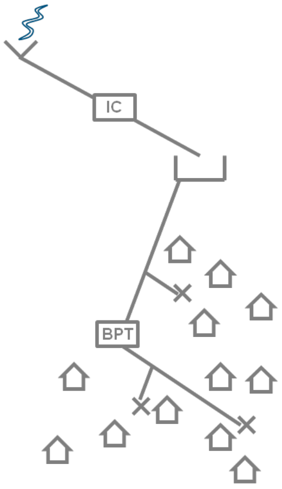
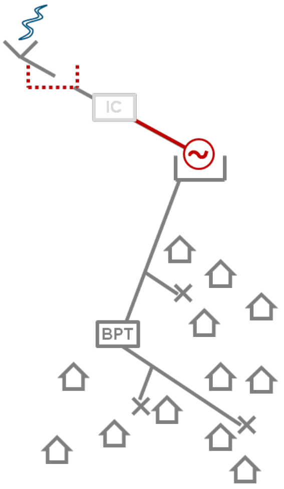
Drinking Water and Hydropower

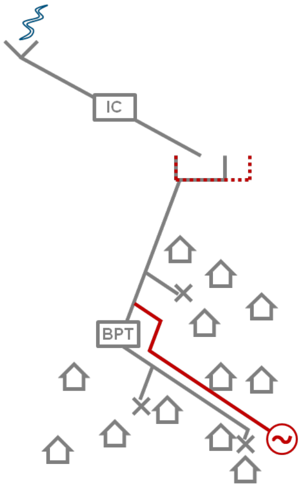
Feasibility Study for Inline Hydropower in rural Nepal

Helvetas Swiss Intercooperation

Water Resource Management Programme, WARM-P







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Surkhet (Nepal), September 2012

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Acronyms and Abbreviations

AEPC	Alternative Energy Promotion Centre
BPT	Break Pressure Tank
CDM	Clean Development Mechanism
DC	Distribution Chamber
DWS	Drinking Water Scheme
DWSS	Department of Water Supply and Sewerage under the Ministry of Urban Development, Gov. of Nepal
HPP	Hydropower plant (scheme)
IC	Interruption chamber
GO	Governmental Organisation (complimentary to Non-Governmental Organisations)
GW, GWh	Gigawatt (10^9 Watt), Gigawatt hours
IHP	Inline Hydropower Plant (scheme)
kW, kWh	Kilowatt (10^3 Watt), Kilowatt hours
lps.	litre per seconds (flow measurement)
MW, MWh	Megawatt (10^6 Watt), Megawatt hours
NEA	Nepal Electricity Authority
NGO, iNGO	International Non-Governmental Organisations
REDP	Rural Energy Development Programme
RERL	Renewable Energy for Rural Livelihood
RVWRMP	Rural Village Water Resources Management Project (Finish NGO)
SHS	Solar Home Systems
UNDP	United Nations Development Programme
VDC	Village Development Committee
WARM-P	Water Resource Management Programme

1. Introduction and rationale

Safe drinking water, readily available all day through and electricity, whenever the switch is turned on. What sounds like a matter of course for every Swiss household, is out of reach for the majority living in rural Nepal.

The landlocked country, which is primarily associated with its high mountains, hosts a rapidly growing population of some 30 millions[1]. Supply of energy is poor. Only half of the population is connected to electricity through the national grid. Production of electricity is way below demand and cannot keep up with an annual increase of 10 %[2]. Daily load shedding is not only experienced in the Kathmandu valley but all parts Nepal, where the national grid is present. The same is true for fossil fuels. Long queues in front of petrol stations are a result of notorious fuel shortage. Specifically the supply of urbanised areas in the hills (which includes Kathmandu) is crucial.

The situation is relatively better for drinking water. Until 2010, 80 % of the country's population had access to drinking water. However functional coverage is far below this figure[3]. More importantly, those average numbers hide the fact of an immense discrepancy between urbanised and rural areas. In particular, neither proper water supply nor electricity is available in most remote villages of Mid- and Far-Western Development Regions.

Helvetas' water project WARM-P supports rural communities to realise drinking water schemes from available water sources. Access to safe drinking water certainly is one of the basic and pressing needs. However most of the villages where drinking water schemes are realised do not have access to electricity either. Light is obtained from sooty burning wooden sticks, torches or so-called Solar Sets. Other electronic devices – besides mobile phones and radios – are basically inexistent.

Bearing in mind the existence of hydropower plants which are incorporated in Swiss drinking water systems, the question of "why no to try this in Nepal" has risen. Switzerland actively promotes Inline Hydropower Plants (IHP), as existing infrastructure is there used for energy production without further environmental intervention. The produced electricity is considered of high ecological value.

Beside the national grid, which currently covers only half of the population, there are numerous mini grids implemented in Nepal. Those grids are typically supplied by a small hydropower plant and provide a limited number of villages with electricity. All the currently implemented mini hydro plants are fed by small rivers or rivulets.

The following report aims to answer the question, whether it is reasonable to combine mini grid systems with drinking water schemes. Significant synergies may be expected, as infrastructure required for both applications can be shared.

2. Objective

The combination of drinking water systems and small hydropower plants seems to be a success in Switzerland. Although topographic preconditions are comparable in Nepal, no such systems seem to be implemented. This report investigates the feasibility of Inline Hydropower in the context of rural Nepal, particularly in the western and mid-western districts, where WARM-P is currently active.

Feasibility

Exploring the feasibility of such new concepts includes an assessment of the domestic market for small hydropower plants. The availability of technical solutions, which are needed to electrify a village, will be explored. This not only includes appropriate turbines and generators but all elements of a mini grid (distribution grid, lighting solutions, etc.).

Based on available data and field visits to existing drinking water schemes (DWS), the theoretical potential will be estimated. Necessary civil work and additionally required infrastructure to upgrade a drinking water scheme for energy production will be considered. Synergies that optimally could be used during implementation and operation will be identified.

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[1] Population of Nepal amounts to 30.5 Million in 2011 (World Bank)

[2] 10.7 % from 2010 to 2011, according to NEA's annual report 2011

[3] Only 20 % of the population with water supply are served by a well working system (Functionality Status of Water Supply [...], Department of Water Supply and Sewerage DWSS, 2011

Focusing on three technically promising sites, the financial viability of an IHP will be assessed as well. Estimates of initial investment and operational costs will be made. This estimation will be confronted to collected information on the willingness and ability to pay of future beneficiaries..

In addition to those hard facts, a statement on the social feasibility of IHP will be made. This for instance includes the question whether villagers are reluctant towards drinking water which has gone through a turbine.

Sustainability

A project definitely is only feasible if sustainable. Sustainability of IHP therefore will be investigated in all its dimensions. As there are no realised projects to date, potential sustainability issues can only be conjectured based on experiences with existing drinking water schemes or mini grid projects. Suggestions on how to overcome those issues will be made.

3. Assessment methods

This assessment has been conducted by Moritz Güttinger with major support of the WARM-P team of Helvetas Swiss Intercooperation Nepal. Moritz holds a Master Degree in Environmental Science and has some 4 years working experience in small and large hydropower business in Switzerland. However he has not yet conducted any studies on general feasibility of hydropower.

The mandate for the assessment in Nepal lasted some 6 months including 3 weeks of preparation in Switzerland. Most of the work has been done from Surkhet with excursions to the targeted sites in neighbouring districts. An industry assessment has been conducted during a one month stay in Kathmandu. Officially employed by Helvetas Swiss Intercooperation (hereinafter referred to as “Helvetas”), the engagement was enabled as the assignment ran under the umbrella of Swiss civil service.

3.1. Overall conceptual framework

The following table provides an overview of the major questions and how they were methodically approached. As there was little evidence of existing IHP schemes in Nepal, the technical feasibility was investigated first. This was done from two sides. On one side the available energy in WARM-P sites was assessed with statistical analysis and field visits to promising sites. On the other side the national and relevant international market of hydropower products was screened. This was done in order to find out, whether there are hydropower products available, which can deal with the conditions we find in drinking water schemes.

Only after having found that there actually are existing drinking water schemes with enough head and discharge, further feasibility dimensions have been investigated. Those dimensions include basically economic and social aspects of an IHP project.

Table 1: Overview on methodology to assess the feasibility of IHP in WARM-P schemes.

Dimension	Main issue	Approach
Technical	• Topography, discharge & head of relevant drinking water systems • Solutions on the market (characteristics, costs, experiences)	• Analysis of WARM-P schemes' database • Field visits of promising sites • Visit manufacturers, advisors, NGOs, GOs • Field visits to implemented IHP
Social	• Willingness to cooperate • Stability of population (problem of migration) • Cultural reluctance towards IHP	• Field visits of promising sites / discussion with future beneficiaries
Economic	• Investment required • Expenses for operation and maintenance • Willingness to pay • Productive use • Support from agencies (financial or non-financial) • Support from carbon financing / payments for environmental services	• Manufacturer, advisor • Field visits of promising sites • In-house experts / advisors • NGOs, GOs • In-house experts, advisors
Institutional	• "How much" institution is necessary	• Comparison with experiences of DWS
Knowledge	• Level of required knowledge	• Manufacturer, advisor
Environment	• Impact on drinking water quality	• Manufacturer

Statistical analysis of WARM-P schemes

Statistical analysis has been conducted based on a database of all realised WARM-P schemes since 2001. This allows an overview of all relevant schemes under the assumption that the characteristics of realised schemes do not fundamentally differ from those, which are going to be supported in future.

Unfortunately it was not possible to obtain information on those schemes which have not been realised under WARM-P. The district agency of DWSS actually keeps record of all schemes in the respective districts but was not open to share the database.

Field visits

Field visits have been made in two sequences. At start they were meant to provide an idea of the conditions in rural Nepal (Assurani village in Dadeldhura district). The site in Dadeldhura was selected as there is a hydropower plant installed which is combined with a drinking water scheme and has been supported by a partner organisation of WARM-P (the Finland funded RVWRMP).

After completion of the industry analysis, extensive field visits to four different sites have been carried out. The locations were selected by the WARM-P team based on the following conditions.

- site in former or current working districts of WARM-P, where a gravity fed drinking water scheme was either present or under development (Far- and Mid-West Development Region)
- perennial discharge of the largest source at least 0.5 lps.
- significant head, meaning either presence of BPT / IC or steep topography (WARM-P team statement)

The selection of the sites was influenced by the accessibility of the respective location. Due to time restrictions, all villages had to be visited in the monsoon time (second half of July, first half of August). During monsoon roads are often disrupted because of landslides or rock fall. Many riverbeds, which are more or less dry during the rest of the year, cannot be crossed during monsoon.

Technical survey

All visited sites have been roughly surveyed, which specifically included collection of GPS data of the infrastructure (intake, reservoir tank, etc.) and measuring flow at different places of the system. GPS data have been collected with state of the art devices, flow measurements were conducted using the bucket method.

Community and household interview

In every visited village a one day survey has been administered in order to gain an idea of the social and economic situation of the families. Two types of interviews have been conducted. First the users committee of the DWS and other interested members of the community were asked general questions about the situation in the community. The questionnaire included economic issues (presence of markets, place and cost of agro processing, etc.) and social issues (size of village, migration, etc.).
After the community survey a set of households representing approximately 20 % of the community was randomly selected. Households were drawn from an updated list of DWS beneficiaries. Each household was interviewed for about 1 hour. The discussions with the selected families aimed at finding how interested they are in lighting solutions from IHP. Specifically their ability and willingness to pay was enquired. The questions were set up in such a way to enable a natural conversation. This turned out to be successful as interviewees felt valued[4] and were open to disclose even sensitive information on income, assets and expenditures of the family. However every household was informed before the interview, that they were free not to answer and that their answers had no consequences on later development of a site.

Industry analysis

An industry research was carried out in order to find hydropower solutions that are applicable in drinking water schemes. As small hydropower manufacturer are basically inexistent on the internet, the main source of information was by word of mouth. Talking to experts in the hydropower field led to involved organisations, which again knew about particular manufacturers.

The research involved not only meeting with manufacturer but also with relevant governmental and non-governmental agencies that are active in small hydropower.

4. Inline Hydropower IHP

4.1. Motivation and concept

Motivation

The principle of gravity fed drinking water schemes in rural Nepal is to bring water from a hygienically safe source to the point of use at lower elevation. The basic principle of a hydro power plant (HPP) is basically the same. The only difference is that hydropower is not interested in the water itself but in the potential energy of water between source and point of use level. Both drinking water and hydropower schemes require infrastructure to first trap the water, store it to a certain extent and then bring it to the location, where it either flows through a turbine or is being consumed.

The idea of inline hydropower is to combine the two water applications, sort of “bring them in line”. Herewith the same infrastructure – or at least a part of it – serves two purposes. This certainly adds complexity to the management of a system but also comes with various options for synergies. The most obvious synergy is that investments are shared and therefore reduced compared to equivalent of a single application infrastructure. However there are further synergies, which might not be obvious, but are nonetheless important.

Development of a scheme – be it a DWS or a HPP – includes identification and measurement of water sources, carrying out a topographic survey, judging landslide exposure et cetera. Additionally future beneficiaries have to be trained how to manage and use the newly available resources and awareness building is required. Even though the content of those tasks is not completely the same for DWS and HPP, there is a significant overlap, which allows synergies during the planning phase. The same is true for implementation. Transportation of material for instance is a significant cost factor.

