by Mr. Kandel, is the economy of MHP schemes. Mr. Kandel pointed out that even though there are many well-functioning MHP plants in Nepal, not all are success stories. A fairly common problem is that villagers are unable to pay the tariffs that they have agreed to when the project was set up. Thus, the plant is installed and the operation is planned based on an economic situation that turns out to be different than initially thought. This leads to problems with collecting enough funds for maintenance.

4.1.7 Distance to MHP repair services and spare parts
One problem connected to the economy of MHP schemes is the difficulty to access repair services and spare parts (see figure 2, section 1). All interviewees included in this study agree that the geographical distance from MHP plants to service centers and spare part retailers causes a problem to MHP maintenance. Plant operators have to make long trips to access services or new spare parts, which is both costly and takes time, during which the plant operation might have to be stopped. All the MHP plant operators included in the Plant operator survey stated that they buy spare parts from Butwal. Alternatively, a technician can
be sent for from the MHP companies, which also is expensive and time-consuming. The road condition in Nepal and the remote location of the majority of the plants is naturally a part of this problem.

Mr. Devendra Adhikari at AEPC/ESAP is the only one of the interviewees that questions the impact of this problem. He agrees that this has been a great problem, but that improved telecommunications, improved infrastructure and the increased number of MHP plants leading to an increased number of technicians out in field has improved the situation. With telecommunications (most remote villages have access to mobile networks and relatively many villagers have mobile phones) it is now possible to call the MHP technicians and resolve problems over phone and the increased number of technicians in field means that the chance of having a technician in the vicinity when a fault occurs increases. However, Mr. Adhikari notes that the access to MHP service works yet again depends on the type of community: the reasoning above holds true for some areas and some MHP schemes, while the maintenance situation in other areas is basically the same as ten years ago.

The interviewees offered many ideas and thoughts on solutions that could address the above listed issues.

4.1.8 Increased salary for plant operators
Since the high turnover rate of plant operators is a central problem, the interviewees suggested various ways to counteract the believed causes for plant operators leaving their jobs. Increased salaries could decrease the competitive advantage of jobs abroad and could help attract plant operator candidates with higher education level. Mr. Ranjitkar shared an idea that had been discussed briefly at NMHDA: to introduce a minimum wage for plant operators. How this minimum wage would be paid for was not clear yet. Mr. Kharel had thoughts along the same line, suggesting that ESAP could sponsor higher salaries. Currently, ESAP has no specific financial support for MHP maintenance, according to Mr. Devendra Adhikari.

4.1.9 Additional job
Another way to increase the income for plant operators is to engage in a second job on the side of operating the plant, such as farming, carpenting etc. This could also keep plant operators from getting bored during slow and lonely days at the plant. Furthermore, most plants only operate at peak hours, which leaves large parts of the day free for operators to do other things. Mr. Acharya tells that because of these reasons, DCRDC encourages plant operators to engage in an additional job, but that only few have followed the organization’s recommendation.

NMHDA also suggests this at training, according to Mr. Ranjitkar. He believes that this is a good way to address the lack of motivation that follows on low salary and lack of work tasks.

4.1.10 Contract between community and plant operator
According to Mr. Acharya, DCRDC at one point tried to find a solution to the problem of high plant operator turnover, by suggesting that communities write a contract with operators,
binding them to work for a certain amount of time with a fine if they leave before this period of time has ended. However, this is not done and Mr. Acharya says that DCRDC realized that concept with contracts would not work. The explanation is of a social nature: the installations of MHP plants in villages are projects carried out by whole communities working together. Social relations are strong between community members, and writing a contract with a close friend or relative seems neither necessary nor natural to the villagers. The work around the MHP plants build on cooperation and trust, and this is also what makes these projects so successful: every villager contributes to the building of the plant, and in this way every villager has a personal interest in the success of the project.

4.1.11 Awareness training

Mr. Kandel is especially passionate about the idea of an increased focus on awareness in the plant operator trainings, or additional training focusing solely on the awareness part, since he thinks that lack of awareness is one of the major causes for poor maintenance. He means that plant operators need to gain further awareness of how important their work is for the development of the community, to gain a greater responsibility when operating the plant. Hopefully, this knowledge will also make them more satisfied and happy with their job. Equally important for the success of the MHP plant, is that the community is informed about the possibilities that electricity offers through commercial end-uses, and the importance of such end-uses for the economy of the plant.

Mr. Kandel is a strong proponent of a decentralized R&M center, and his vision is that such a center could both conduct awareness training for operators and spread awareness information to the community. However, he is of the opinion that additional awareness training should be given to older operators in the first hand. This is because he sees that younger people tend to move away from the remote areas.

Not fully sharing the view of Mr. Kandel, Mr. Devendra Adhikari at ESAP/AEPC means that awareness training is built into the whole system from the beginning to the end of a MHP project. He says that both formal and informal trainings are given along the way, and the facilitating organizations such as DCRDC play an important part in this. Naturally, training should be adjusted to the needs of the community – some communities might need a lot of information throughout the process while others already have the awareness needed.

4.1.12 Additional plant operator training

Advanced plant operator training already exists, even if only a few number of plant operators are allowed to attend it – those who operate very remote plants with very limited access to service assistance and new spare parts. The idea of advanced plant operator training is naturally to improve maintenance and decrease the need for assistance from MHP technicians, addressing the problem of long distances to MHP expertise. One hypothesis before arriving at site in Nepal, was that maintenance could be improved by giving more education to as many plant operators as possible. However, social factors resulting in a high turnover rate of operators showed that the solution was not that uncomplicated. Mr. Khatiwada is skeptical about giving too many plant operators additional training. He brings up the fact that technical training seems to increase plant operators’ chances of getting the coveted jobs in the Gulf countries.
Mr. Ranjitkar at NMHDA says that the organization has specific criteria when choosing which plant operators should get advanced training: they should have worked for two years, and should preferably have a higher level of education than the average plant operator. This is to ensure that the plant operators that receive training will be able to utilize and distribute the knowledge they learn, since the goal of the advanced operator training is that also neighboring MHP plants and their operators will benefit from training in this way. Optimally, plant operators who receive advanced training will teach neighboring operators, but if they don’t, they will at least be able to help when problems occur and in this way decrease the need for technicians from the MHP companies.

NMHDA would rather increase the number of plant operators with advanced training, to create decentralized sources of knowledge instead of establishing decentralized R&M centers, since they are concerned with the economic viability of such a center. This model is made possible now that there are many more plants than only a few years ago, and in some regions small clusters of MHP plants have arisen.

An idea along the same line of thought was shared by Mr. Om Prasad Gurung, who is a MHP chairperson in Ghandruk VDC. He wants to make additional knowledge even more accessible to the plant operators by bringing the teacher to the students and arranging advanced trainings at the MHP sites. This way the training could become cheaper, and it could easily focus on the practical parts.

4.1.13 Decentralized R&M centers
All interviewed persons acknowledged that a MHP R&M center closer to the location of the MHP plants would improve the maintenance situation. Mr. Kandel, Mr. Upadhyay and Mr. Kunwar are all engaged in realizing this center, and the idea as presented by them is that the center would offer both sales of spare parts as well as maintenance and repair services. This would relieve plant operators of the long and costly trips to Butwal or Kathmandu. More specifically, the center suggested by the three men mentioned above would be located in Burtibang, which is a village quickly growing into a small city, located in Western Baglung district. Mr. Upadhyay and Mr. Kunwar, who are DCRDC employees stationed in Burtibang, say that there are over 50 MHP plants in the area that would benefit from a R&M center in this location.

Not doubting the benefit that a R&M center in Burtibang would give surrounding MHP plants, Mr. Devendra Adhikari at AEPC/ESAP still questions the economic viability of the
center. He means that the idea would have been more feasible ten years ago, but that improved infrastructure, improved telecommunication and an increased number of MHP technicians in field decreases the demand for the center’s services and that it will not have enough business to stay economically sustainable.

Mr. Devendra Adhikari is also concerned about the long-term sustainability of the R&M centers. There is a limitation to the number of MHP that can be installed, and he suspects that within a few years the number of plants that want to refurbish to higher capacity will increase, and the number of completely new MHP projects will decrease. With refurbishments, there will be many installation company technicians in field, who will be able to carry out the services that the centers will offer. Another reason that he thinks the need for R&M services will decrease is that plant operators gain more and more knowledge themselves. Many MHP plants have been installed in the past 2-3 years and the plant operators of these plants will become more and more confident about their tasks, the longer they work.

ESAP is actually currently doing an investigation about the need for decentralized R&M centers in seven locations in Nepal, on a request from the program’s donors, but the results have not yet been published.

Mr. Ranjitkar at NMHDA is also skeptical about the economic viability of the center, and prefers the idea of giving advanced training to a larger number of plant operators that would act as decentralized sources of knowledge.

Oshin Power Services in Butwal, however, is positive about the idea and convinced that it would be very helpful to the MH-powered communities in the area. Instead of seeing the business of the center as competition, they are happy that there will be a provider of more simple MHP R&M services in the area, according to Mr. Kafle and Mr. Thakar Adhikari, engineer and CEO at Oshin Power Services. It will save their technicians precious time if they do not have to make the long travels to Baglung district for minor services. Oshin Power Services see this as a chance to distribute the workload by coordinating with the R&M center in Burtibang.

However, Mr. Kafle and Mr. Thakar Adhikari says that Oshin Power Services recommends the establishers of the center to engage in non-MHP R&M work as well, to stay economically sustainable. Even though the customer base is made out of 50 MHP plants, probably growing with ten new sites per year, the demand of services might not be enough to sustain the business. Mr. Devendra Adhikari at AEPC/ESAP agrees that this is a way to achieve economic sustainability.

Further recommendations from the interviewees, along with details about the financial and organizational structure of the suggested center, are presented in section 6 of this report.

4.1.14 Maintenance manual

Finally, a solution that was suggested to the interviewees by the writer of this report, was to make maintenance manual posters, that could be attached to the walls in the power houses. None of the interviewees had thought about this solution previously, and the reactions were of mixed character. All the interviewees were aware that all plant operators when attending the
basic plant operator training received a personal copy of a maintenance and trouble-shooting manual, which could be of help when maintaining and doing repair work on the plant. What many interviewees were not aware of, however, was something that was discovered when talking to plant operators during the field trips of this study: many of the plant operators did not have the manual or did not use it. Out of eight MHP plant operators that were asked about their use of the maintenance manual, only two used it.

The reason why they did not have the manual varied: either it was lost or the plant operator had taken over after a previous operator who had taken the manual with him, and the current operator had not attended training yet. A maintenance manual poster could help specifically in the last case: when one person from the village has to take over operating the plant instantly without a chance to get training first. In this case simple maintenance instructions could help the replacing operator by at least letting him/her know the maintenance routines, even if he/she cannot do more advanced trouble-shooting or repair work.

Mr. Khatiwada agreed that such an idea would be helpful in some cases, but also noted that in a larger context, this solution would probably not make a major impact on the general maintenance situation. Mr. Kandel shared the same view, and would rather put focus on increased awareness among operators. Mr. Ranjitkar at NMHDA on the other hand, was very positive about the idea. Mr. Devendra Adhikari at AEPC/ESAP was also critical about the impact that such a poster would make on the maintenance situation.

Despite the mixed reactions on the suggestion, a maintenance poster was made during the stay in Nepal with help of DCRDC staff. The poster was based on the information in the maintenance manual handed out at the basic plant operator training. It was translated into Nepalese and printed in one plastic copy as a prototype for DCRDC in case they, NMHDA or some other organization would be interested in trying the solution. The poster in Nepalese is shown in Figure 20 and an English translation is found in appendix B.
4.2 What is the quality of maintenance performed at MHP plants? Which parts of maintenance are working and which are not?

In this section, the results of the Plant operator survey are presented. To evaluate the results about maintenance quality and regularity it is of interest to know something about the participating plant operators; what training they have had, what access they have to maintenance instructions/manuals, and how long they have worked.

Table 3 shows this information, as well as the name of the plants and their location. Each plant/plant operator is given an index number between 1-6. This way the answers contributing to the following statistics can be derived to the plant operators’ and the plants’ characteristics.
Table 3: Characteristics of plants in Plant operator survey.

<table>
<thead>
<tr>
<th>No</th>
<th>Plant name</th>
<th>Location</th>
<th>Years at work</th>
<th>Training</th>
<th>P.o. has maintenance manual</th>
<th>P.o. uses maintenance manual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kut Khola 2nd</td>
<td>Rajkut VDC</td>
<td>18 months</td>
<td>One of the two p.o.s has had MHP project management training.</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Bhuji Khola 6th</td>
<td>Burtibang VDC</td>
<td>1 year</td>
<td>Basic plant operator training</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>RCG MHP</td>
<td>Burtibang VDC</td>
<td>5-6 years</td>
<td>No training</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Bhuji Khola 2nd</td>
<td>Burtibang VDC</td>
<td>5.5 years</td>
<td>Basic plant operator training</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Chare Khola</td>
<td>Kunemangale VDC</td>
<td>1 month</td>
<td>Basic plant operator training</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>Ghatte Khola</td>
<td>Ghandruk VDC</td>
<td>7 years</td>
<td>Basic and advanced plant operator training</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Rajkut VDC and Kunemangale VDC are remote rural areas, where most people make their living from agriculture. Burtibang VDC is a village area quickly growing into a small city with establishment of small industries and conveniences such as a hospital. Ghandruk VDC is one of the areas in Nepal visited by most tourists and most inhabitants support themselves on tourism. The observations of MHP experts are that maintenance quality is better in areas where the value of electricity is obvious, such as in areas with tourism and business opportunities. Ghandruk VDC is definitely an area corresponds to that description. Burtibang VDC does not have any tourism, but have many opportunities of commercial use of electricity. However, observations and learnings from the field trip to Burtibang show that this has not necessarily led to good maintenance. The give a better understanding of the different maintenance situations in Ghandruk VDC and Burtibang VDC, they are described briefly in Textbox 3 and Textbox 4 following on the results of the Plant operator survey. Information in the textboxes is based on observations and learnings from field.

Table 4 shows the satisfaction of job and salary of plant the surveyed plant operators.
Table 4: Satisfaction of job and salary of surveyed plant operators.

<table>
<thead>
<tr>
<th>No</th>
<th>Salary</th>
<th>Satisfied with salary?</th>
<th>Happy with job as p.o.?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NPR 3000/month</td>
<td>Question not asked.</td>
<td>Question not asked.</td>
</tr>
<tr>
<td>2</td>
<td>NPR 4400/month</td>
<td>No.</td>
<td>Yes.</td>
</tr>
<tr>
<td>3</td>
<td>NPR 2500/month. Also operates an adjoining plant where he earns NPR 4000/month plus food.</td>
<td>Yes, he is very satisfied with the deal including the two salaries and food.</td>
<td>Yes.</td>
</tr>
<tr>
<td>4</td>
<td>NPR 5500/month</td>
<td>Question not asked.</td>
<td>Ok. P.o. has no idea of where else to work.</td>
</tr>
<tr>
<td>5</td>
<td>NPR 4000/month</td>
<td>Yes.</td>
<td>Yes.</td>
</tr>
<tr>
<td>6</td>
<td>NPR 5000/month</td>
<td>Not enough, but it is OK.</td>
<td>Yes.</td>
</tr>
</tbody>
</table>

Table 5: Plant operator survey results: How often do you grease bearings?

<table>
<thead>
<tr>
<th>Answers</th>
<th>Statistical results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Every 15th day.</td>
<td></td>
</tr>
<tr>
<td>2. Every 15th day.</td>
<td></td>
</tr>
<tr>
<td>3. Every 15th-20th day.</td>
<td></td>
</tr>
<tr>
<td>4. Every 3 months.</td>
<td></td>
</tr>
<tr>
<td>5. One time a week.</td>
<td></td>
</tr>
<tr>
<td>6. One time a week.</td>
<td></td>
</tr>
</tbody>
</table>

According to the maintenance schedule distributed at the plant operator training, turbine bearings should be greased every 3 months (see appendix A).

Table 6: Plant operator survey results: How often do you measure the temperature of machine and bearings?

<table>
<thead>
<tr>
<th>Answers</th>
<th>Statistical results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 4-5 times a day.</td>
<td></td>
</tr>
<tr>
<td>2. Every second hour.</td>
<td></td>
</tr>
<tr>
<td>3. Daily.</td>
<td></td>
</tr>
<tr>
<td>4. Daily, at peak load hours.</td>
<td></td>
</tr>
<tr>
<td>5. 2-3 times a week.</td>
<td></td>
</tr>
</tbody>
</table>

According to the maintenance schedule distributed at the plant operator training, temperature should be checked daily (see appendix A).
Table 7: Plant operator survey results: How often do you listen to sounds, vibrations and look for things that are out of the ordinary?

<table>
<thead>
<tr>
<th>Answers</th>
<th>Statistical results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Daily.</td>
<td></td>
</tr>
<tr>
<td>2. Daily.</td>
<td></td>
</tr>
<tr>
<td>3. Daily.</td>
<td></td>
</tr>
<tr>
<td>5. Daily.</td>
<td></td>
</tr>
</tbody>
</table>

According to the maintenance schedule distributed at the plant operator training, these things should be checked daily (see appendix A).

Table 8: Plant operator survey results: How often do you clean the powerhouse?