Synergies and improved sustainability is even expected during operation, as the same person is responsible for operation and maintenance of both systems. Obtaining two services from the same scheme is an additional incentive to properly maintain present infrastructure

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[4] Some household expressed being bothered by other NGO previously doing surveys in their villages and afterwards disappearing without coming back to them.

Concepts

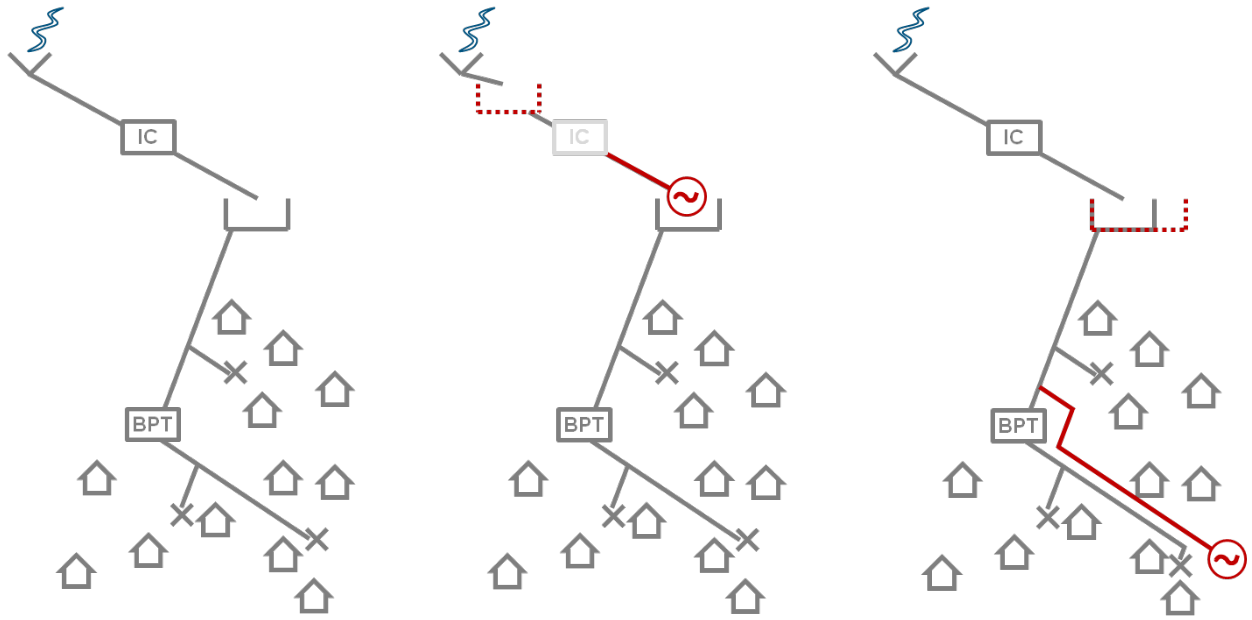
Starting with a drinking water scheme, there are principally two ways to make it an IHP scheme (see Figure 1). In the first option a hydropower plant is located within the water distribution system. Potential energy is extracted from water that is then conveyed to the tap stands. The second option is to place the turbine at the end of the DWS. After passing through the turbine, water exits the DWS and is not available for domestic use. Still water is ready for irrigation of paddy or commercial crops.

It is not possible to strictly classify sites being promising for either one option, thus most of the schemes are likely to be feasible for a combination of the two previously described concepts (i.e. using surplus water in the upper part of the DWS). Table 2 shows the necessary preconditions, synergies and the needed investments for both concepts.

Table 2: Specifications of two theoretical IHP concepts. Strict distinction is commonly not possible in reality.

	Concept 1	Concept 2
Preconditions	• High head in upper branch • Short distance between source and RVT • No cultural reluctance towards water from turbine	• Surplus water (demand < supply) • High head in lower branch
Synergies	• Intake • Transmission line (partially)	• Intake • Transmission line • Reservoir tank • Distribution line (partially)
Investment	• Transmission line (higher density) • Forebay (if necessary)	• Penstock (reduced length) • Reservoir chamber (if necessary)

Figure 1: Concepts of inline hydro power schemes (left: DWS without IHP, middle: IHP concept 1; right: IHP concept 2t)



4.2. Inline Hydropower in Switzerland

Presence

Some of the earliest hydropower plants in Switzerland have been realised in combination with drinking water systems. Hoteliers found that the pipes which convey spring water to their hotels can also be employed as penstock. They attached simple turbines, which were only in operation in the evening hours to lighten the rooms.

Today's hydropower plants in Switzerland are of larger size, nevertheless there are some 100 IHP which produce approximately 100 GWh per year (less than 0.2 % of national electricity demand). The technically and financially viable potential for IHP in Switzerland is estimated to be about two times higher[5].

Some IHPs are incorporated within large drinking water schemes of big cities. Those drinking water schemes are significant consumer of electricity, i.e. to pump water from one reservoir to another or to provide pressure in filter systems. Power plants in such schemes do not produce energy from an overall perspective but rather reduce the energy demand of the whole system. Still the produced electricity can be sold as ecologically valuable energy.

Technical

Nearly all hydropower plants, which are included within Swiss drinking water systems have power output of more than 10 kW, 90 % have flow between 10 lps. and 200 lps..

There are some small hydropower plants in Switzerland, which provide electricity for a farm or a separated mini grid only – some may even use drinking water to run the turbine. But almost all IHP in Switzerland are connected to the grid. The key motivation is the immense feed-in tariff granted by the national grid operator.

Financial

Small hydropower plants – including IHPs – receive so-called cost covering feed-in tariffs. This is a societal wish and aims to support the diffusion of renewable energy sources in Switzerland. The granted tariffs range between CHF 0.15 and CHF 0.35 per kWh, depending on size and design of the power plant (low head turbines for instance receive more).

The price, paid by the national grid operator is way higher than the value of the energy on national and international electricity markets (which is currently at CHF 0.05 per kWh). The difference between granted tariff and true value of the energy is called the ecological value. Costs of this subsidy mechanism are socialized among all consumers, which are connected to the grid.

Conclusion

The situation for IHP in Switzerland is very unlike to the one in Nepal[6]. Basically two major differences are identified:

- IHPs in Switzerland are much larger in terms of power output and could not be applied within the conditions we find in Nepal. Only sites above approximately 10 kW are developed in Switzerland. This requires larger head and higher discharge, than we can find in the considered area in Nepal.

- IHP in Switzerland would never been realised if they were not connected to national grid and could not profit from a system of cost covering feed-in tariffs. The costs to produce electricity in small IHP are about five times higher than the value of the effective energy produced.

4.3. Inline Hydropower in Nepal and other developing countries

Nepal

If IHP is strictly understood as combination of hydropower with drinking water systems (and not with irrigation), then it must be stated, that there is almost no IHP plant successfully running in Nepal. Even though there is a vital market for small hydropower plants, there is neither a governmental agency nor a national or international NGO, which actively promotes IHP. None of the visited manufacturer knew about one of their products being installed in combination with a drinking water system.

Obviously IHP is not a broadly discussed topic in the Nepali hydropower scene; still two plants could be found which virtually run on drinking water. Interestingly enough, the local beneficiaries and even the manufacturer of the plant in Rupandehi (see page 19) didn't perceive their power plant as an IHP. The terminology, and the lack of awareness, could be a reason, why it turned out to be difficult to find successfully running schemes.

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[5] Strom aus der Trinkwasserleitung, Elias Kopf, 28.11.2011

[6] This statement is true for the examined area in mid and far west of Nepal (Doti, Dadeldhura, Achham, Dailekh, Jajarkot).

It is not probable that the situation for larger systems – comparable to those in Switzerland – is drastically different. Drinking water is a notorious problem in basically all larger urbanised areas in Nepal and it is not very likely, that operators of large and complex drinking water schemes are able to additionally manage an IHP.

Low head turbines in Asia

There are several countries – specifically Vietnam and China – where small hydropower units are broadly implemented. The so-called Family Hydro systems consist of either low head propeller turbines (head: 1 – 2 m) or tiny Turgo turbines (max. head: 20 m). These devices are commonly placed in small streams or within rice fields. The power output of those systems ranges between 200 W and 1’000 W, which serves one or several households for lighting and battery charging. Due to an immense market – more than 100’000 units per year are sold in Vietnam, more than 30’000 in China – the systems are produced in large quantities and sold at affordable prices. A Family Hydro Set with power output of 100 W costs between US$ 20 and US$ 30, additional costs for civil work and wiring range between US$ 40 and US$ 60.
As quality of those systems is low and no guarantee is issued, annual cost for operation and maintenance are estimated to be at the same level as the initial investment[7].

The low head turbines, which are widespread in many Asian countries, are not applicable within drinking water schemes in Nepal, because of inverse conditions. The hilly region provides significant head, but only very little water is available all year round.

4.4. Hydropower in combination with irrigation

The term inline hydropower in this report is strictly understood as a combination of hydropower with drinking water schemes. On a larger scale the combination of irrigation and hydropower is applied in many projects all over the world. Certainly there are also possibilities for this kind of multi-use system at smaller scale in rural Nepal. However this has not been covered within this report. But the results, which are true for drinking water, are transferable to irrigation to a certain extend (available turbine solutions, costs, granted subsidies, etc.). Particularly the features of pond irrigation schemes – being intensively promoted by another Helvetas programme and by the government of Nepal – are comparable to drinking water schemes.

5. Electrification Options

5.1. Diesel generator

The sound of diesel generators certainly is familiar with everyone, who’s been travelling through Nepal. Mainly used in urban areas, they bridge power supply during load shedding in hotels, restaurants and offices (even Helvetas’ WARM-P office in Surkhet operates one). However diesel generators are not present in the rural areas, where WARM-P is currently active. Even if ability and willingness to pay would be high enough to purchase a generator, costs for fuel and transportation hurdles are too high to make diesel generator a viable solution to electrify rural communities[8].

5.2. Solar Set

Small solar panels are an eye-catcher in the unspoiled landscape of rural Nepal and such solar panels are widespread. At least a few households in almost all villages are equipped with a Solar Set. Sometimes also referred as Solar Home System (SHS), these sets consist of a photovoltaic panel – usually mounted on a wooden stick – a battery, load controller and lighting devices (either a florescent lamp tube or WLEDs).

There are various suppliers offering systems of different sizes. During the field visit mainly 20 W systems have been encountered, which are able run three lamps for 4 h under average conditions (no dense cloud coverage all day through). Charging of mobile phones is possible and successfully applied.

Penetration

Precise numbers for Solar Set coverage in Nepal could not be found. However the devices are present even in very remote villages but penetration is generally higher in road corridors. This was confirmed during the field visits, where

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[7] The Pico Hydro Market in Vietnam, Oliver Paish, Dr John Green, IT Power

[8] In some close-to-road markets Diesel engines are used to drive mills, grinders or rice hollowers. However mechanical energy is directly applied without producing electricity.

remote villages (Gadgaun: 15 of 44, Khamohale: 5 of 16) were less equipped than those which are near the road (Kitu Katuje: 17 of 25, Bada Awal 5 of 11).

Costs

AEPC and other agencies and NGOs promote the distribution of Solar Sets and grant subsidies[9]. Furthermore private vendors roam around in the rural villages and sell new but also second hand systems, which makes it difficult to identify a reliable price. Interviewed households stated paying between NRP 2’000 (heavily subsidized) and NRP 12’000 to NRP 14’000. The latter seems to be a good approximation of the current price for a 20 W system.

Expenses for operation and maintenance are negligible[10].

Sustainability

The reported experiences from Solar Set owner ranged from “perfectly working since 4 years”, to “bigryo” (damaged) after few months only. Even though AEPC has released binding quality standards, Solar Sets clearly face sustainability problems. From 15 interviewed households with Solar Sets, 3 households faced significant problems and one system was completely broken.

5.3. Grid

The state owned Nepalese Electricity Authority (NEA) is responsible for electricity supply through the national grid. In 2007 only 48 % of the population was connected to the grid, most of it living in urban areas. According to the Ministry of Energy only 8 % of the people in rural areas have access to electricity (Ministry of Energy).

Extension of the transmission system in Nepal is slow as NEA is already struggling with managing the existing grid. Furthermore there is little incentive to connect additional consumer as production capacities are not even capable of keeping up with increasing demand from existing users.

Nevertheless it seems to be a popular promise among regional politicians, to provide their voters with electricity as soon as they are in the aimed position. Those promises are unlikely to be kept and most contacted villagers don’t expect the presence of grid “in the next 100 years”. A vast majority of the WARM-P schemes are so remote, that it is fair to assume that grid will not be present within the next 10 years.

Tariff

At places where grid is present the current tariff is composed in such a way that monthly sum of NRP 80 is paid for the first 20 kWh (in Nepal one kWh is also referred as “unit”). Additional consumption is charged progressively in order to encourage energy efficiency (starting with 7.3 NRP/kWh).

5.4. Mini Grids

Whereas per-user grid connection costs are comparably low in the densely populated area, this is not true for the hilly and mountainous part of Nepal. The grid developer not only faces high investment cots but also triggers high costs for subsequent operation and maintenance.

One solution to overcome high transmission costs is the installation of mini grids for limited number of beneficiaries. The government of Nepal, NGOs and international donors encourage the realisation of mini grids mainly through AEPC (see page 12). The majority of those mini grids are connected to a small hydro power plant[11] ranging from 2 kW to 100 kW, which accordingly supplies one or more villages with electricity.