<table>
<thead>
<tr>
<th>Answers</th>
<th>Statistical results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Daily.</td>
<td></td>
</tr>
</tbody>
</table>
| 2. P.o. cleans the floor and wipes the machine free from dust, but he has never cleaned other parts of the powerhouse. | • 4 out of 6 plant operators (p.o.s) sweep the powerhouse floors daily, and the other two p.o.s sweep the floors at least two times a week.  
  • Two p.o.s say that they wipe of the machine at least every 2-4 days.  
  • Observations when visiting the powerhouses: most powerhouses looked fairly clean, with two exceptions: at Bhuji Khola 6th (interview no 2) the floors and machine were clean, but the ceiling and all the electrical equipment were covered in dust and spider webs, and at Ghatte Khola (interview no 6) it was very clean compared to the other plants. |
| 3. In the morning. |                     |
| 4. The whole powerhouse is cleaned every 6th months, but the floor is cleaned every 2-3 days. |                     |
| 5. Daily. |                     |
| 6. The floors are swept daily. The p.o. wipes off the machine with 2-4 days interval. |                     |

According to the maintenance schedule distributed at the plant operator training, the area in and around the powerhouse should be cleaned daily (see appendix A).
Table 9: Plant operator survey results: Do you check tension of the belt between shafts of turbine and generator and if so, how often?

<table>
<thead>
<tr>
<th>Answers</th>
<th>Statistical results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It was properly checked during last fitting. Belt has been working poorly since plant started operating.</td>
<td>Daily 3/5</td>
</tr>
<tr>
<td>2. Daily, in the morning when the plant is shut off.</td>
<td></td>
</tr>
<tr>
<td>3. Tension is checked when it seems to be loose, so not regularly.</td>
<td>1/5</td>
</tr>
<tr>
<td>4. Daily, in the hour when the plant is shut off.</td>
<td></td>
</tr>
<tr>
<td>5. Daily, in the evening before the starting up the plant.</td>
<td></td>
</tr>
<tr>
<td>6. No belt, there is direct coupling. (Not included in the statistical results.)</td>
<td></td>
</tr>
</tbody>
</table>

According to the maintenance schedule distributed at the plant operator training, the belt tension should be checked daily (see appendix A).

Since Kut Khola 2nd has had continuous problems with the belt since the plant started operating and the p.o. does not have any routine on checking the belt tension under normal operation, thus the empty space corresponding to 20 % or one out of five plants in the results chart above.

Table 10: Plant operator survey results: Do you ever stop the turbine to do maintenance and if so, what do you do?

<table>
<thead>
<tr>
<th>Answers</th>
<th>Statistical results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No. No planned stops are made.</td>
<td>Yes, every 3-6 months. 1/6</td>
</tr>
<tr>
<td>2. P.o. knows that the inside of the turbine should be cleaned, but they don’t have any planned stops for this.</td>
<td>No, only if there is a problem. 5/6</td>
</tr>
<tr>
<td>3. The turbine is only stopped if there is a problem.</td>
<td></td>
</tr>
<tr>
<td>4. The turbine is only stopped if there is a problem.</td>
<td></td>
</tr>
<tr>
<td>5. No.</td>
<td></td>
</tr>
<tr>
<td>6. Yes. Every 3-6 months the operators open the turbine to check it, even if there is no problem.</td>
<td></td>
</tr>
</tbody>
</table>

According to the maintenance schedule distributed at the plant operator training, the runner and buckets of the turbine should be checked every 3 months. (see appendix A).
Table 11: Plant operator survey results: Do you write down meter values of produced energy daily?

<table>
<thead>
<tr>
<th>Do you write down meter values of produced energy daily?</th>
<th>Statistical results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes.</td>
<td></td>
</tr>
<tr>
<td>2. P.o. had misunderstood this and kept daily values of power instead of energy.</td>
<td></td>
</tr>
<tr>
<td>3. No.</td>
<td></td>
</tr>
<tr>
<td>4. No, not regularly. Occasionally he does. In the beginning of his time as p.o. he did this, but not anymore.</td>
<td></td>
</tr>
<tr>
<td>5. Yes, everyday.</td>
<td></td>
</tr>
<tr>
<td>6. There is no energy meter due to that the plant is too old to be part of the CDM (Clean Development Mechanism) program.¹ (Not included in the statistical results.)</td>
<td></td>
</tr>
</tbody>
</table>

According to the maintenance schedule distributed at the plant operator training, plant operators should look at meter readings daily. (see appendix A).

Table 12: Plant operator survey results: Do you write down values of current, voltage and frequency daily?

<table>
<thead>
<tr>
<th>Do you write down values of current, voltage and frequency daily?</th>
<th>Statistical results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Question not asked.</td>
<td></td>
</tr>
<tr>
<td>2. Yes, these values are checked and noted three times a day.</td>
<td></td>
</tr>
<tr>
<td>3. No.</td>
<td></td>
</tr>
<tr>
<td>4. No, only occasionally. In the beginning of his time as p.o. he did this, but not anymore.</td>
<td></td>
</tr>
<tr>
<td>5. No.</td>
<td></td>
</tr>
<tr>
<td>6. Yes.</td>
<td></td>
</tr>
</tbody>
</table>

According to the maintenance schedule distributed at the plant operator training, plant operators should look at meter readings and check frequency daily. (see appendix A).

¹ Energy meters are installed in newer plants, since keeping a record of how much energy is renewably produced can give the community economic compensation from UN’s CDM fund.
Table 13: Plant operator survey results: How often do you check civil parts?

<table>
<thead>
<tr>
<th>Answers</th>
<th>Statistical results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Civil parts are checked every 2-3 days, and cleaned when there is need.</td>
<td></td>
</tr>
<tr>
<td>2. Daily, but it is harder to do this daily in the rainy season.</td>
<td></td>
</tr>
<tr>
<td>3. Only if flow of water decreases.</td>
<td></td>
</tr>
<tr>
<td>4. In rainy season the p.o. cleans canal, intake and desilting basin.</td>
<td></td>
</tr>
<tr>
<td>5. Every 2-3 days.</td>
<td></td>
</tr>
<tr>
<td>6. Every day.</td>
<td></td>
</tr>
</tbody>
</table>

The maintenance schedule distributed at the plant operator training has many individual instructions for the different civil parts (for details see appendix A), but at least the intake, headrace canal, forebay tank, and tailrace should be checked for damage or debris every day.
**Maintenance case study: Ghandruk VDC**

As mentioned many times before in this report, Ghandruk VDC lies in an area on the foothills of the Himalayas, frequently visited by tourists from all over the world. MHP has enabled the villagers to offer new and more services to tourists, and as the majority of the villagers are engaged in tourism the benefits of electricity are very obvious to the whole community. As a result, the plant operators of the MHP plants in the area are well aware of their responsibility and that the quality of the work they perform affects the work of their fellow community members.

From observations made on field trip to MHP plants in Ghandruk VDC, the maintenance quality is very good. Speaking to the plant operator of Ghatte Khola (plant no 6 in the Plant operator survey) he mentions that only one village load fuse has broken in the plant’s seven years of operation, which is amazing considering that most breaking fuses is one of the most common problems for the majority of the MHP plants. Ghatte Khola was by far the most clean and well organized plant out of the 10 plants visited in Nepal. While speaking to the operator of Ghatte Khola, a plant operator of one of the neighboring plants came by. He confirmed that sharing of knowledge and cooperation also works well in the area; plant operators of adjacent plants share knowledge from training, and though the this plant operator had only had basic plant operator training, he had learnt a lot from the operator of Ghatte Khola who had attended advanced plant operator training.

Yet another plant operator from the area was met during the trip, Mr. Man Prasad Gurung. Also he had operated the plant since its installation 10 years ago and during these ten years no village load fuse had broken, which he explained was a result of checking the village load carefully at least two times a day. He also mentioned that all MHP plants in the area have a habit of shutting down the plant in case of thunder, thus saving the ELCs from being damaged. The plant operator has only attended basic plant operator training, but has gained so much practical knowledge during his years operating that he has even built a temporary 2kW plant himself, to restore his guesthouse, which is a second business apart from his job as a plant operator.

**Maintenance case study: Burtibang in Burtibang VDC**

The village of Burtibang (in Burtibang VDC) is the trading and transportation center of western Baglung district and is currently growing quickly from a village into a smaller city. With this, power demand is also growing day by day, forcing the two MHP plants supplying the village (RCG MHP and Bhuji Khola 2nd, no 3 and 4 respectively in the Plant operator survey) to produce more power than they are designed for, thus causing them to wear out faster than they would have done at a balanced load situation. The situation is also causing risk for severe damage to the machines, which in turn causes danger to plant staff as well as risk of serious power loss to the community.

As an example, when visiting Bhuji Khola 2nd at 6 pm (peak load hour), the plant was running
with power output higher than its rated capacity of 34 kW, frequency at 45 Hz, and voltage at 200 V, due to excess load. In the powerhouse it was noted that the village load fuses on the switchboard had been removed and the wires twined together, which is obviously done because the plant is frequently overloaded and they did not want to keep changing the fuses. This is a great danger, since overcurrent cannot be discovered and could cause the generator to overheat. Accordingly, the generator of both the MHP plants powering Burtibang have broken down, resulting in great repair costs and inconvenience to the community.