The distribution of electricity from an IHP also needs a grid and therefore is nothing else than an “extra small” mini grid (output at IHP sites is expected not to exceed 2’000 W).

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[9] Current subsidy varies between $ 29 and $ 143 per system / household (RERL under AEPC)

[10] Some NRP 100 for distilled water every other year

[11] There are projects, where mini grids are fed by solar panels, wind turbines or a combination of both. However those technologies require storage and therewith add complexity to the system, which again could become a sustainability issue.

5.5. Lighting solutions

Conventional lighting sources

In some villages they are called “Julo”, in others “Dialo” or “Jharro”. The old lighting sources are still present in households of all visited villages. There were even families, which own a properly working Solar Set and still burn Dialo while cooking. Dialo is a resin rich piece of wood obtained from the pine tree (resin production is stimulated by cutting the bark, as a defence mechanism the tree produces a resin soaked layer which is then harvested). The wood steadily burns like a candle, but emits a sooty smoke. Such lighting sources cause respiratory diseases and eye problems. Thus, although the wood is seemingly available for free, related health costs are high.

Kerosene fed lamps, so-called Laltin, can also be found in the villages. As Kerosene supply has to be assured, they are rather seen in less remote settlements. Interviews in Gadgaun revealed high operational costs (NRP 300 per month[12]).

Lighting solutions for IHP

The technology of lighting solutions is developing rapidly causing significant efficiency increases. AEPC for instance still requests that at least 100 W are provided to every household for lighting only. At the same time, there are organisations which successfully promote LED based lighting, where less than 10 W is required per household[13].

Besides the traditional but inefficient incandescent light bulb, there are currently two lighting solutions, which are broadly available in Nepal. Compact fluorescent lamps (CFL) dominate the market and can even be found in very remote bazaars. LED bulbs, the other alternative, consist of a bunch of light emitting diodes. They require a slightly higher investment but are more efficient and have higher life expectancy. LED bulbs are currently only available in city bazaars (and in smaller bazaars upon request).

Table 7 on page I (annex) provides an overview of the available products in Surkhet bazaar in September 2012. The required wattage per bulb ranges between 1 W and 23 W. Prices for large quantities start at NRP 150 for CFL bulbs and go up to NRP 275 for LED bulbs.

For this study 40 W per household are taken as minimum demand for lighting and mobile charging purposes. 40 W is enough to light up five rooms with 7 W CFL bulbs and it is “double the output of a large Solar Set”.

6. Hydropower market in Nepal

6.1. Overview

Nepal’s mountainous topography and the high annual discharges as a result of the Monsoon should be a good precondition to set up a strong hydropower market. However implementing large hydropower projects of several MW power output seems to be almost impossible because of weak or outright absent administrative bodies. In 2011 a total hydropower capacity of 652 MW was installed, which supplied 83 % of the national electricity consumption[14].

The situation for small hydro projects ranging up to one Megawatt (Table 1) is somewhat more favourable, as legal hurdles are lower and because those projects are subsidised by several donors. As a result, around 30 mostly family managed and privately owned micro hydropower equipment manufacturing companies have been established in Nepal, mainly in Kathmandu and Butwal. Most of these workshops are specialised in one particular turbine type and size. Only a few of them offer the so-called Peltric Set and even less workshops produce turbines with power output below 1’000 W.

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[12] 200 ml of Kerosene are consumed within 2 days if Laltin is used for 4 h daily. One litre of Kerosene is locally available at NRP ~100. Monthly costs therefore sum up to NRP 300.

[13] Mini grid in Kholsi village, supported by RIDS (see page 54)

[14] NEA’s annual report 2011

Table 3: AEPC's terminology for size of hydropower plants

Terminology	Power output
Large hydropower plants	> 1 MW
Mini-Hydro	100 – 1'000 kW
Micro-Hydro	5 – 100 kW
Pico Hydro (Peltric Set)	< 5 kW

6.2. Suitable Turbine Type

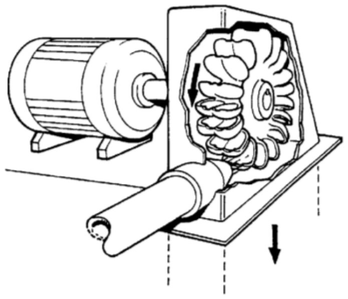
The selection of the appropriate turbine type depends on the particular site characteristics, the dominant ones being head and flow available. Other considerations are running speed, the capability of the turbine to produce under partial load and whether the turbine is locally available and can be transported to the site[15].

Pelton turbine

Because of the limited discharge, the Pelton turbine is likely the only appropriate for rural drinking water schemes. Pelton turbines are generally used at sites with high head (e.g.. the Swiss Alps), can be properly designed for little flow and are able to deal with partial load.

The Pelton Turbine consists of a runner with a series of split buckets, which are hit by one or several jets from controllable nozzles (see Figure 2). The material of buckets is adapted to the site specific head; most manufacturer use aluminium, bronze or cast iron. It is possible to equip Pelton turbines for low head sites with cast plastic buckets, which allows a cost advantage[16]. Gautam Engineering and Kathmandu Metal Industries (KMI) offer such systems but neither one was willing or able to show a successfully operating site.

Figure 2: Pelton turbine (horizontal shaft)



Turgo turbine

The concept of Turgo turbine is a modification of the Pelton turbine. Water enters the runner at an angle of 20° and exits on the opposite side, which makes it possible to produce smaller runners with the same flow capacity. There are Turgo turbines available in Kathmandu, which are imported from Vietnam (see appendix). However the maximum head is limited to 15 m and the minimum flow starts at 3 lps. which does not make it a promising solution for IHP in Nepal.

No Nepali workshop currently produces Turgo turbines for low flow sites.

Crossflow turbine

The crossflow turbine, sometimes also referred as Banki or Ossberger turbine, is probably the most successful turbine type in Nepal. The technology was adapted to the manufacturing facilities in Nepal in the mid 1970s mainly through Swiss and German aid programs. Nowadays, the crossflow turbine is the broadest applied turbine in Nepal with many domestic companies having capacities to produce it. Yet the crossflow turbine is not a solution to be implemented at drinking water systems as the minimum flow has to be above 10 lps., while the flow within drinking water schemes is in the order of 2 lps..

Ghatta and Improved Ghatta

There is no precise number, but it must be ten thousands of water mills, so-called Ghatta, which are currently running in all rural areas of Nepal. The constructions consist of a simple chute instead of a penstock, which is made of a hollowed tree trunk. The water being brought from a stream through a headrace shoots down the chute and drives the wooden

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[15] A good overview on small hydro turbines in Nepal can be found in:
Small hydro power: technology and current status, Oliver Paish, United Kingdom, 2002

[16] It is possible to apply plastic buckets at Pelton turbines up to a head of 60 m (Gautam Engineering, June 2012)

blades of a propeller. The vertically shafted propeller then drives – either direct or through a system of belts – various agro processors like grinders, hullers or oil expellers.

With those simple constructions the force of water has been used since centuries and still most of these Ghattas have not been improved yet. Nevertheless there are programs run by several agencies, which aim to help users improving their Ghattas. The most effective way to significantly increase the efficiency is through replacement of the turbine's wooden parts (rotor and shaft) with metallic parts. Many metal workshops in Nepal have been taught how to manufacture those turbines and several NGOs and the national AEPC run initiatives to support rural communities to improve their Ghattas.

As the necessary water discharge is high, neither traditional Ghattas nor Improved Ghattas are relevant to be combined with drinking water systems. Only surface water (ranging from small rivulets to large rivers) can provide enough discharge of 30 -100 lps..[17]

6.3. Peltric Set

The Peltric Set is a standardized product manufactured by several workshops in whole Nepal. As turbines of selected manufacturers can deal with flows starting at 0.5 lps., it is a promising solution to be applied within drinking water schemes.

The idea of Peltric Set was to standardize a product, such that manufacturing companies can reach larger volume of sales and buyers are able to easily compare products from different suppliers. Nevertheless the term Peltric Set is variously used and detailed definitions vary from person to person asked. Generally it is understood as a set of devices to provide electricity by using the force of a small stream with relatively high head. Both, Pelton turbine and induction generator, are purchased as one package, which is ready to produce electricity for a small grid with lighting and battery charging demand only.

Manufacturer of Peltric Sets (officially more than 50 workshops[18]) offer systems which can deal with heads and discharge as listed in Table 4. The national promoter of Peltric Sets, AEPC, only defines the power output, which has to range between 1 kW and 5 kW. The lower limit is particularly important as no project below 1 Kilowatt is supported under the current Peltric Set subsidy scheme.

All visited manufacturer provide a bring-in-warranty of 1 year. If the scheme is supported by AEPC the Peltric Set providers have to guarantee a minimum power output based on the previously determined head and discharge (they are financially penalised if agreed values cannot be reached).

Generally the plants are not installed by the manufacturer itself, if not explicitly requested. The cost of a skilled engineer travelling to the often very remote sites is just too expensive compared to the size of project[19]. This is why the companies offer in-house courses for a member of the beneficiaries who will later then install the system and be responsible for a proper technical management of the power plant.

Peltric Sets are comparable small hydropower plants, thus achievable profit margins are limited. A successful entrepreneur is forced to scale up production. Other manufacturer maintain their Peltric Sets production at low volume and declare it as a charitably act to help their country. Anyway, there is no big money to be made in this business which might explain why design and production process of these units have changed so little in previous years.

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[17] Further Information on Ghatta and Improved Ghatta: Participation in Improved Water Mill (IWM), brochure by Centre of Rural Technology Nepal, December 2011, www.crtnepal.org

[18] The latest list can be downloaded from AEPC's website. During the enquiries for this report, not all the listed companies actually offered Peltric sets. Some are only resellers, others have shifted their focus towards production of larger units.

[19] KMI offers a 600 W Peltric Set at around NRP 60'000. Installation charges for such a plant can easily amount to NRP 30'000.

Table 4: Characteristics of Peltric Sets in Nepal

Net head	Discharge	Overall efficiency	Power Output
20 – 200 m	1 – 30 lps.	~50 %	1 – 5 kW
Maximum head varies with manufacturer, most of the offered systems have max. head of 60 m	The minimum flow of a Peltric Set is not strictly defined. Some manufacturers claim that their system can deal with less than 1 lps.	Hydraulic to electric	Some manufacturers offer systems which are designed for power output lower than 1 kW or they promise good efficiency at partial load

6.4. Relevant Agencies and NGOs

It seems that almost every technically focused NGO in Nepal promoted at least one hydropower project or has run a hydropower related program at some point in its history. Nevertheless there could not be found any organisation that thoroughly assessed the potential of hydropower combined with rural drinking water schemes.

6.4.1. Centre for Rural Technologies Nepal (CRT)

CRT is a national NGO which develops and thereafter promotes technologies for rural Nepal. A related machine workshop[20] was established, which is legally and officially independent from CRT but receives the majority of orders from them. About 5 years ago, CRT developed a small hydropower plant comprising of an in-house manufactured turbine and a motor-generator directly mounted on the same shaft (so-called Motor Dynamo-based Family Hydro). Both the buckets of the Pelton runner and casing are manufactured in their own workshop. As those plants were designed for 1.5 – 3 lps. and heads between 30 m and 50 m, their solution seemed to be promising for IHP application. CRT's annual report 2011, which refers to 18 successfully installed units, providing energy for lighting, radio operation and mobile charging, thus further strengthening that expectation.

Hope was however squashed after the second meeting with representatives of CRT. Actually they couldn't provide a record of any plant being in operation today. From initially intended 100 units, only 18 have been realised. More than 30 already manufactured units are lying idle in the backyard since then (reason: inappropriate design by a former engineer). The project is not active anymore; neither a proper track record nor a report on lessons learnt has been made available. CRT is now focusing on other technologies.

Even though CRT is the only NGO that has been active in low flow turbines (and very cleverly communicates through the website), the author of this report does not recommend any cooperation with CRT. Their working approach clearly is not demand driven but is much more oriented on the technology which their engineers are currently passionate about.

6.4.2. Alternative Energy Promotion Centre (AEPC)

Established in 1996 AEPC is a governmental body under the Ministry of Environment, Science and Technology. It is the nodal agency for the promotion of alternative energy in Nepal and has supported almost all off-grid electrification projects in Nepal. AEPC currently runs two major programs, which are funded by different donors. Their activities do partly overlap.

Renewable Energy for Rural Livelihood (RERL)

The UNDP and World Bank funded program has been started in 2011 and replaces the still well known Rural Energy Development Programme (REDP). Small hydropower schemes are supported among various other renewable energy technologies. Nevertheless there is no option to get an IHP project subsidised as only projects beyond 10 kW are supported.

Energy Sector Assistance Programme (ESAP)

The program is funded by Denmark, Norway and the government of Nepal and currently runs in phase II, which ends 2012. Rumour has it that major changes are explored for its third phase – i.e. inclusion of CDM (chapter 9.1) within the mini-grid schemes and consolidation of RERL and ESAP.

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[20] Rural Energy & Technology Service Centre

ESAP itself currently runs a programme, which aims to support mini grid projects[21]. The subsidies under that programme are substantial as they cover a major share of the investment. However the subsidy policy is complicated and depends on various parameters like number of households, power output of power plant, place of project and its distance to the closest road head. Three particular issues are of concern for IHP projects:

i. No subsidy to be expected for projects below 1’000 W und the current subsidy policy.
AEPC only supports schemes ranging from 1 kW to 1 MW. As per discussions with AEPC staff, they have not received applications for schemes below 2 kW. Although there is a clear trend towards larger schemes, they are open to discuss their subsidy policy (and lower the threshold), if IHP has turned out to be highly feasible in Nepal.

ii. Minimum demand per household is set at 100 W.
Even though there are efficient lighting devices available today which can light several rooms with a fraction of 100 W, AEPC has not changed this policy for years. The consequences are that mini grids, where the design demand for lighting are set at 40 W per household, receive less than 50 % of the subsidies of conventional projects[22].

iii. Support for community based schemes only.
Family owned hydro power plants, where only a part of the community profits, are technically feasible within selected drinking water schemes. Such systems cannot apply for subsidies, as AEPC exclusively supports community based schemes.

Contact at AEPC

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Bharat Poudel (Sr. Engineer/AEPC), bharat.poudel@aepc.gov.np

6.4.3. Sundar Nepal Sanstha (BNA)

Based in Surkhet, Sundar Nepal is a regional non-profit organisation which delivers a bunch of services ranging from sanitation awareness building and agricultural advisory services to supporting villages in their claim for drinking water schemes. More important: it is qualified as a Regional Renewable Energy Centre of AEPC.

As a Regional Renewable Energy Centre they are responsible for all micro hydro projects in the Mid-Western districts of Nepal. Sundar Nepal is the office to contact first, if projects are aimed to receive subsidies under the AEPC programs. They provide relevant information and coordinate the procedure to apply for certificates and permissions, which are crucial to realise hydropower projects.

At the time of the investigation for this report, Sundar Nepal had not realized any HPP project in combination with drinking water schemes. If Helvetas decides to include small hydropower plants into their drinking water scheme activities, Sundar Nepal is the nodal agency not only to coordinate for AEPC subsidies but also to source for any information related to small hydro projects.

Contact

Bal Mukunda Kunwar, Mini Grid Engineer, bkunwar@sundarnepal.org.np, +977 9858051321

6.5. Manufacturers

In the following section only two suppliers of hydropower plants are portrayed. Kathmandu Metal Industries and Gautam Engineering are the only manufacturers that provide appropriate solutions for drinking water schemes. Essentially the minimum flow condition of 1 lps. cuts down the list of manufacturers. There are a few more suppliers of small turbines, but they either have poor reputation or disqualified themselves by having little interest in collaborating with Helvetas. All contacted companies and advisors are listed in the appendix.

Trend towards larger power plants

According to almost all stakeholders, a general trend towards larger units can be detected in the small hydropower sector. Mini grids and subsequently power plants have been growing in size and power output within the last few years. Even though almost all contacted manufacturer and agencies referred to this trend, there is very limited material available, which can support this development. AEPC has published data of supported schemes until 2009. Figure 3 and

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[21] Mini-Grid Support Programme, MGSP

[22] This regulation however is not that grave, as there is a subsidy limitation of max. NRP 97’500 per kW, which is below 10 times the household subsidy.

Figure 4 clearly indicate, that the number of supported small schemes (below 5 kW) is decreasing whereas the number of supported schemes with a power output between 5 kW and 100 kW are increasing in number.

The trend towards larger schemes might be caused by different reasons; certainly one of them is the economy of scale. From a manufacturer's position, small hydropower plants can only be sold with small margins compared to larger units. Furthermore expenses for marketing, sales and contact with governmental agencies do not depend on size but number of units sold. Because of this hydropower plant producer (which are able to manufacture IHP) shy away from smaller power plants and openly declare that they are much more interested selling units in the range of 50 kW to 500 kW.

AEPC, being the national promoter of small hydropower schemes, also encourages planning for larger schemes (i.e. by incorporating several communities within one mini grid). They experienced, that larger schemes with beneficiaries that are able to make productive end-use are more sustainable than small schemes for lighting purposes only.

Figure 3: AEPC supported Pico Hydro schemes (below 5 kW)

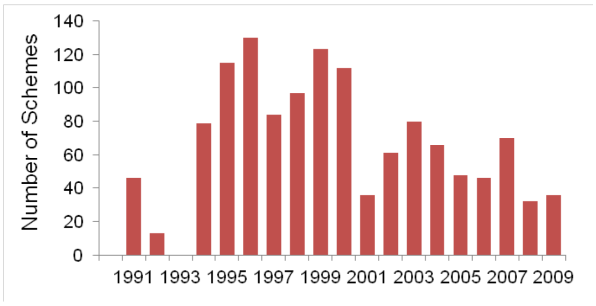
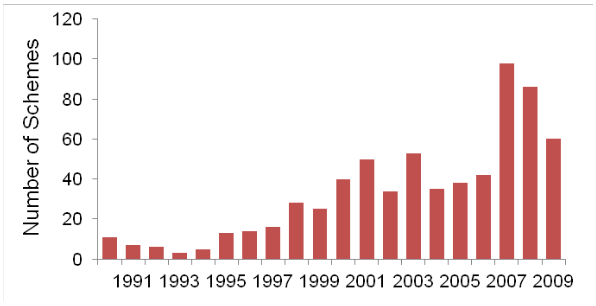


Figure 4: AEPC supported Micro Hydro schemes (5 - 100 kW)



6.5.1. Kathmandu Metal Industries

Having the head office located in the centre of Kathmandu (Chetrapati), Kathmandu Metal Industries produces most of the power plants in their factory in Bhaktapur. In the more than 100 years old history of the workshop, Thirta Man Nakarmi who is the present managing director represents the 3rd generation.

Products

KMI offers small hydropower plants varying from 200 W to 100 kW. Their smallest Peltric-Set unit reaches maximum power output of 600 W (see Table 14). It is designed for heads between 20 m and 200 m and flows between 1 lps. and 2 lps.. According to Thirta Man this model can even deal with less flow without major decrease in efficiency.

Each unit is tailored to the particular site's condition. KMI manufactures around 100 Peltric-Sets annually for domestic customers only, but some of the larger hydropower plants are exported.

Warranty and maintenance

One year bring-in warranty is provided for all products. According to Thirta Man there is almost no maintenance work required at the machines itself. Only bearings have to be replaced within 3-4 years which costs 300 per piece and can locally be conducted by the scheme technician.

However the availability of maintenance is guaranteed as all parts (except generator) are locally produced. KMI sells spare parts but does not offer a specific after-sales service and hence doesn't precisely know, where the systems are installed.

Track record

Akkal Man Nakarmi, father of Thirta Man, who directed the company until 2005, is known as the “father of Peltric-set”. KMI is well known in Nepal's hydropower industry as an experienced and reliable supplier of high quality goods (Bhim Malla, June 2012).

Approximately 500 units of Peltric Sets below 1 kW have been sold to date and some are in operation since more than 22 years. Still there are no plants which have been installed in combination with drinking water schemes (Thirta Man Nakarmi, Mai 2012).

Contact

Thirta Man Nakarmi, managing director, +977 9851033418

6.5.2. Gautam Energy Engineering

Gautam Energy Engineering is a manufacturer of hydropower solutions ranging from small 100 W systems to 100 kW plants. Based in Butwal (Rupandehi district), they deliver large HPP to whole Nepal whereas their distribution area for the small systems lies in the districts around Butwal.

Products

Concerning small systems Gautam differentiates between two types of solutions:

i. Laltin[23] & Family Set
   ranges from 100 W to 500 W, buckets of the Pelton turbine are made of Plastic. The system does not include an IGC to divert surplus energy but there is a capacitor box, where voltage is metered (including overvoltage protection).
ii. Peltric Set
   ranges from 0.4 kW to 5 kW and can either be purchased as automatic or simple system. Automatic systems consist of a “jet off system” which activates as soon as load is absent and subsequently diverts the water jet from the turbine. This prevents the runner from over-rewing, which could damage the system.
   Buckets of the Pelton runner are made of bronze or mild steel. An IGC diverts surplus energy to the ballast heater.

Warranty and Maintenance

One year bring-in warranty is provided for all products. As the small plants are mainly sold in the districts around Butwal, the operator of a scheme usually directly approaches Gautam in case there is anything wrong with the system. The availability of spare parts is guaranteed as the whole system (except generator) is manufactured locally.

Track Record

One micro hydro site near Butwal could be visited during the meeting with Hari Gautam. Unfortunately the 1 kW-system was not running, as the source yielded too little water at this time (beneficiaries said that it has been shut down only 5 days before). See also site description at page 19.

The reputation of Gautam Energy Engineering is good, several mini hydro insiders say. The “Laltin & Family Set” shows, that there is a way to reduce cost for small and simple systems. Hari Gautam claimed that there are numerous schemes around Butwal, where his plants are successfully running. Despite his promise and several requests he did not provide a corresponding list.

Contact

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7. Relevant drinking water schemes

7.1. Water Resource Management Programme WARM-P

Having started in 2001 and now running in the third phase, Helvetas’ WARM-P is particularly known for its support of drinking water schemes in rural Nepal. It is currently active in four districts of Nepal’s Mid-West Development Region (Achham, Dailekh, Kalikot, Jajarkot). The goal of the programme is to establish “[..] sustainable water resources management and sanitation systems devised by local communities (especially Dalits, women and Janjati) to improve livelihood”.[24]

Amongst other activities WARM-P supports communities and their administrative bodies (VDC) to prepare so-called Water Use Master Plans (WUMP). A WUMP is basically a VDC wide inventory of all water sources and of all water users – be it for domestic, irrigation or any other purposes. However deriving a WUMP is not only localization and classifying of water sources but incorporates discussion and decision finding processes within the affected communities. The whole process is conducted in a participatory and transparent way; marginalized groups (Dalits, women and Janjati) are particularly empowered to claim their rights on the prevalent water sources.

Decisions for drinking water schemes or any other water related infrastructure investments are then based on the WUMP. WARM-P again supports various projects with money and expertise. All projects are co-financed by the beneficiaries themselves and the local administrative body.

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[23] Laltin is a Kerosene fed candle used for lighting, which is aimed to be replaced by the „Laltin & Family set“

[24] WARM-P Programme Document 2010-2012

7.2. WARM-P supported schemes

Rainwater harvesting schemes

WARM-P supports not only gravity fed drinking water schemes but also helps, where no perennial surface water is available. Ferro cement tanks of 6 m^3, so-called rainwater harvesting tanks, allow storage of water for drinking and washing purposes of a single household. In some areas even small ponds are built, in order to store irrigation water for kitchen or commercial vegetable gardening. However those systems are not feasible to be combined with hydropower.

Gravity fed drinking water schemes

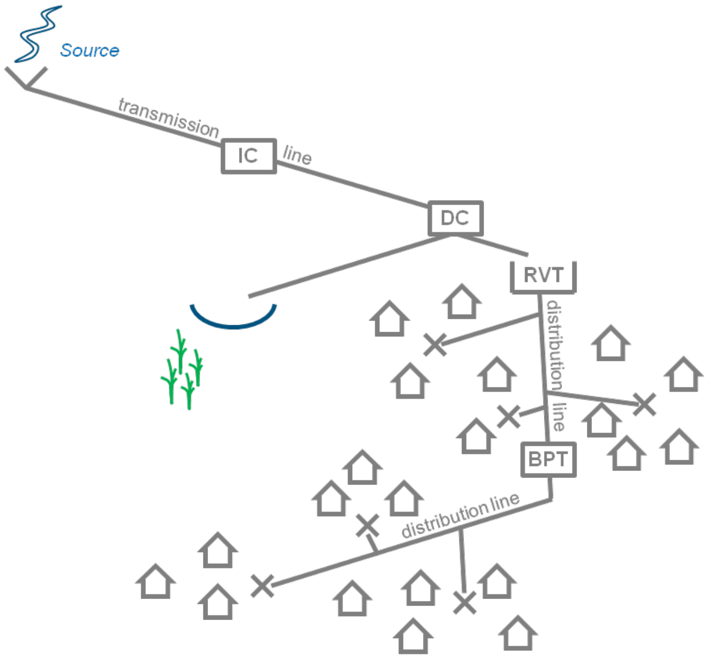
The majority of WARM-P supported projects are gravity fed drinking water schemes with approximately 60 beneficiary households (Figure 6). These systems consist of one or several sources, with enough discharge to satisfy the need of every connected household all the year round[25]. Only water sources, which are safe for drinking without further treatment, are taken into account.

The pipe between intake and reservoir tank (RVT) is called transmission line. The decision of material and diameter depends on various factors and the ideal solution is only found based on iterative calculations. If head between source and reservoir chamber is high, it is usually favourable to incorporate a so-called interruption chamber. Both interruption chambers (IC) and break pressure tank (BPT) release the pressure within the upper pipe and convey the water to the lower pipe[26].

An RVT compensates the difference between available flow and demand pattern through the day. Demand for drinking water is commonly high in the morning hours, fluctuates during the day and is almost zero during night time. Water is obtained from public tap stands, which are allocated within the settlement in such a way, that 3 to 8 households share one tap stand (see also Figure 5 and Figure 7).

WARM-P also supports multi-use schemes, where source discharge exceeds the daily demand for drinking water. Both transmission and distribution line are overdesigned to bring the excess water to the tap stands. It is then utilized to either irrigate private kitchen gardens or small commercial crops. Some sites even have irrigation ponds, which allow irrigation on larger scale, mainly for commercial purposes.

Figure 5: Typical WARM-P supported drinking water scheme



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[25] The so-called safe yield reflects the discharge at a source, which is available all the year round. For identification of the safe yield several measurements are made during the driest time of the year (Mai, June). From the measured discharges a safety margin is deducted again.