The problem seen in Burtibang is obviously caused by an unexpected growth rate of the city and of the use of electricity. When Bhuji Khola 2nd and RCG MHP were built 7 and 5 years ago, the power capacity was calculated from the number of households benefited at the time and assuming each household would use only 100 W. At this time the residential end-uses probably consisted only of lighting and an occasional television, but with increasing income of Burtibang’s inhabitants, along with the development of cheaper electronics, the need for electricity is now far from only concerning lighting. Commercial end-uses have probably increased a lot, and a new hospital is currently under construction. This development could not easily have been predicted 9-10 years ago when the two MHP projects were initiated.

Despite this problem, the two plants are not very well maintained (see Plant operator survey results above). Furthermore, there seems to be no plan on how to solve the problem of increasing power demand. According to Mr. Acharya, DCRDC has suggested the community to build a third MHP plant, as the quickest way of addressing the electricity scarcity. There is a site that has been proven to be feasible for a 100 kW MHP plant and DCRDC is ready to facilitate the project, as soon as the community provides the specifications needed, including information such as number of households benefited, how much resources the community is prepared to contribute in money and labor, an agreed tariff that could cover the costs of the project etc. However, according to Mr. Acharya, it seems as Burtibang is becoming a too big community to be mobilized together. With a growing population and growing economical activity, people are less acquainted with each other and are busier with their own individual work. Together this makes it harder to make the people want to contribute time and unpaid labor to realize the MHP plant. Being supplied by the national grid is not an option, since the closest grid connection is 35 km away and Mr. Acharya approximates that it will be 10-15 years before grid extension reaches Burtibang, especially since the national grid itself already suffers from electricity scarcity.

Since the population of Burtibang in average is richer than that of a smaller village, one solution could be to select a contractor to do the construction work of a new MHP plant, and let villagers contribute more financially instead. However, there seems to be no interest in this solution either. The reason is most probably that villagers are not aware of the serious condition of the plants powering their daily life. All they know is that there is power in their outlets – so they use it. As long as there is power, they will not initiate a project that they will have to finance, even if voltage level is low at peak hours. They are also probably not aware of the damage that the low voltage level causes to their electrical equipment. The core of the problem is thus again lack of awareness.
For the maintenance quality, it is also of interest to know whether the MHP manufacturing and installation companies provide any instructions besides the maintenance manual distributed at the plant operator training. The MHP company survey included such a question: *At installation, do you provide plant operators with maintenance recommendations for your equipment?*

On this question, the answers of the three surveyed companies differed. One company said that they do not provide any written recommendations, since they know that the training of operators is taken care of by governmental support programs. However, they state that the plant operator, if chosen at the time of installation, is informed orally about maintenance procedures. Another company said that they provide the plant operator with a photocopy of the maintenance manual distributed at the plant operator training. The third company said that plant operators are instructed orally at installation, and that they are also provided with the company’s own manuals in written form. This manual contains general information about the parts and the technology of the plant as well as maintenance recommendations. The latter include, among other things, recommendations to check civil parts every 15 days, to clean the powerhouse daily, and to grease turbine bearings once a week. The turbine bearing temperature should be checked every day, and if it is too hot, the recommendation is to apply more grease. They do not provide recommendations to check the tension of the belt, since plant operators do not have the instrument that is needed for that, but they are instructed that if there are some vibrations in the machine, the problem might be the tension of the belt.

The companies were also specifically asked about their recommendations on opening and checking the turbine at regular intervals. On this question, two of the three companies said that they do not recommend this. However, one of the companies – Oshin Power Service Ltd. Pvt. – said that their turbines are designed with a hatch on top, which is easily removed even by plant operators without much technical experience. This way the turbine can easily be cleaned from debris, and they are recommended to do this one time a year. Only plant operators who have worked for many years might have learned to disassemble and assemble the turbine properly, in which case they can check the turbine more thoroughly, but this is not part of the recommendations given by the company.

### 4.3 What are the most frequently occurring failures and faults, and why are these the most common? Are they a result of lacking maintenance or are there other reasons?

Information about fault type and fault frequency was gathered from several sources.

Plant operators in the *Plant operator survey* were asked about what faults had occurred (big and small) since the plant started operating. The answers from the six contributing plant operators resulted in the fault statistics represented in *Figure 21.*
It should be noted that a breaking fuse is actually not a fault, since the function of the fuse is to break to save more expensive equipment. However, the frequent breaking of fuses gives a hint about the maintenance quality, as fuses break when the plant is run in a condition that is hazardous to the plant’s own equipment or to people.

Statistical information was also collected from DCRDC’s document archive. For each MHP plant DCRDC puts together a report one year after the plant was installed, at the so called 1-year guarantee check, and among other things these reports contain information about faults that occurred during the first year of operation. Information from 18 reports was collected and the result is presented in Figure 22. Mr. Kandel pointed out that the information provided by plant operators for the Plant operator survey and in the 1-year guarantee checks cannot be fully relied on – he means that operators probably do not remember all faults that have occurred, and the statistics can be used more as pointer to what problems are most common.
In the *MHP company survey*, MHP companies were asked about the most common repair services that they perform on MHP equipment (i.e. what faults are most common). They were also asked about the reason for the higher frequency of certain faults. A summary of the three companies’ answers follows:

- All three companies stated that faults in the ELC is one of the most common reasons for need of repair services and one company adds that the faults occur especially often in the thyristor in the ELC. All three companies also stated that the reason for this generally is lightning, especially in the hilly regions in monsoon season, with an even higher fault frequency in Baglung district since the ground there is rich in minerals like iron and copper.

- 2 of 3 three companies stated that changing of turbine bearings is also very common. Considering this fault, the companies had different ideas about why it happens. One company believes that faults in turbine bearings generally occur due to irregular greasing or to running of turbine in overload condition. The other company said that the fault might depend on manufacturing fault or lacking maintenance, saying that if a bearing is run for a longer time in a faulty condition (which can depend on either manufacturing fault or maintenance) it will eventually break. They also mentioned that another possible reason for damaged bearings is a fault in the ELC that makes the turbine speed, which if not noted in time, will damage the bearings.

  The third company mentioned that they have seen an increase in damage to generator bearings lately, which is less likely to depend on lacking maintenance since the generator bearings of the type of generator that is used do not need regular greasing and plant operators are not instructed to do this. The company believes that the rise in generator bearing faults depends on manufacturing faults; the manufacturing of the generators has recently been taken over by a new company, and he believes that the new company is using old bearings to clear the stock.

- Faults in fuses and MCCBs are also reported to be common, which is believed to depend on overload or in the case of MCCBs also possibly lightning.

- Faults in generator are said to occur sometimes (though less often than all the faults mentioned above) and the reason for this is also overload or lightning.

- One company mentioned that damage to the turbine runner is common after 5-6 years of operation.

MHP companies were also asked how often they test their equipment. The answer was more or less the same for all three companies, namely that they test penstock pipes for pressure, as well as ELCs and generators, all before delivery of equipment. Until very recently there has been no testing lab for turbines in Nepal, so most companies have not had the possibility to test this piece of equipment. However, one company has a demonstration plant on their premises and can thus test also turbines both at manufacturing and before delivery.
5 Discussion

The discussion will be arranged in a different order than the results. Discussion of results from the Plant operator survey will be presented first, followed by discussion of the MHP company survey, and ending with a summary and discussion of the answers from the qualitative interviews.

5.1 Discussion of results: What is the quality of maintenance performed at MHP plants? Which parts of maintenance are working and which are not?

The aim of the Plant operator survey was to gain results that could be used to verify or contradict the observations and opinions of the interviewed experts. Is maintenance really not carried out regularly at most MHP plants? The results of the Plant operator survey both correlate with and contradict the experts' observations.

Some maintenance routines seem to be carried out regularly, not surprisingly the easier ones, such as listening for and looking for things out of the ordinary, measuring of the machine and bearing temperature.

When it comes to other routines, both easy ones and ones that demand more effort from the operator, the results vary. Examples are checking civil parts, writing down meter values, greasing of bearings and opening the turbine (which, however, is only recommended by Oshin Power Services).

It needs to be taken into account that the interviewed plant operators in all cases were surrounded by DCRDC staff and community or users' committee members, putting them in a pressed position, which might well have made their answers describe a situation that is somewhat better than the reality. What speaks against this however, is that to rather many questions, the plant operators gave answers that did not correspond with the maintenance instructions. A reason for this might be that the plant operators actually did not know or have forgotten what the recommended maintenance instructions are.

Unfortunately, a number of questions that were included in the Plant operator survey could not contribute properly to the results, since too few answers had been collected due to varying reasons such as lack of time at the interview or sudden bad weather interrupting the interview. Two such questions that would have been very useful in evaluating the level of motivation of plant operators and the correlation of this and maintenance quality are: Do you have another job apart from being plant operator? and Why did you want to become plant operator?. The reasons why the que

One important result from the plant operator survey is the clear difference in maintenance regularity between the MHP plant in Ghandruk VDC (Ghatte Khola, indexed no 6 in the Plant operator survey) and the rest of the included MHP plants. This correlates well with the experts' observations on how maintenance depends on type of community. Although this result was important, it would have been equally important to back up these results by interviewing more plant operators in Ghandruk VDC or similar areas. One plant operator from an adjacent plant was interviewed shortly, but
not as thoroughly as the operators contributing to the Plant operator survey. The answers given at this short interview are presented in

Textbox 4 Maintenance case: Ghandruk VDC, and seemed to confirm that the maintenance quality was high at other plants in the area around Ghatte Khola. However, for the scientific relevance of the study, it would have been good to include more plants from areas like Ghandruk VDC in the Plant operator survey.