[26] BPT differ from IC, with respect to water loss. ICs normally just consist of a water barrel and surplus water is lost. Whereas BPT automatically close the upper pipe, if there is no water flow in the lower pipe.

7.3. Statistical properties of WARM-P schemes

Some statistical analysis has been done, based on an internal database of WARM-P drinking water schemes. The database consists of 262 gravity fed DWS representing almost all implemented schemes since 2001. The respective data are likely not to be representative for the whole sample of DWS in the targeted districts as WARM-P particularly focuses on community with water hardship.

Figure 6: Number of households per scheme

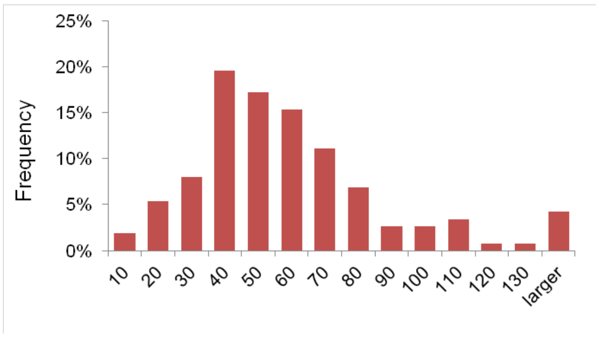


Figure 7: Number of households per tap stand

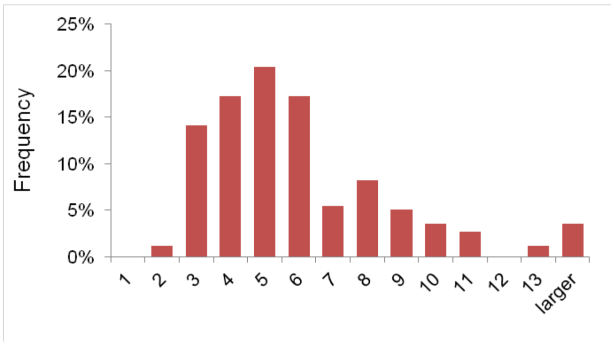


Figure 8: Safe Yield - source discharge, which is perennially available (total number of schemes: 257)

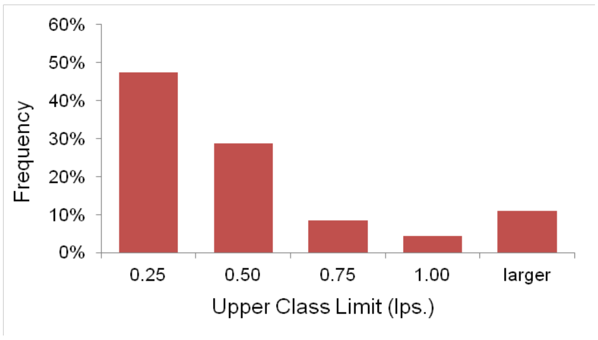


Figure 9: Safe Yield where BPT & IC are present (total number of schemes: 257)

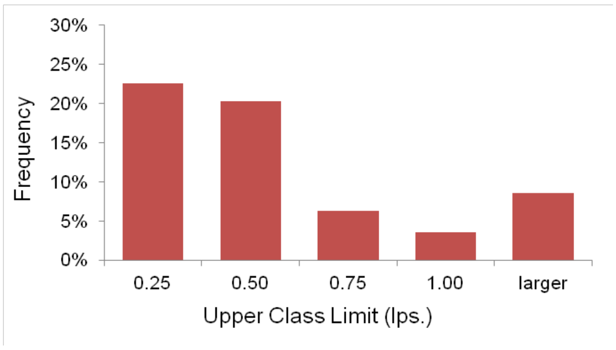


Figure 10: Number of break pressure tanks BPT and interruption chambers IC (total number of schemes: 262)

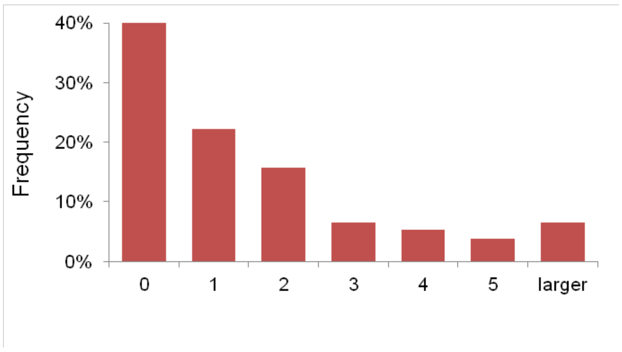
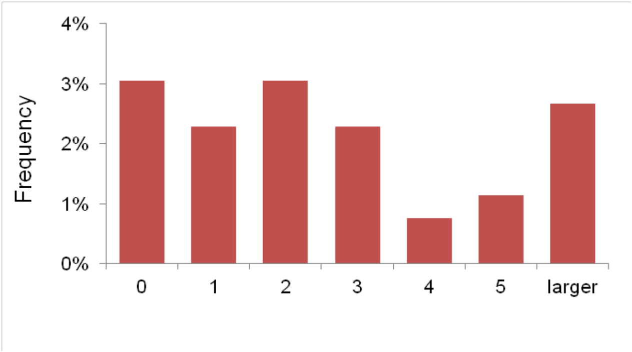


Figure 11: IC & BPT where Q_{SY} is larger than 0.75 lps. (total number of schemes: 262)



Size of schemes

Around 60 households in average benefit from one WARM-P supported drinking water scheme. This number however overestimates the amount of households, which are effectively connected to a single scheme. Some schemes consist of several, independent sub schemes, with own sources, RVT etc.. The figures in the database reflect a scheme with all its sub schemes.

Energy within the system

The power output of a hydropower plant is determined by the available water discharge and the difference in elevation within the respective system. The feasibility of hydropower plants within drinking water scheme therefore depends on the discharge at source and the head between source and tap stand. Whereas the discharge at every WARM-P supported scheme is available from the database (safe yield), this is not true for elevation. Therefore the presence of IC and BPT is taken as indication of a steep topography. Both IC and BPT are commonly used to break the pressure within a water pipe where the prevailing pressure exceeds 60 m.

Discharge in drinking water schemes is generally very low. Figure 8 shows, that a vast majority of the schemes – more than 75 % – have less than 0.5 lps. available. Only 15 % of the systems have more than 0.75 lps. and some 10 % have more than 1 lps.. Of those schemes which have more than 1 lps. almost all range between 1 lps. and 2 lps.. The small discharges illustrate that only turbines, which can deal with very little flow are suitable to be incorporated within drinking water schemes.

The situation is somehow better with respect to available head. More than half of the schemes are equipped with at least one IC or BPT, which indicates a minimum difference in elevation of 60 m (Figure 10).

For a complete assessment of the energy within a system both head and discharge have to be assessed in combination. However the comparison of Figure 8 and Figure 9 point out a surprising fact. The bars for discharges above 0.75 lps. are almost similar in both graphs. Only 3 % of the schemes with discharge higher than 0.75 lps. do not have any BPT or IC. Hence concluding it can be said that almost all sites, which are fed by a high yield source, are in steep topography and subsequently fulfil technical preconditions for IHP.

Table 5: Specifications of gravity fed drinking water schemes

Demand	
Domestic	45 L per capita per day
School	10 L per student per day
Health post	500 L per bed per day
Tap stands	
HH per tap stand	~ 6 HH (between 3 and 11)
Head at tap stand	~ 5 m (max. 20 m)
Discharge	0.1 lps. (regulated)

8. Field visits

8.1. Assurani, Dadeldhura district

General

Assurani near Makali River is a small village located in the far west of Nepal (Dadeldhura district). It is accessible only through a 6 h walk from Jogbudha. 21 households have been counted in 2007 of which in 2012 only 13 are permanent residents – 8 households have dislocated and live in lower areas for a few months per year.

Current scheme

A multipurpose scheme has been implemented in 2007 with support of RVWRMP. The scheme serves for drinking water and irrigation of kitchen gardens. A 2 kW hydropower plant uses surplus drinking water to provide electricity for lighting in evening hours. The reservoir tank of the drinking water scheme and forebay tank for the hydropower scheme are placed next to each other (the overflow from the drinking water tank feeds the forebay). Using the same intake and transmission line from source to reservoir and from source to forebay makes the system in Assurani an IHP. No further synergies have been used (i.e. combination of penstock and distribution line).

Experience

The scheme has been implemented in 2007 (hydropower plant in 2008) and is running without major difficulties since then. This is especially true for the drinking water scheme. Villagers are enormously grateful and proud having clean water available all the year round. They used to drink water from the nearby Mahakali, which was associated with health problems. They expressed a breakdown of their drinking water scheme as the main concern, with much higher priority compared to the hydropower scheme (and irrigation).

However the power plant does not make the impression of being properly maintained. During the visit, villagers mentioned that the power output is lower than promised (about 50 % only) and that the plant does not always run smoothly. A minor leakage could be detected at the junction between penstock and turbine.

Rumour had it, that AEPC has not granted a “certificate of completion” to date. As a result of this, not all subsidy payments have been transmitted to the manufacturer (who sold the plant at subsidized rate to the village). The consequence of this: no warranted maintenance work is done by the manufacturer.

Electricity is not used for productive end use in Assurani. Besides light for cooking, reading and having the possibility to feed the cattle after dark, some villagers charge their mobile phones. Yet the latter are not widely used, as there is only coverage from Indian providers in this area.

8.2. Sata Khola, Rupandehi district

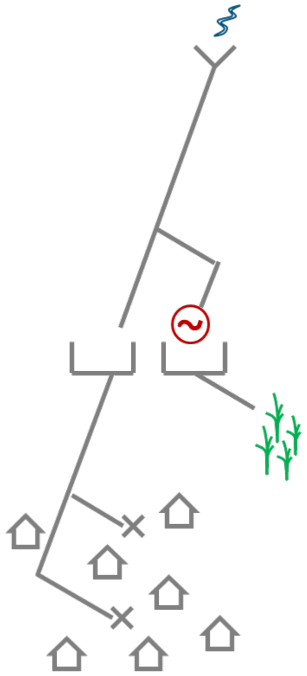
General

The site is located east of Butwal (Rupandehi district) where flat Terai rises towards hilly lands. It is accessible from Butwal through a 1h ride (first on paved then on gravel road) and a subsequent 30 minutes walk. Access to markets is good as the road head is close; the grid of NEA reaches the neighbouring village.

Current scheme

Implemented in 2006 the multipurpose scheme serves 18 households with drinking water and electricity. The water drop between source and reservoir chamber amounts to 87 m. A 1 kW plant is connected to the transmission line and produces 500 W at a discharge of 1 – 1.5 lps.. The water is then used for irrigation (Figure 12).
The Sata Khola scheme has not been supported by Helvetas.

Figure 12: Schematic sketch of the Sata Khola scheme.



Experience

The visit of this site has been spontaneously organised, thus no person with detailed information on the power plant and its performance was present. The plant has not been operating since three days because of uncommon dryness during this time (temperature was at 42° Celsius). Apart from this, villagers declared, that the plant is successfully running without major problems since implementation. This however is surprising, provided that the national grid of NEA is reaching the neighbouring village.

8.3. Gadgaun, Doti district

General

Gadgaun is a remote village with currently 44 households in Doti district (Lanakedareswor VDC). The site is accessible from Dhangadhi through a 4 h drive and more than 10 h walking. Latter can be cut down to 3 h only, if the river in B.P. Nagar can be crossed by vehicle (detailed information on the accessibility can be found in Figure 18).

Current scheme

A drinking water scheme has been implemented in 2008 with the help of Helvetas. Discharge at source exceeds the demand for drinking water, which motivated the designer of the scheme to oversize the transmission line (between source and reservoir). The excess water at the reservoir tank is used for irrigation of Khet. Even a pond has been constructed, which however is in poor condition and currently not in use.

The fact that there is a steep topography, comparably much water and highly motivated villagers makes Gadgaun a promising site for IHP.

Options for IHP

Two options have been investigated. Option A follows the idea to use as much as possible of the existing infrastructure in order to limit the necessary investment. Based on the available power the wattage per household is then calculated.

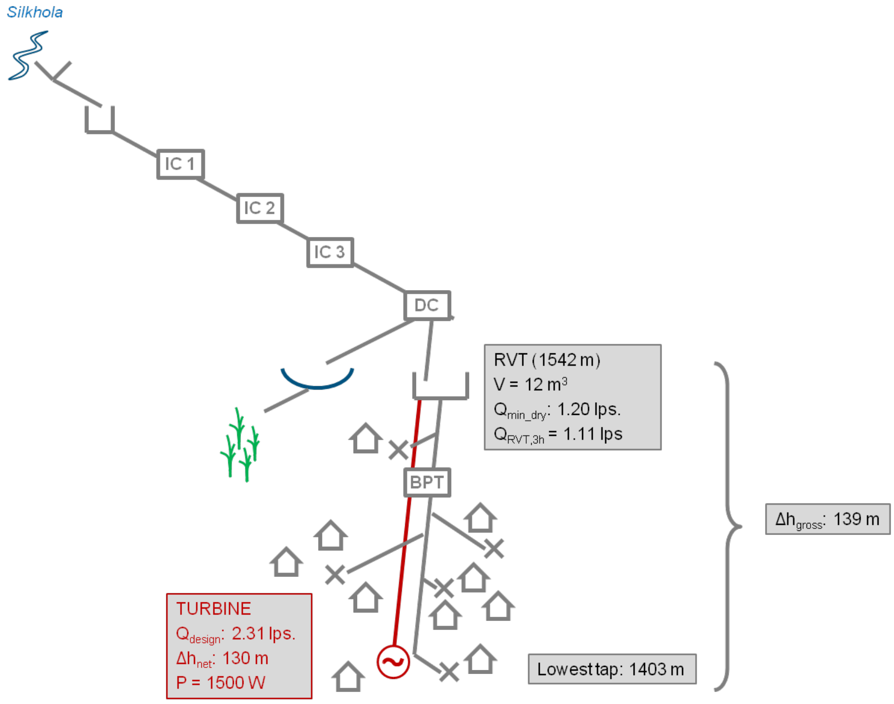
Option B on the other side starts with an average wattage per household, which has to be available during 4 hours of operation. 40 W[27] are selected as minimum power per household with an additional 200 W which is enough to charge at least 2 laptops or similar devices.

Option A

Figure 13 shows a sketch of option A, which leads to a power output of 1'500 W. This is enough to serve each household with 30 W. The whole drinking water system remains untouched; the reservoir tank is used as forebay of the hydropower scheme. The hydropower plant is placed at the lower end of the village, which makes it possible to use the water afterwards for irrigation of paddy.

Making use of the difference in elevation between intake and reservoir is not recommended, even though the available head is significant. The topography in this section is difficult (steep and rocky). Not only the long transmission line had to be replaced completely, but also a forebay tank had to be installed far from the settlement. As the settlement is arranged along a relatively steep area, availability of head is not crucial. Thus it is wise to prefer solutions, where penstock and power house are near the village.

Figure 13: Option A for IHP at Gadgaun village



Option B

Starting with a demand of 40 W per household plus 200 W for a charging station, the necessary power output sums up to 2'360 W. The position of the power house remains unchanged. Right next to the existing RVT a new forebay with volume of 25 m^3 needs to be constructed. The required RVT volume is calculated from the discharge at turbine and the available water from source.

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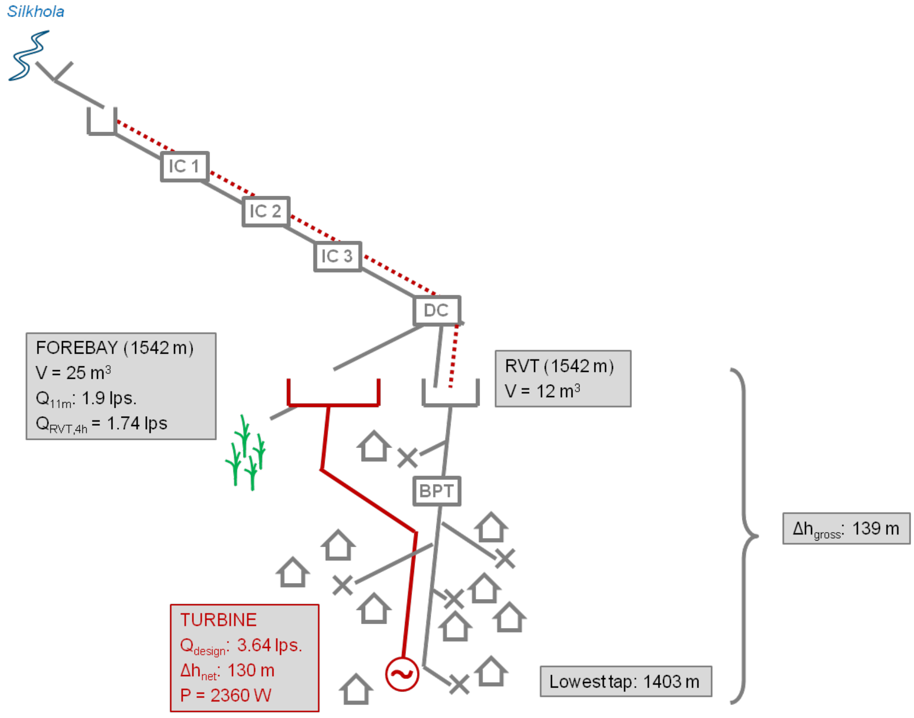
[27] Most Solar Sets, which are widespread in Nepal, have a power output of 20 W. Usually 3 LED bulbs are connected to the system. In order to set an incentive for IHP and to provide the possibility for lighting in the yard or the nearby cattle shed, the demand for each household is set at "2 Solar sets" which equals 40 W.

Figure 14: Option B for IHP at Gadgaun village. The dotted line indicate, that the transmission line requires replacement in those sections, which transport less than 1.9 lps..



8.4. Bada Awal, Dailekh district

General

Bada Awal is located at the southern border of Dailekh district and is part of Piladi VDC. It can be accessed from Surkhet through a 4 h drive to Bhimchula with a subsequent 1 h walk to the village. In monsoon time the already poor road to Bhimchula is sometimes disrupted in consequence of landslides.

Current scheme

The visited drinking water scheme is a sub-scheme of a larger project with different sources. Those sources are scattered and feed independent systems. There is only one source which yields 0.5 lps. (all others have less than 0.1 lps.). The respective scheme has been built in 2008 and currently provides water for approximately 50 people. Households are scattered, nevertheless only two tap stands have been realised.

Basically there is enough surplus water available all the year round to allow irrigation of kitchen gardens. Application of irrigation couldn't be observed, as field visit has been undertaken during heavy monsoon.

Option for IHP

There is no reasonable option for an IHP in Bada Awal if only the existing infrastructure can be used. The combination of a reasonable but not immense head (30 m), a small discharge (0.75 lps.[28]) and only small storage capacity (2.5 m^3) allows a power output of 150 W, which is equal to little more than 10 W per household.

Option B

The necessary power output amounts to 650 W, which is enough to satisfy 11 households with 40 W and provide electricity for a 100 W charging station. This can only be reached with a new reservoir tank at higher elevation (see Figure 15). Subsequently a new transmission line has to be realised, which goes through difficult terrain (steep and

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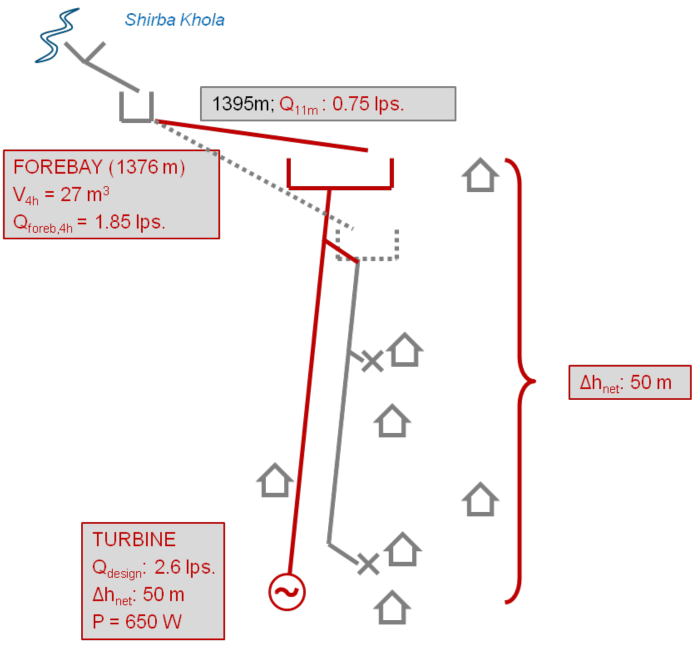
[28] The so-called safe yield reflects the discharge at the source, which is available all the year round. In order to reach a reasonable flow, an 11 month exceedance flow of 0.75 has been assumed. However this not a qualified assumption and has to be investigated, if the site is followed up.

rocky). The power house' location at the bottom of the village allows irrigation for the kitchen garden of the lowest households only or for paddy cultivation further down.

Figure 15: Option B in Bada Awal



8.5. Kitu Katuje, Dailekh district

General

Kitu Katuje is located in the Karnali river valley near the Karnali highway in Pipalkot VDC (Dailekh district). It is accessible from Surkhet through a 6 h drive on both paved and gravel road. During monsoon time landslides or high going rivers can lead to significantly longer journeys. The visited village consists of approximately 25 households.

Current scheme

In Kitu Katuje there is no drinking water scheme realised yet. A water use master plan for the whole VDC is currently under development. As a result of this, information on number and position of beneficiaries' households and source yield has not been available in documents. Particularly uncertain was the circle of beneficiaries of the future drinking water schemes (some households migrated a few kilometres west in the past years but still claim to be part of the community). Additionally there were conflicts with regard to the source (Katu Mul). The source has been exclusively used by no more than one household but is now expected to feed the entire drinking water scheme.

Options for IHP

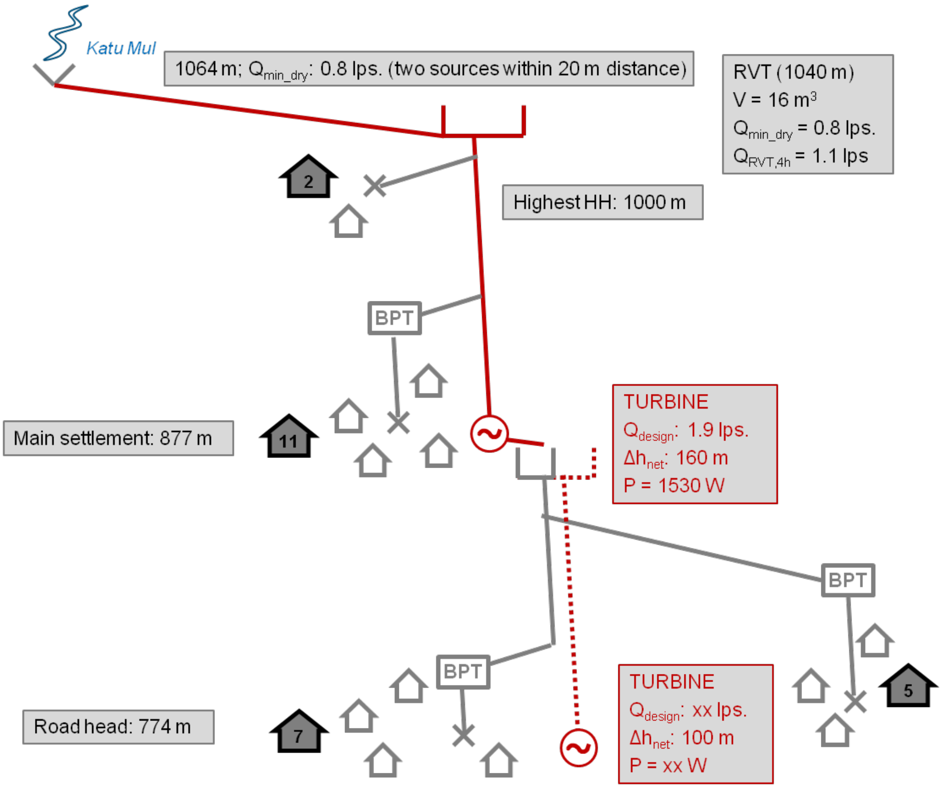
Because of the steep topography the target area is generally highly feasible for hydropower. Rumour had it, that there were plans for a larger hydropower mini grid a few kilometres away (for which Kitu Katuje is out of reach).

As neither a realised project nor a draft of the planned drinking water scheme has been available, a virtual scheme was sketched (see Figure 16). The drawing was done based on position and elevation of source, village centre and road head and the respective number of households. Starting with 25 beneficiary households and additional demand for a charging station and energy losses, the necessary power output comes to 1'500 W.

As difference in elevation between source and village is high, the respective hydropower plant could be installed above the main settlement. This comes with several advantages. Firstly, water that has flown through the turbine is at an elevation, where it can be used for irrigation of kitchen gardens in the main settlement. Secondly, it is possible to add another hydropower plant at a later stage. With this, an expansion of the small market at the road head could be anticipated and additional electricity could be provided for hotels, motor workshops or other consumers.

To overcome the differences about the source (which commonly arise during the development of almost every drinking water scheme) it could be wise not to start the DWS and the hydropower plant simultaneously. The DWS could be independently realised in such a way, that only minor additional investments are necessary to upgrade it for IHP. After one or two years – as soon as the community has proved to be able to successfully run their infrastructure – they could be approached again for the hydro project. Such a procedure could significantly add institutional sustainability and helps to reduce the risk of failure (see also chapter 11.3).

Figure 16: Sketch of a virtual drinking water scheme with IHP in Kitu Katuje



8.6. Khamohale, Achham district

General

Khamohale in Chalsa VDC is located above a side river of Karnali river (about 4 h walk from where it flows into Karnali). It can be reached from Surkhet through a 5 h drive with a subsequent 7 h walk. Walking distance heavily depends on the level of Karnali. In dry time it can be safely crossed by ferry (even a bridge is currently under construction), which reduces walking time to 4 h. On the recently built Mid-Hill Highway it is possible to approach the village by vehicle, which further reduces the walking distance to 2 h.

Current scheme

The visited village is part of a drinking water scheme consisting of two sub schemes (realised in 2006). However household number and elevation of source, reservoir tank and settlement have been mixed up in the available survey documents. Collected GPS-data showed that there is indeed some head between source and reservoir tank, but only a few metres difference between reservoir tank and tap stands. It was not possible to make out the reason for the discrepancy. It was speculated, that the exposure to a landslide right above the RVT could have altered the decision where to build the RVT.