The answers given at the Plant operator survey varied much, but one thing that almost all plants had in common (Ghatte Khola excluded) was that maintenance was lacking to some degree, which leads to the assumption that maintenance is irregular at most MHP plants around DCRDC’s working area. The Plant operator survey also conveys that every MHP plant has a unique maintenance situation.

5.2 Discussion of results: What are the most frequently occurring failures and faults, and why are these the most common? Are they a result of lacking maintenance or are there other reasons?

The main aim of the MHP company survey was to investigate which faults are most common at MHP plants and what MHP technicians believe causes these faults. It is of interest to see whether the most common faults depend on lacking maintenance, or on other reasons that are outside the responsibility of the operators.

According to the interviewed MHP companies, three of the most common faults: breaking turbine bearings, fuses, and MCCBs, are commonly caused by situations that the plant operator could have prevented. The most common cause for breaking fuses is that the plant is overloaded and together with lightning, this is also the most common cause for breaking MCCBs. Two causes for breaking turbine bearings are believed to be overload or irregular greasing, both possible to be taken care of by the operator. One company opened up for that it might be manufacturer fault that causes the bearings to break. MCCBs and fuses might not be the most expensive parts to replace, but their frequent breaking signals that plants are often run in overload conditions, which also is causing wear and possible damage to the turbine, the generator and the bearings.

The fourth part brought up by MHP companies as one the most commonly breaking, was the ELC, which was said to break because of lightning, thus independent of the work of plant operators. One interesting aspect however, is that plant operators at some of the plants in Ghandruk VDC shut down the plants when there is thunder, according to Mr. Man Prasad Gurung, a plant operator who was interviewed shortly on one of the field trips. As a result, he had never had any problems with the ELC during his ten years of operating.

Naturally, one has to be critical when asking the companies why their equipment breaks, since a company would not gladly admit that it depends on their own manufacturing process. However, the above mentioned parts are all purchased by the companies and integrated into their equipment, that is, none of them are manufactured by the companies themselves. On the other hand, turbine bearings could easily be worn out or damaged if incorrectly installed. The frequent overload situations could also be caused by incorrect plant design. However, these possibilities fall outside the scope of the study. The quality of the equipment and parts
purchased and used by the companies could also be the cause for frequent breaking. Good quality could also be the reason that the equipment in some plants seem to last longer, such as the ELCs in Ghandruk VDC, but the varying quality of equipment too falls outside the scope of the study and has not been investigated.

The parts reported by MHP companies to be the most common to break correlate with the faults reported by plant operators in the Plant operator survey. However, the data from DCRDC's archive of one-year guarantee reports does not correlate with the other two information sources. This fault frequency data is topped by damage to civil parts, which is known to be a great problem due to the heavy rains in monsoon season and the many landslides. Perhaps the interviewed plant operators did not think of to mention civil parts, since this most often can be taken care of without consulting a MHP technician. Perhaps damage to civil parts is most common during the first year of operation, since this is when the plant design is put to its test. The latter alternative is at least believed to be the reason that the one-year guarantee fault statistics differ from the faults stated by MHP companies and plant operators; it is possible that the type of faults that occur during the first year of operation are of a different kind - after all, the point of the one-year guarantee is that the community should not have to pay for faults that might depend on faulty design calculations or installation work.

5.3 Discussion of results: What issues affecting maintenance quality do MHP plants face, what are the reasons behind these issues, and how can they be addressed?

All consulted experts recognize that maintenance is lacking in a majority of the MHP plants (speaking of MHP plants facilitated by DCRDC or MHP plants in Nepal generally, depending on the position of the interviewee). Some see it as a considerable problem, whereas others like to focus on the improvements in maintenance quality that has been seen within the past years. Accordingly, the will to support maintenance solutions financially vary. Also, the opinions of the consulted experts go apart when it comes to what they believe are the reasons for lacking maintenance and even more so when it comes to what solutions should be applied to address the maintenance issues.

The differing opinions on the maintenance issues probably depend a great deal on the positions the interviewees have in the MHP installation system. People working frequently in field, such as DCRDC staff and installation technicians from MHP companies are bound to have a more involved and detailed knowledge about the problems facing MHP schemes and the communities. Working on this level probably also makes the problems seem more urgent than they do to people working on a higher level in the system, for example at NMHDA or AEPC/ESAP. This could explain ESAP's choice not to set aside a specific budget for maintenance, while DCRDC staff sees maintenance as one of the biggest problems facing MHP projects.

Lack of proper evaluation of the continued operation of MHP plants and lack of communication between the levels in the system of implementing MHP projects is also believed to contribute to the differing opinions at decision and community level. In the system described in this report, ESAP is involved in the MHP schemes until one year after installation. However, many communities still turn to DCRDC staff for advice or help, even after the one-year guarantee period has ended. The result is that information about how
maintenance works is informally conveyed to and observed by DCRDC staff and other people in field, but there is no formal transfer of that information to higher levels in the system.

A contributing cause for differing opinions could also be the subjective interest of the interviewees, since almost all consulted experts belong to an organization or group in the MHP installation system with own interests. DCRDC staff for example, are very eager to improve the situation for the communities and interested in seeing increased financial support for this, while the people working at decision-making level answer to donors and have an interest to defend their previous decisions.

During the field trips 10 different MHP plants were visited and from observations and interviews it is clear that the maintenance quality varies from plant to plant. It is also clear that the maintenance quality varies with the type of community, as noted in the discussion about the Plant operator survey above. Maintenance is working very well in some communities, where the benefits of electricity are more apparent to the community members. Many of the solutions suggested to address observed maintenance issues, are either already implemented (such as additional job to increase income or sharing of knowledge between operators) or not needed in these communities (such as increased salary or awareness training). Therefore, it seems that the discussion should be about how to achieve the maintenance standard that they have in Ghandruk VDC and similar areas, in the remote villages with other conditions. When comparing the two types of communities, it is obvious that the most important difference is the awareness about the importance of continuous electricity and the income-generating businesses that electricity can be used for.

Places like Burtibang, that have become too large to keep the sense of MHP as a common property and that at least seem to be in question for connection with the national grid in a relatively near future, need to be addressed in a different way than the remote communities discussed above. However, also here the immediate need is information to create awareness about the situation.

Most interviewees actually highlighted lack of motivation and/or awareness as the most important cause for lacking maintenance. Irregular maintenance routines, high turn-over rate of operators, less interest in learning practical knowledge during installation – they are all different sides of the same coin. Thus, the problem is well recognized throughout the system, which is a good start. However, the suggestions on how to address the problem varied.

Interviewees at both the institutions that conduct plant operator training, NMHDA and Oshin Power Services, seemed to think that they had enough information concerning awareness. However, among the 22 full days of training, NMHDA devotes only six hours to information about socio-economic effects of MHP, the responsibility of plant operators and similar subjects, and Oshin Power Services gives these subjects only two hours, although Mr. Kafle was careful to note that they inform about the importance of maintenance throughout the whole training. Considering the amount of knowledge that needs to be taught at the basic plant operator training and the limited time, perhaps awareness training should be initiated before plant operators get to training. Interviews and observations pointed to that MHP schemes would benefit from raised awareness about the opportunities of MHP in the whole community, and this would naturally involve the plant operator. It is clear that a community’s wish to work and pay for the installation of a MHP plant does not necessarily mean that the
community also is aware of all the opportunities and possibilities that come along with electricity and it definitely does not mean that the person becoming the plant operator has an understanding of the limitations of the plant or the consequences of irresponsible operation.

Mr. Devendra Adhikari means that awareness training should be included throughout the process from initiation of project to its completion and continued operation. He also means that DCRDC plays a very important role in this aspect of a MHP project. However, perhaps DCRDC lack the resources to put in the extra effort that is needed to make a difference. In the end, information needs to be repeated over and over again and learnt in an interactive way to make a change. So perhaps ESAP should consider setting aside some funds for the improvement of maintenance. Naturally, ESAP has a limited amount of money to distribute and understandably it is a difficult trade-off between giving more communities access to electricity and increase support for the ones that already have MHP. However, why support new projects if the existing ones are not working as well as they could?

If ESAP decided to devote specific funds for improved maintenance, there would naturally be many ways in which these funds could be used. A few of the interviewees suggested that increased salaries of plant operators could increase motivation and decrease turn-over rate, and perhaps salaries could be subsidized by ESAP. However, the difference between the current plant operator salaries, and the salaries of competing jobs in Gulf countries, are probably too big to be able to address with subsidized rises in salary. A better option would be to create a system in which the plant operator salary increases with the income of the plant, so as to create an incentive for the operator to both promote commercial end-uses and maintain the plant properly – two factors that could improve the economy of the plant. Another way to increase interest in the work plant operators do, and thus their motivation, could be to offer more practical training, which would naturally also increase knowledge. The idea suggested by Mr. Om Prasad Gurung – to organize additional practical training at the MHP sites – could lower costs for this solution and probably increase learning as well.