Ironically the anticipated landslide occurred just one year after completion of the drinking water scheme and washed away 4 houses. All houses have been rebuilt on higher elevation. The reservoir tank has been partially affected but is still in use without any rework needed.

An irrigation pond has been realised with the help of another Helvetas program. The pond is fed from the same system but has been in poor condition during the visit (plastic lining was torn down, villagers stated not to use it). Still the drinking water system is used for irrigation. One household at the lowest tap stand has started tomato plantation within a plastic greenhouse only two years ago.

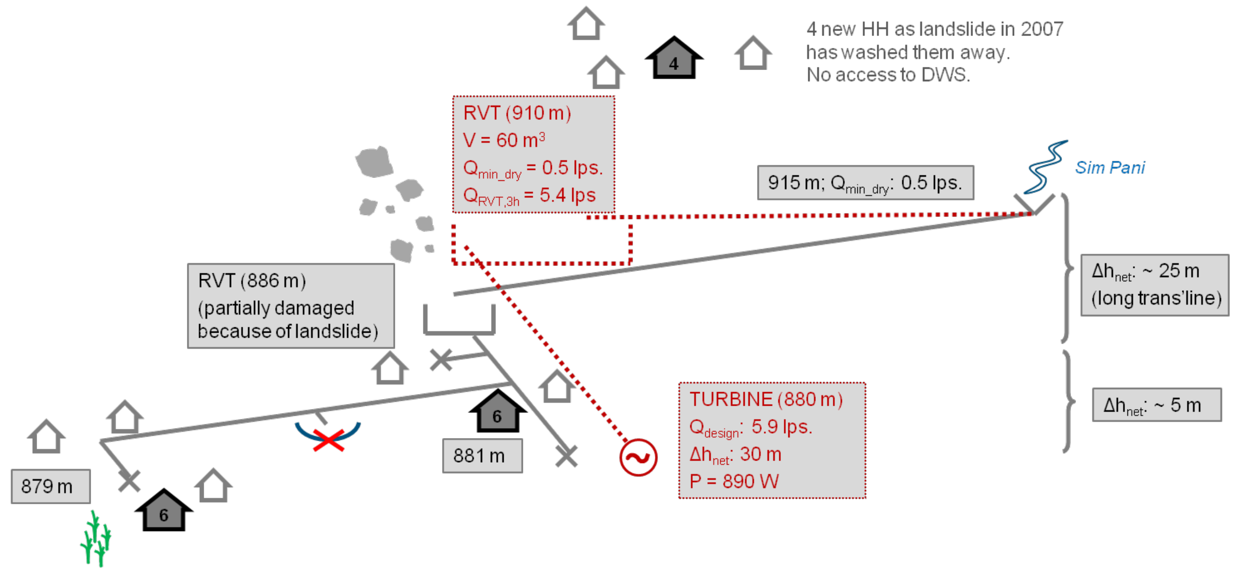
Options for IHP

The lowest households of Khamohale are located on a plateau from where the settlement is distributed along the hill (settlement is relatively widespread). As the perennial source is only a few metres above the main settlement (with new settled houses even above the source) there is little energy available in the system. The necessary power output of 890 W could only be reached if an immense reservoir tank of 60 m^3 was build. The realisation of such a scheme is not recommended, as the respective area is exposed to potential landslide.

Installing the turbine way below the village (Figure 17) is another approach to overcome the lack of head within the settlement (the topography falls right after the last household). This however is not recommended, mainly because water could not be used to irrigate either kitchen gardens or commercial crops nearby the settlement. Plus, as a hydropower plant needs daily management and has to be quickly reached in case of emergency it is wise to place it as close as possible to the settlement.

Concluding it must be said, that the drinking water scheme of Khamohale is not feasible to be combined with a hydropower plant.

Figure 17: Sketch of an IHP scheme (rejected) in Khamohale, Achham district



8.7. Grid designs of visited sites

The design of a mini grid for an IHP scheme does not significantly differ from those of larger grids[29]. Almost all small hydropower plants below 1 MW in Nepal feed a system, which is not connected to the national grid of NEA. Sundar Nepal, which is the regional representative of AEPC, supported the draft of grids for the visited sites and derived the cost calculations.

Sketches of the mini grids for Gadgaun, Bada Awal and Kitu Katuje can be found in the appendix. The grids are designed to deal with a maximum demand of 40 W of each household simultaneously. The main outcomes of Sundar Nepal's calculation are:

- Distribution of electricity is possible on 220 V single phase line with the thinnest conductor available (so-called "Squirrel")
- Poles are made of locally available tree trunks (protected with bitumen paint)
- Voltage drop at the most distant household is less than 2 % (AEPC allows up to 10 %)
- Energy losses are negligible within the grid
- As both voltage drop and energy losses are negligible, there is no need to locate the power house at a certain position (i.e. in the centre of the grid)

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[29] Mini grids in Nepal are commonly fed by small hydropower plants, which are located near a river or rivulet. If the distance between power house and the settlement is too large, it is necessary to transform electricity for transportation (critical for technical sustainability). This is not needed in IHP schemes, as the power plant is within the village and transported power is low (40 W per household).

- Construction of the mini grid can be done by local workers with support of an experienced professional

8.8. Willingness and ability to pay

The assessment of willingness to pay for electricity is a complex task and explicit numbers will never be valid for more than the evaluated village. Still the interviews, which have been conducted in four visited schemes, provide indications on how much future beneficiaries are able and willing to pay for lighting. An overview on the collected data is provided in Table 12.

Ability to pay

The major property of families in rural areas is their house, a shed and both Khet and Bari land. The difference in welfare within the community is articulated specifically in ropani of land the families own. Some own more than they can cultivate by themselves, others don’t possess any land. Cash savings are only existent in very few of the interviewed households. The common way to quickly make cash available is through selling cattle – mainly goats – or by taking loans from local money lenders.

Even though many goods and services are paid in kind, cash money changes hands also in the most remote village that has been visited (Gadgaun). Education and health – at some households amounting to more than NRP 100’0000 annually – are the main cash expenses. Furthermore there are many households, where expenses for alcohol and tobacco reach NRP 5’000 or more per year. Interestingly enough, expenses for health and alcohol/tobacco don’t necessarily correlate with level of welfare of the respective household.

Willingness to pay

Willingness to pay has been assessed through simply asking the head of household, how much he’s ready to spend monthly in order to have light in all rooms of the house. The declared number varied between NRP 25 and NRP 200, while a threshold of NRP 50 was clearly mentioned most frequently. This number is probably influenced by the routine from their existing drinking water schemes. A monthly contribution of NRP 50 per tap stand is commonly asked from the beneficiaries to pay the operator and raise a fund for maintenance and reparation. From an economic perspective willingness to pay should be higher, as many of the interviewees face higher expenditures with their current lighting solutions (battery for torch, depreciation of Solar Set). This however illustrates why models which, strictly follow economic rules will not succeed in finding the true willingness to pay.

Almost all households repeatedly emphasized during the discussion, that they are willing to pay whatever the community decides to be the appropriate. Subsequently it is important, that the monthly contribution is extensively discussed during implementation and that its purpose is clearly communicated.

Willingness to invest

Willingness to invest has not been assessed separately, but numerous Solar Sets show that many families are capable and willing to invest in energy sources for lighting and charging purposes. Whether this is also true for investments into community owned energy infrastructure is questionable.

8.9. Cost Overview

Table 6 provides an overview on the indicative costs of IHP schemes as described in the previous chapter. Numbers have tentative characters as most of them base on rough estimation only. Comments and further information on the respective sources are listed beneath the table (referenced by numbers).

Civil works

Intake and water way to the reservoir tank are assumed as cost related to the drinking water scheme and therefore do not appear here. For Option A in Gadgaun there is no need of investment into a reservoir as the existing RVT is utilized to store the water for 3 h.
Costs for excavation labour and penstock material are average numbers applied by WARM-P to estimate costs of drinking water schemes. In this case the diameters of penstock pipes are relatively large in order to reduce head loss within the system. It could be beneficial to design smaller pipes, which would save costs but raise friction losses (hence further optimization needed for a detailed design study).
Cost indications of power houses have been provided by Sundar Nepal and base on their experience with power plants in mid-western Nepal. Transportation costs are included in the respective cost factors.

Generation

Costs of turbine and generator including all electromechanical and hydraulic devices within the power house are taken from the quotation of Gautam Energy Engineering (valid August 2012). Quotation of KMI, which is another Peltric Set supplier, does not differ significantly (less than 10 %). No transportation costs have been considered as it is expected, that they are covered by AEPC's subsidies (which are particularly provided for transportation).

Distribution and lighting

Design and cost estimation of the mini grid was conducted with the help of Sundar Nepal. Several cost factors, i.e. earthing sets, can be associated with either generation or distribution.
Sundar Nepal and AEPC do not incorporate costs for bulbs as they occur at household levels. Nevertheless they have been considered here in order to get an idea of the overall costs for lighting.

Development

The costs for development of a site, which includes engineering activities and monitoring, could be allocated in different ways. In this case it is assumed that those tasks, which require highly skilled labour, take one week each. Obviously those expenses will be higher in the first projects but then will decrease with additional experience of all involved partners.

Subsidies

Subsidies depend on the number of beneficiaries and installed power output. As AEPC's policy still follows 100 W per household for lighting purposes, the refunded sum is capped (see also comment below Table 6).
Subsidy must not be expected if power output is below 1'000 W, which is true for Bada Awal.
Transportation subsidies are not considered even though they are significant. For this calculation the expenses for transportation are assumed to be at the same level as the subsidies.

Table 6: Salient features and cost overview of 4 virtual IHP projects in three sites (if not specified in NRP)

	Gadgaun		Bada Awal	Kitu Katuje
	Option A	Option B	Option B	Modular
Number of beneficiaries (households)	44 HH	44 HH	11 HH	25 HH
Power output	1'500 W	2'360 W	650 W	1'530 W
Power per HH (hours of operation)	30 W (3 h)	40 W (4 h)	40 W (4 h)	40 W (4 h)
Details				
Gross head / net head	140 / 130 m	140 / 130 m	50 / 50 m	175 / 160 m
Flow	2.3 lps.	3.6 lps.	2.6 lps.	1.9 lps.
Penstock diameter (WARM-P)	90 mm	110 mm	90 mm	90 mm
Penstock length	420 m	420 m	158 m	350 m
Reservoir volume (1)	-	25 m^3	27 m^3	16 m^3
Civil work				
Intake	-	-	-	-
Head race	-	-	-	-
RVT / forebay (1)	-	125'000	113'000	125'000
Penstock (work) (2)	81'000	81'000	30'000	68'000
Penstock (material) (3)	247'000	300'000	45'000	228'000
Power house (work) (4)	8'000	8'000	8'000	8'000
Power house (material) (4)	10'000	10'000	10'000	10'000
Generation				
Peltric Set (5)	80'000	105'000	52'000	80'000
Installation, testing, commission charge (5)	6'000	6'000	6'000	6'000
Hydraulic material (valves, joints, etc.) (5)	44'000	49'000	25'000	44'000
Induction generator controller(5)	38'000	45'000	25'000	38'000
Ballast heater (5)	4'000	6'000	3'000	4'000
Main Switch (5)	4'000	4'000	2'500	4'000
Power house wiring / tool set (5)	18'000	18'000	14'000	18'000
Distribution and lighting				
Conductor / insulator / poles / lighting arrestor (6)	101'000	101'000	32'000	68'000
Earthing Set (6)	9'000	9'000	9'000	9'000
Bulbs (7)	44'000	44'000	11'000	25'000
Development				
WARM-P support (8)	15'000	15'000	15'000	15'000
Survey of HPP and grid (8)	15'000	15'000	15'000	15'000
Design of HPP system (consultant) (8)	15'000	15'000	15'000	15'000
Supervision during HPP realisation (9)	20'000	20'000	20'000	20'000
Supervision during grid realisation (9)	20'000	20'000	20'000	20'000
AEPC Subsidies				
Peltric Set (10)	146'250	230'100	-	149'175
Transportation (11)	-	-	-	-
Cost overview				
Civil work	346'000	524'000	206'000	439'000
Generation	194'000	233'000	127'500	194'000
Distribution and lighting	154'000	154'000	52'000	102'000
Development	85'000	85'000	85'000	85'000
Total investment	779'000	996'000	470'500	820'000
Subsidies	146'250	230'100	-	149'175
Total investment after subsidies	632'750	765'900	470'500	670'825
...per HH	14'381	17'407	42'773	26'833
Annual O&M (4% of investment)	575	696	1'711	1'073

Comments relevant for Table 6

(1) A closed ferro-cement tank is suggested in Kitu Katuje. For Gadgaun and Bada Awal, open tanks are appropriate. Calculation by Mohan Bhatta, WARM-P engineer. Transportation cost included. Community contribution not included.

(2) Cost for excavation for pipe (average in all active districts): NRP 193 per meter.

(3) For this calculation the diameter of the pipes has been calculated by WARM-P team members. It is possible, that diameter and subsequently costs have been overestimated. Prices for pipe material base on the latest quotations from WARM-P suppliers (September 2012).

(4) Labour: 20 days of NRP 400 per day. Material: experience of former projects. Experience of small hydro projects (Sundar Nepal)

(5) Based on quotation of Gautam Energy Engineering. The numbers for Kitu Katuje have been taken from quotation of Gadgaun Option A (respective quotation has not arrived within time).