Hopefully and probably, increased awareness and motivation would decrease the turn-over rate of operators, which would make a big difference to the general maintenance situation. Many Nepalese men are forced to seek work abroad due to poverty and lack of opportunities within their own country. Increasing awareness about electricity’s opportunities in the whole community could in the long run create more economical activity within Nepal, which could raise the standard of living and reduce the incentive to move abroad.

Thus, based on the many opinions and observations heard during this study, the recommendation for the MHP support program studied (sponsored by ESAP and facilitated by DCRDC), is to increase focus on awareness of plant operators and the rest of the community.

It should be noted that this study only generally investigates and discusses different solutions to maintenance problems, apart from that of a R&M center in Burtibang, which is discussed in detail in the following section. If the solutions above should be investigated in depth, many more aspects than discussed in this report would need to be considered.
6 Results and discussion: a MHP R&M center in Burtibang

This section aims to answer the fourth research question. As mentioned, this question was investigated to provide background information for a business development plan for a R&M center in Burtibang.

- Assuming that a decentralized repair and maintenance (R&M) center located closer to the MHP sites would help to improve the maintenance situation: how would the business of the center be structured and financed, and is the solution economically viable?

Referring to the discussion in section 5.3 above, a R&M center does not address the underlying cause for lacking maintenance, but helps to improve a situation where maintenance issues exist, and probably will for some more time. Furthermore, even with perfect maintenance, there will always be a need for R&M services.

The answer has been found mainly by interviewing a number of people who would be engaged in the future business of an R&M center: Mr. Kunwar and Mr. Updahyay, who are interested to start and run the business, Mr. Kandel who is supporting Mr. Kunwar and Mr. Upadhyay in their work, and Mr. Thakar Adhikari and Mr. Kafle at Oshin Power Service Ltd. Pvt. who are also supporting and assisting Mr. Kunwar and Mr. Upadhyay by providing price information and expert advice. Concerning the content in this section, all information that is not directly referred to a person or another source, is based on discussions and own reasoning.

To plan the business of a MHP R&M center in Burtibang, a wide range of aspects have to be investigated: the market, the business organization, the product/services to be offered, the competitive position, promotion of the business, the development plan including schedule and budget, the operation and management of the running business, as well as a thorough financial analysis to prove that the business is economically viable.

Naturally, it is vital that the business is financially sustainable, and the financial statements make out the backbone of a business plan. However, the financial situation of this business has not been fully worked out, due to missing information that could not be collected during the time of the study. What information is missing is explained in section 6.4.

Due to the confidentiality of information included in the business development plan, only some of the business aspects listed above are described in this report.
6.1 The market
According to Mr. Kunwar and Mr. Upadhyay the number of MHP plants that are located at such distance from Burtibang that they would benefit from the R&M center is over 50 and the number is confirmed by ESAP (AEPC/ESAP u.d.). This includes ESAP-sponsored plants facilitated by DCRDC, as well as other plants.

Concerning business growth, the trend shows that the market in the area is growing. The numbers of installed MHP projects has been increasing over the past ten years, both nationally and in the area of the planned R&M center (see Figure 14 and Figure ). Though several different organizations/investors implement MHP projects in the targeted area, DCRDC is the main facilitator in Baglung and adjoining districts and numbers of DCRDC’s MHP projects give a relevant outlook on the target market (see Figure 15) Reviewing the number of new installations in the previous years with 10 or more MHP plants in both 2010 and 2011, and with 17 projects in different stages of completion only in Baglung, it is believed that the numbers from DCRDC can be used to estimate a market growth of 10 new MHP plants per year in the near future. The growth of 10 MHP plants per year is thought to be a safe estimation, since this only accounts for DCRDC-facilitated projects, and other organizations/facilitators most probably also will add to the increased number of customers.
Mr. Devendra Adhikari at AEPC/ESAP expressed a belief that the installation of new MHP plants will soon slow down since there is a limit to the number of plants that can be installed in the area. However, Mr. Acharya estimates that it will take ten to fifteen years before the national grid reaches many of the remote areas around Burtibang, and furthermore, the existing MHP plants will be in need of continuous R&M. Thus, the market is believed to be stable for at least the next ten to fifteen years. Naturally, if maintenance work performed by plant operators is improved by means of other initiatives, the demand for R&M services might decrease. However, there is no risk that the demand will disappear altogether and in addition, the R&M center will most probably have to expand its business with R&M services for other customers than MHP plants, which will assure a sufficient market size.

However, the main goal of the center is to serve MHP plants, and the exact size of that market not only depends on the number of customers, but on the amount of products/services the customers demand per year. This information is not yet collected, but is needed to evaluate the success of the business and the task lies upon Mr. Kunwar and Mr. Upadhyay.

6.2 Product/service description
The main products and services offered at the R&M center will obviously be targeted at MHP customers, but according to Mr. Kafle, the center will probably have to offer R&M services to other electrical and mechanical businesses create a sustainable business. According to Mr. Kunwar and Mr. Upadhyay the center will offer:

- **Sales of spare parts:** The R&M center will purchase spare parts from manufacturers/retailers in Butwal and transport them to the center’s location in Burtibang, Baglung, where they will be sold to the customers. It will make sure to stock the different types of parts needed for the different types of mechanical and electrical equipment that exist within the customer base. (To be able to do this, Mr. Kafle also suggests that Mr. Kunwar and Mr. Upadhyay collect detailed technical information about the equipment in the targeted MHP plants.)

- **R&M services:** Senior and junior technicians will offer R&M services for turbines, electric load controllers (ELCs) and other mechanical and electrical equipment. The services will be available at the R&M center, or if needed due to type of fault, at the site of the MHP plant. Technicians will also offer guidance on repair of civil parts of the MHP plant, where the actual work is most often carried out by community members. The most severe faults that require work on the turbine runner or casing will have to be done by technicians from the manufacturing company, but most minor repair works will be done by technicians from the center. (In the MHP company survey, the companies were asked what repair services that had to be repaired by them as manufacturers of equipment, and the answer was that all parts could be manufactured and replaced by any manufacturer, but it is obviously much easier for MH-powered communities to turn to the company that manufactured and installed the plant and that knows all about its design details.)
And with the addition suggested by Mr. Kafle:

- **R&M services for other customers than MHP plants:** Senior and junior technicians will offer R&M services for other electrical and mechanical businesses in the area. The services will be available at the R&M center, or if needed due to type of fault, at the site of customer’s business.

The actual center will be built to host the activities listed above. The building will have 4-5 rooms: one workshop for service work, one storage room for spare parts, one to two rooms for office work, and one room that in the future will be used to hold trainings for plant operators and the community.

Though no numbers are included in this report, it can be said that the construction cost and the cost of land are the two most expensive parts of the establishment of this business. Thus, the option of renting already existing premises should be looked into, though it could not be done within the time limits of the study.

After having achieved a stable profit-making business, Mr. Upadhyay and Mr. Kunwar have the ambition of a second business phase, which would also include educational activities for MHP operators and for the community. They are aware that a sustainable business has to be established before additional activities can be planned for, but they are very passionate about the possibility to provide the important service of education in the future and they stress that the main purpose of the R&M center is to serve the community.

Mr. Kandel is also very engaged in this idea, since he is of the opinion that awareness training for both operators and community is the most important way of improving maintenance and economy of MHP schemes.

### 6.3 Competitive position

Based on observations and learnings, the following apprehension about the competitive advantage of the business has been made:

The competitive advantage of this business is mainly geographical. In fact, this business is started as a result of the observed great need for its services in the planned location. Currently, there is no competition in any location close to Burtibang. Thus the main competitors are the MHP companies in Butwal and Kathmandu.

Giving further advantages to the planned location of center is the quick growth of Burtibang. The fact that it is the main area for trade and transportation connections in western Baglung will highly benefit the business, since customers can combine visits to the R&M center with other errands in the village/city. Strengthening the choice of the location even more, the government is currently building a new highway passing through Burtibang.

Considering possible future competition in a geographical location that could affect the center’s market size, an advantage is the well-established customer relations that Mr. Upadhyay and Mr. Kunwar have with the MH-powered communities in the region. They have worked for many years as field coordinators for DCRDC’s branch office in Burtibang, and
thus they are well known and trusted by the communities that will serve as a large part of the business’ customer base. (There are also a number of MHP plants in the customer base that are not facilitated by DCRDC.)

Finally, comparing with MHP companies in Butwal and Kathmandu, the third competitive advantage is the accessibility of the services provided by the business: When going to Butwal for spare parts or repair services, the customers might be confused about where to go and might have to visit several different stores for different purposes. As opposed to this, the R&M center will offer all services/parts that might be needed in one single, easily accessible location that most customers will be familiar with.

**Thus the main competitive advantages can be summarized as:**

- Advantageous geographical location
- Well established customer relations
- Easily accessible services

### 6.4 Financial situation and sustainability

Since Mr. Upadhyay and Mr. Kunwar who will be the owners of the R&M center do not have any capital to invest in its starting-up, the total development budget (which is not included in this report) will have to be covered by subsidy or soft loans (loans with a below-market rate of interest). Mr. Upadhyay and Mr. Kunwar probably do not have enough resources to provide collateral for a large bank loan, and accordingly the business is dependent on at least some amount of subsidy. However, it is important that the owners contribute some of their own resources to increase the will to run a profitable business.

One possible donor is the governmental program that sponsors the installation of MHP plants; ESAP. However, it does not have a specific budget for MHP maintenance and Mr. Devendra Adhikari, who is Component Manager of the "Mini Grid Rural Electrification Component" at ESAP was not sure whether the program would be able to sponsor the establishment of the business, or if he believed enough in the need for, and the sustainability of, the business in the first place.

Other possibilities of sponsors are private organizations and donors that would be interested in supporting the business. On this matter, a number of organizations, and companies with businesses related to energy and hydropower have been contacted by the writer of this report. The responses have all been very positive about the idea, but mainly negative about the economic support.

Currently, the most important matter is to collect the information that is missing so that a business plan can be completed. Without thorough financial statements, there will be no chance of finding a donor from either the private or the governmental sector. The information that is lacking is:

- Sales potential of MHP services and products of the more than 50 MHP plants in the area around Burtibang.
• Sales potential of R&M services and products for other businesses in and around Burtibang.
• Based on the above information, how prices should be set and at what levels.

This information will be collected by Mr. Upadhyay and Mr. Kunwar.

6.5 Risk assessment

According to Mr. Kandel, the two major risks threatening the establishment of this business are insufficient funds and the difficulty of finding a senior technician that wants to work in Burtibang for a reasonable salary. The risks are listed in the table below, with advice on how they could be addressed.

Table 14: Risk assessment chart

<table>
<thead>
<tr>
<th>Identified risk</th>
<th>How risk is addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient amount of subsidy/soft loans to start business.</td>
<td>This is the single largest risk of this business. Without sufficient capital this business cannot be started, since co-founders do not have any capital of their own to invest. The only way of addressing this risk is continuing to apply for support from feasible donors/loaners.</td>
</tr>
</tbody>
</table>
| Problems finding a senior technician that wants to work in Burtibang, which is a relatively small city in a remote location, for a reasonable salary. | Mr. Upadhyay and Mr. Kunwar have two alternatives of addressing this risk:  
- The first and preferred alternative is to offer the senior technician part of the ownership in the company, which would hopefully make him/her agree to a more reasonable salary.  
- The second alternative is to give the technician the salary he/she demands, which could possibly increase the need for support from donors/loaners. |
| Decreased market or lower rate of market growth than expected. This could occur if maintenance quality at plants increases as an effect of initiatives taken towards improving maintenance from private organizations/donors or from the governmental sector. This could also occur if the various programs (mainly ESAP) supporting MHP disappear or change so that there is less or no funding for new MHP projects. | Events similar to the examples stated to the left are hard or impossible to predict and are thus hard to address. The political climate in Nepal is uncertain, and naturally there is a chance that something might happen to the governmental support program. Also, even though there are no initiatives taken towards improving MHP maintenance as of now, part of the aim of this report is to suggest such initiatives and if some of them would be realized the market for the R&M center would hopefully decrease. However, since the center will offer R&M services to other businesses than MHP, this could cover the possible decrease in the MHP market. |
Besides these risks, it could be argued that the lack of previous experience of starting and running profit-making businesses of Mr. Upadhyay and Mr. Kunwar who will be responsible for and owners of the business, is a risk. This risk can be addressed by business training from donors (without donors there is no business) and continued support from more experienced MHP professionals such as Mr. Kandel and MHP industry experts such as Mr. Kafle and Mr. Thakar Adhikari at Oshin Power Services.

7 Conclusions

- The maintenance situation at every MHP plant is unique when it comes to maintenance quality and possible causes for lacking maintenance. However, all MHP experts interviewed for this study agree that lacking maintenance is a considerable problem for a majority of the MHP plants. Some interviewed experts refer to MHP plants facilitated by DCRDC, and others refer to MHP plants in all of Nepal. Supporting this view, the statistical investigation of maintenance quality at DCRDC-facilitated MHP plants conveyed that maintenance is lacking to some degree at most plants and thus maintenance can be supposed to be irregular at a majority of the MHP plants in DCRDC's working area.

- The most frequent faults in MHP plants are commonly caused by lacking maintenance and operation. Frequent faults as reported by both MHP companies and plant operators are breaking fuses (rather a symptom than a fault), MCCBs, ELCs and turbine bearings. ELCs often break due to lightning, but this could also be avoided by shutting down the plant when there are thunderstorms.

- Maintenance quality depends on type of community in which the MHP plant is located. Maintenance quality is good in areas where the benefits of electricity are obvious to the whole community. A good example of this is Ghandruk VDC, where tourism has created many businesses now depending on a continuous power supply. The awareness level of the community and the need for electricity for income-generation increases the responsibility of the plant operator and thus improves the maintenance.

- Problems in maintenance identified by experts interviewed in the study include high turn-over rate of plant operators, lack of awareness, lack of motivation, lack of practical training, low education level of plant operators, defective economy of plants, and long distances to MHP R&M services and spare parts.

- Solutions to the above problems, suggested by experts interviewed in the study include increased salary of plant operators, encouragement to take on an additional job, awareness training, additional plant operator training, a decentralized MHP R&M center, and with the contribution from the report-writer: a maintenance manual poster to be put in powerhouses.
• The most important solution to address maintenance is increasing awareness of plant operators and whole communities. Information needs to be spread about the socio-economic benefits of MHP, as well as the need for continuous power supply, especially if commercial end-users rely on the MHP plant for electricity. Work to increase awareness will probably require financial resources specifically set aside for this purpose.

• A MHP R&M center in Burtibang is an important measure to improve the maintenance situation for the over 50 MHP plants in Baglung and adjacent districts. The R&M center does not address the original cause for lacking maintenance, but considerably facilitates maintenance by decreasing costs and increasing accessibility of R&M services.

• All interviewed experts agree that a MHP R&M center in Burtibang would benefit the MHP plants in the area, but some interviewees are questioning the financial viability and sustainability of the business. Two things are clear concerning the economy of the suggested R&M business: 1) it would most probably have to expand business opportunities by offering electrical and mechanical R&M services for other customers than MHP plants and 2) the establishment of the business depends on the granting of subsidy or soft loans.
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DCRDC. "Project status of MHP run by DCRDC, Baglung in Baglung, Parvat, Myagdi and Kaski districts; Projects supported by AEPC/ESAP; Status up to March 2012." 2012.


Kerala Electrical & Allied Engineering Co. Ltd. "Operation & Maintenance Manual for Brushless Alternator, Type - ACT/ACT-R."


Personal Communications

Plant operators interviewed for the Plant operator survey (MHP plant name is in brackets.)

Mr. Bk, Prithi Lal (Bhuji Khola 2nd) 
Interviewed 2012-04-16

Mr. Chantyal, Yam Bahadur (Chare Khola) 
Interviewed 2012-04-30

Mr. Gurung, Karna (Ghatte Khola) 
Interviewed 2012-05-08

Mr. Kumal, Hari Lal (RCG MHP) 
Interviewed 2012-04-16

Mr. Kunwar, Pratap (Kut Khola 2nd) 
Interviewed 2012-04-14
Mr. Shestha, Yubatr Prasad (Kut Khola 2nd)  
Interviewed 2012-04-14

Mr. Thapa, Chitra Bd. (Bhuji Khola 6th)  
Interviewed 2012-04-16

**Company representatives interviewed for the MHP company survey**

Mr. Kafle, Pravesh. Oshin Power Services Ltd. Pvt., Butwal  
Interviewed 2012-05-14

Mr. Krishna, Sharma. North Engineering Company P. Ltd., Butwal  
Interviewed 2012-05-14

Mr. Raut, Basanta. Dhaulagiri CEM Engineering Pvt. Ltd., Baglung  
Interviewed 2012-04-25

**Qualitative interviews in Sweden**

Mr. Ruyter, Peter. Cargo & Kraft Turbin Sverige AB  
Interviewed 2012-02-23

**Qualitative interviews in Nepal**

Mr. Acharya, Ganga Prasad. Sub-engineer at DCRDC, Baglung  
Interviewed 2012-04-11

Mr. Adhikari, Devendra. Component manager of AEPC/ESAP’s MHP section, Kathmandu  
Interviewed 2012-05-16

Mr. Adhikari, Thakar. CEO of Oshin Power Services Pvt. Ltd., Butwal  
Interviewed 2012-05-15

Mr. Chapagain, Pravesh. Coordinator at NCDC, Kathmandu  
Interviewed 2012-05-21

Mr. Gurung, Karna. Plant operator at Ghatte Khola MHP plant, Chhomrong (Ghandruk VDC)  
Interviewed 2012-05-08

Mr. Gurung, Man Prasad. Plant operator of the first ACAP-sponsored MHP plant in Chhomrong (Ghandruk VDC)  
Interviewed 2012-05-10

Mr. Gurung, Om Prasad. Chair person of Ghatte Khola III MHP plant, Chhomrong (Ghandruk VDC)  
Interviewed 2012-05-07
Mr. Kandel, Shambhu Raj. Former Regional Coordinator at DCRDC, Baglung
Interviewed 2012-04-02 (Kathmandu) and 2012-04-22 (Baglung)

Mr. Kafle, Pravesh. Engineer at Oshin Power Services Pvt. Ltd., Butwal
Interviewed 2012-05-14

Mr. Kharel, Ishwary Prasad. Consultant Engineer for AEPC/ESAP, Kathmandu
Interviewed 2012-04-29

Mr. Khatiwada, Niraj. Mini-Grid Engineer at DCRDC, Baglung
Interviewed 2012-04-09

Mr. Kunwar, Hem Bahadur. Field Coordinator at DCRDC, Burtibang
Interviewed 2012-04-15

Mr. Lal Upadhyay, Netra. Field Coordinator at DCRDC, Burtibang
Interviewed 2012-04-15

Mr. Ranjitkar, Purna N. Executive Director at NMHDA, Kathmandu
Interviewed 2012-05-17
## Appendix A

Manual distributed at the basic plant operator training (Title in Nepalese)

Translated to English with the help of Mr. Subodh Kumar Ghimire, Biomass Engineer, DCRDC, 2012-05-25

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Particulars</th>
<th>Time to check</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Daily</td>
</tr>
<tr>
<td>1</td>
<td>Diversion weir/dam</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check for river debris in weir/dam</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check for cracks in weir/dam wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check for sand deposit in weir/dam</td>
<td>x</td>
</tr>
<tr>
<td>2</td>
<td>Intake</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check for river debris in intake</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check the velocity of water flow at intake</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check how much sluice gate is open</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check the water level at intake</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check the condition of the trash track</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check for cracks in the intake wall</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check if the direction of water flow has changed</td>
<td>x</td>
</tr>
<tr>
<td>3</td>
<td>Headrace canal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check for debris in headrace canal</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check the water level</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check for leakages</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check water that is also used for agricultural purposes</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check the condition of the canal wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If the headrace is made of pipe, check for leakage around joints</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Make sure that pipes are clean</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check whether pipes are clean or not</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check for blockage of water flow</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check for soil erosion on the downside of canal</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check for rocks and stones susceptible to fall and damage the canal</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check for the risk of landslide around canal</td>
<td>x</td>
</tr>
<tr>
<td>4</td>
<td>Desilting basin/forebay tank</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Check the water flow</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check the condition of the trash track</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Check for leakages</td>
<td>x</td>
</tr>
<tr>
<td>5</td>
<td>Check the sand level</td>
<td>x</td>
</tr>
<tr>
<td>Check for cracks in the concrete</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Check for the risk of soil erosion or landslide around structure</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

**Penstock pipe**

| Check for leakages | x |
| Check the condition of expansion joint, and check for leakages | x |
| Check if anchor block is sinking | x |
| Check for rust on pipe | x |
| Check for cracks in anchor blocks | x |
| Check for the risk of soil erosion around anchor blocks | x |

| Check for cracks in the support piers | x |
| Check for the risk of soil erosion around support piers | x |
| If the pipe is made of polyethylene, make sure that the penstock is underground | x |
| Check nut bolts on all flanged joints | x |
| Check the condition of the paint covering the pipe | x |
| Check for the risk of landslides around pipe | x |

**Power house**

| Check that the area in and around the power house is clean | x |
| Check for leakages from all valves | x |
| Check that valves can be turned easily | x |
| Check for vibration in turbine bearings | x |
| Check turbine speed | x |
| Check the grease level of turbine bearings | x |
| Check the seals of turbine bearings | x |
| Listen for unusual sounds of turbine | x |
| Check that shaft is correctly aligned | x |
| Check the runner and the buckets of turbine | x |
| Check that runner casing and bolts are not loose | x |
| Check coupling rubber and bolts | x |
| Check for vibration in coupling | x |
| Check for wear of coupling | x |
| Check belt tension | x |
| Check the tightness of shaft pulley | x |
| Check the water flow in ballast tank | x |
| Check that the generator and the area around the generator is clean | x |
| Check that the generator ventilation is unobstructed | x |
| Check the temperature of generator bearings | x |
| Check the temperature of generator | x |
| Check for vibration in generator bearings | x |
| Check the grease level in generator bearings | x |
| Check the seals of generator bearings | x |
| Check the voltage level of generator output | x |
| Check whether ELC is working or not | x |
| Look at meter readings | x |
| Check the frequency | x |
| Check whether the load is connected or not | x |
| In the case of 3 phases, check whether load is equal in all phases or not | x |
| Check that fuses are not blown | x |
| Check the heat of wires and connections | x |
| Check the condition of the earthing plate, and its coal and salt level | x |
| Check for the risk of landslides around power house | x |

<table>
<thead>
<tr>
<th>Tailrace canal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check for leakages in canal</td>
</tr>
<tr>
<td>Check for blockage of water flow</td>
</tr>
<tr>
<td>Check for cracks on surface and wall of canal</td>
</tr>
<tr>
<td>Check for risk of soil erosion inside and around canal</td>
</tr>
<tr>
<td>Check for rocks and stones susceptible to fall and damage the canal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distribution lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check for damage on insulators</td>
</tr>
<tr>
<td>Check the tension in overhead lines</td>
</tr>
<tr>
<td>Check the gap between lines</td>
</tr>
<tr>
<td>Check the condition of the barbed wires around the transformer</td>
</tr>
<tr>
<td>Check distribution switch, fuses, etc.</td>
</tr>
<tr>
<td>Check for tree branches susceptible to touch the overhead lines</td>
</tr>
<tr>
<td>Check the condition of distribution poles</td>
</tr>
<tr>
<td>Check the tension of stay wires</td>
</tr>
<tr>
<td>Check the condition of lighting arrestors</td>
</tr>
<tr>
<td>Check the earthing connections</td>
</tr>
<tr>
<td>Check the tightness and temperature of joint</td>
</tr>
<tr>
<td>Check that the transformer and the area around it is clean</td>
</tr>
<tr>
<td>Check the silica gel of transformer</td>
</tr>
<tr>
<td>Check the condition of transformer switch</td>
</tr>
<tr>
<td>Check for the risk of landslides around distribution lines</td>
</tr>
<tr>
<td>Check the oil level in transformer</td>
</tr>
<tr>
<td>Check that transformer insulators are clean and in good condition</td>
</tr>
<tr>
<td>Check the consumer connections</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
</tr>
<tr>
<td>Check for illegal connections</td>
</tr>
<tr>
<td><strong>Others</strong></td>
</tr>
<tr>
<td>Check that tool and equipment are in their respective positions and in good condition</td>
</tr>
<tr>
<td>Hold meeting with consumers and consumers committee</td>
</tr>
</tbody>
</table>
### Basic Micro Hydropower Maintenance - Plant Operator Check-list

#### Daily
- Check that tool and equipment are in their respective positions and in good condition, and make sure that there is a sufficient store of spare parts!

#### Weekly
- Check for illegal connections.

#### Monthly
- Check for rust on penstock pipe and the condition of its support.
- Check if direction of water flow at intake has changed.

#### Yearly
- Check if the direction of water flow at intake has changed.
- Check the condition of earthing plate and its coal and salt level.
- Check that transformer switch is working.
- Check the sand level in desilting basin and forebay tank.
- Check that the transformer and the area around it is clean.
- Check the condition of earthing connections.
- Check the tightness and temperature of joint.
- Check that fuses are not blown.
- Check that ELC is working.
- Check that the transformer switch is working.
- Check for the risk of landslides around distribution lines.
- Check that transformer insulators are clean and in good condition.
- Check that civil part (weir, intake, trash track, headrace, desilting basin, forebay tank, penstock pipe, anchor blocks, support piers, tailrace) are in good condition (no leakages, cracks, blockage of water) and clean civil parts from debris.
- Check water level and water flow at intake, in desilting basin and forebay tank.
- Check the openness of the sluice gate.
- Check the runner and the buckets of turbine.
- Check that runner casing and bolts are not loose.
- Check temperature of generator, and generator and turbine bearings.
- Check that valves can be turned easily.
- Check the turbine speed.
- Check for vibration in bearings and coupling.
- Listen for unusual sounds.
- Check belt tension.
- Check water flow in ballast tank.
- Check that generator ventilation is unobstructed.
- Check that the ELC is working.
- Check for leakages around the valves.
- Check if there are no down.
- Check that generator is working.
- Check the heat of wires and connections.

#### If there is any problem, consult the trouble-shooting manual, or contact a technician!

**★ Always check that tool and equipment are in their respective positions and in good condition, and make sure that there is a sufficient store of spare parts!**