(6) Calculation by Sundar Nepal

(7) 5 bulbs per household (NRP 200 per bulb)

(8) One week is required, daily work cost: NRP 3'000 (Sundar Nepal)

(9) Two weeks are required, daily work cost: NRP 2'000 (Sundar Nepal)

10) NRP 97'500 per kW are provided if power output is above 1 kW

11) Transportation subsidies have been neglected, as they are not possible to assess without detailed analysis of the transport ways. Anyway the amount of subsidies have to be enquired at AEPC as IHP project probably do not follow the standard procedure.

9. Carbon financing

9.1. Clean Development mechanism (CDM)

The clean development mechanism – defined in the Kyoto protocol 2007 – is one of the systems, which aims to reduce greenhouse gas emissions by means of a trading system. Whereas the European Trading Scheme (EU CES) is limited to European participants, CDM allows trade of emissions between developed (so-called Annex-I countries) and developing countries. The idea: avoiding emissions in developing countries is mostly economically cheaper than avoiding them in an industrialised economy. The value of such certificates follows somehow the European market but will always be below it.

Developer of renewable energy projects can try to qualify their power plant as a CDM project. This requires a complex, administrative effort and is associated with high investment costs. As soon as the power plant runs, it produces emission certificates, which can be sold to improve the financial viability of the project.

There couldn't be found any indication, showing that CDM could support the financial viability of IHP in Nepal. The main reasons are that IHP are geographically scattered and produce little energy. Other reasons are:

- The process to qualify for CDM is complex and costly (at least US$ 100'000).
- Once the plant is registered, a proper data management is crucial as energy production has to be communicated regularly.
- Expenditures and income are not simultaneous in time (sunk investment at start, harvesting and sale of certificates during lifetime of project).
- The amount of awarded certificates depends on the annual energy production. IHPs do not only have comparable low power output (~ 1 kW) but also run for just 4 hours per day. Thus the energy production is less than 20 % of a common run-of-river plant with same power.
- There are no successfully running projects under CDM, which are comparable to hydropower projects in Nepal.
- It is not doable to calculate expected income from CDM without detailed investigations. However, it is possible to use numbers from bordering India to make an estimate of the expected certificate in Nepal. Taking a 1500 W plant as reference, the annually harvestable certificates amount to 2.2.
  If US$ 7 are paid per certificate (the current price ranges way below), the financial contribution from CDM is US$ 15 for a single plant[30].

The above points are in line with experts from an experienced NGO (myclimate) as well as in-house experts. It therefore is not reasonable to qualify IHP for CDM (even if projects are bundled).

9.2. Programme of Activities (PoAs)

Programme of activities is a simplified modality to develop projects under CDM. It has been set up to support small projects with scattered project area (i.e. city-wide efficient lighting program, national incentive program to switch inefficient industrial boilers, etc.).

Even though processes to qualify for CDM are simplified under PoA and regulatory risks are somehow lowered, there is little chance for IHP. Expected number of plants cannot be compared "to the number of bulbs in a whole city" and annual energy output is small.

9.3. Payment for environmental services (PES)

Payment for environmental services (sometimes also payments for ecosystem services) stands for a mechanism, where owners of a natural resource pay someone to preserve or improve the respective resource (i.e. the subsidies, which are received by Swiss farmers, which are then obliged to cut their grass only after a certain date).

There is no international standard to set up PES and there is currently no such system in Nepal at all (Dr. Bharat Pokharel, June 2012). As PES require a properly working governmental body, it is not reasonable to expect it in close future in Nepal.

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[30] Detailed calculations can be found in: Calculation details of annual income from CDM, at page 23

10. Technical feasibility of IHP

Technically there is no reason, why small hydropower plants could not be combined with drinking water systems in rural Nepal. Inline hydropower schemes do not fundamentally differ from common micro hydro schemes. They are just comparably smaller and additionally use parts of the infrastructure for two purposes – for drinking water provision and electricity production.

Synergies

Synergies are limited with regard to infrastructure that is collectively used. Only the intake construction and the waterway from intake to reservoir are reasonable to be used collectively. The required reservoir volume for hydropower exceeds the need for drinking water by far. As a consequence of this, two reservoirs are necessary in most of the cases – an open tank for hydropower and a closed tank for drinking water.

The lifetime of tap stands and other hydraulic material depends on the pressure they are exposed to. DWS typically are designed in such a way, that only a residual head of 5 m is applied on tap stands. This contradicts with preconditions that are required for hydropower, where head is aimed to be as high as possible. Out of four visited sites there is only one site, where waterways after the reservoir are reasonable to be collectively used (Kitu Katuje). It is expected, that the penstock in most of the feasible sites cannot be used to convey drinking water to the point of use.

Site feasibility

It is useless to propose a fixed number of head and flow that is required for a site to be IHP feasible. The technical feasibility depends on various factors like topography, distance between source and point of use, number of beneficiaries; hence feasibility must be assessed individually for every site. Nevertheless it can be said, that sites with discharge below 0.75 lps. are very unlikely to be IHP feasible. Those sites require large reservoir infrastructure and subsequently face high costs.

WARM-P supported drinking water schemes in Far- and Mid-West-Development Region have turned out to be characterised by comparably little flow. Assuming a flow-threshold of 0.75 lps., there are 15 % of all schemes which are technically feasible; 10 % of the schemes have a discharge larger than 1 lps..

Statistical analysis of the schemes has shown that almost all sites with high discharge have at least one pressure breaking device. As those devices are only installed within systems with at least 60 m head, this indicates that available head is not a critical issue for IHP feasibility.

Technical solutions

All electro mechanical elements, which are required for an IHP are available in Nepal. Generally turbine manufacturer tend to focus on larger plants and have little interest in selling small devices. Nevertheless two suppliers have been found which are active since long and have good reputation in the hydropower scene. Appropriate lighting solutions being able to deal with low wattage are broadly available in Nepal. It is expected that further innovation will bring cost further down and increase the efficiency.

Spare parts

All proposed turbines are manufactured in Nepal; generators are imported from India or China. Manufacturers of Peltric Sets claim, that they are able to supply spare parts for the whole system within short time only. Still, the sheer availability at manufacturer's place does not guarantee, that required spare parts are at the respective site. The example of Assurani illustrates that communication between user and supplier is a crucial issue. The procedure and channel of communication must be clarified when developing an IHP.

11. Sustainability aspects

11.1. Technical

Sustainability seems to be an issue for small hydro power plants. Even though there are no supporting documents available, this can be clearly stated when travelling through rural Nepal. Assessing sustainability of small hydropower plants is a difficult task as even engaged agencies and organisation have little information of completed schemes. Still there are some aspects, which have to be specifically targeted, when developing an IHP scheme.

Hydraulic system

Infrastructure of an IHP which is collectively used is expected to face less sustainability problems than single use systems. This is particularly true for intake, upper pipe system and reservoir chamber. Landslides are a potential threat. However the experience from implemented drinking water schemes should allow an appropriate design of the waterways. Problems with hydraulic hammer, as found in large hydropower schemes, can be avoided with slowly closing butterfly valves (Sundar Nepal).

Generally it is expected, that a multi-use system adds sustainability to a scheme which previously served only one purpose, as there is additional repair incentive, once it is damaged.

Turbine and generator

Climatic conditions in targeted districts of Nepal are rough and not favourable for both civil infrastructure and electromechanical devices. Changing temperature and high humidity certainly stress mechanical devices and strongly affect their lifetime. The example of Assurani (page 19) shows, that 5 years old schemes already show technical problems, which will worsen if not properly tackled. In order to prevent turbine and electro mechanical parts from difficult climate it is worth investing into a proper power house and to sensitise the future operator in this direction.

Most of the contacted experts, which are experienced in mini grid schemes, state that generator and it’s controller are the first devices to break. Suppliers claim that there are sites, which are in operation for more than 20 years without major repair work needed. Still it is wise not to expect lifespan of more than 10 years for electromechanical devices. After this reinvestments are required.

Grid

Experiences of other mini grid projects in Nepal show, that the grid itself is rarely subject to sustainability problems. The distribution system is relatively simple and could be repaired by the beneficiaries with local material.

Alternative sources for electricity

Chapter 5 lists electrification options for rural villages in Nepal. Two of those options are considered to be valuable alternatives to inline hydropower.

Solar Sets require investment in the same range as IHP and have negligible running costs. The problem of lacking ownership is inexistent as only interested and financial capable household invest. Still Solar Sets face sustainability problems. Many systems are broken after only a few years of operation and the environmental damage is assumed to be immense, once all depleted batteries are dumped into the nearest river.
User’s perception of Solar Sets is diverse. Members of Gadgaun village stated, that their investment into Solar Sets is only aimed at bridging the time until they have in IHP scheme realise.

Arrival of the national grid is another threat to sustainability of small IHP schemes. No initial investment is asked from users, which is a major advantage compared to mini grids. Monthly costs are in the same range if the electricity is used for lighting purposes only. However it is not clear, whether existing beneficiaries abandon a properly working mini grid, only to be dependent on the notoriously unreliable national grid. The site in Sata Khola (see page 19) shows that even systems, which are close to the national grid of NEA can be sustainably operated.

11.2. Financial

Investment

The cost structure of an IHP does not fundamentally differ from a small HPP project in Nepal. The main distinction is the collectively used infrastructure. It is assumed that all necessary investments for DWS are sunk investments and therefore do not have to be incorporated within required expenses for the hydropower part.

The costs of four IHP variants have been calculated under chapter 8.8. Those projects significantly differ from each other with respect to head, flow, number of beneficiaries and social context. Still they provide an indication on the necessary investment and expected operation and maintenance costs.

The IHP options in Gadgaun require investments in the range of NRP 15'000 per household, whereas the necessary investments in Bada Awal amount to more than NRP 40'000. The discrepancy is caused by the economy of scale effect. Particularly costs for development and expenses for generation are not linear to power output.

Per-household-costs in Kitu Katuje are significantly higher than in Gadgaun. As power output of the respective options is in the same range, this indicates that high head sites are comparably more expensive. Definitely this statement has to be verified with further examples but it still can be explained with penstock costs. Costs for pipes heavily depend on the water pressure they can withstand once the power plant is in operation. Subsequently costs for pipe material rise disproportional at high head sites.

Operation and Maintenance

Annual expenditures for operation and maintenance, which includes funding money for replacement of defect devices, range between 3 % and 5 % of the initial investment (Sundar Nepal). For calculations in chapter 8.8 an average of 4 % has been taken into account. The annual costs per household herewith range between NRP 600 to NRP 1'700, which includes a contribution for salary of the plant operator.

Productive End Use

Productive end use is frequently mentioned as a major issue if discussion comes to sustainability of small hydropower schemes. If beneficiaries make use of the electricity in such a way, that they generate additional income, it is commonly called "productive end use".

In the context of small hydropower, productive end use is solely understood in combination with mechanical work. This requires a relatively high power output. In case of AEPC, they additionally subsidize mini grid schemes, where productive end use is possible – but a minimum power output of 10 kW is mandatory. APEC perceives it to be impossible to make any productive end use below this threshold[31].

Power output of 10 kW and therewith mechanical productive end use is out of reach for inline hydropower plants in the assessed context in Nepal. But electricity can be productively used even if it is only sufficient for lighting purposes. It was clearly stated by two households in Gadgaun (see page 20), that if light was available in evening time, they were enabled to sew clothes for sale. Even though those households belong to the lowest caste, they declared to be able and willing to pay significantly more than the commonly mentioned NRP 50 per month.

Mobile charging does not seem to be a promising source of income for rural hydropower schemes. Solar sets are widely spread also in very remote regions. Even though some owners in bazaar areas ask for a small charging fee, this is not the case in the villages itself – the electricity from sun is perceived as being there anyway.

No further mechanisms to productively use electricity from IHP could be identified. Most of the applications either need significant mechanical energy or require warmth (i.e. poultry farming), which again can only be provided by larger power plants.

Willingness to pay and invest

Most households in the visited villages declared that they are able to monthly expend about NRP 50 for lighting purposes only (see also chapter 8.8), which is in the same range as monthly costs for operation and maintenance of an IHP per household. Willingness to invest has not been assessed systematically. Even though there are Solar Sets installed in many households, it cannot be assumed, that every community member is able to afford the necessary investment.

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[31] AEPC experiences that productive end is specifically promising in touristic areas. However hydropower plants in remote areas often fail to use the electricity productively. Until now approximately 25 relevant business plans have been submitted.

11.3. Social

Resource conflicts

The example of Kitu Katuje illustrates a problem, which could be articulated if not only a drinking water but also a hydropower scheme is developed at the same time. In Kitu Katuje the highest household claims exclusive rights on the source, even though it is on common ground. The source is far above the main settlement and previously has only been used by the respective household for both drinking water and irrigation. During the visit, the head of household menaced not to agree with any scheme, if he is not provided with privileges (i.e. infrastructure for irrigation of his paddy as compensation).

Even though there are further conflicts in this specific site, the WARM-P staff does not judge them as critical. It is commonly seen, that there are disagreements between future beneficiaries during the genesis of a drinking water scheme. Normally those issues are discussed within the community until a solution is found, which is viable for all.

Still, taking the specific case of Kitu Katuje as an example it certainly adds tension to the discussions, if the topic of IHP is tossed in during a too early time of development. Drinking water is a basic need, which makes it a bit easier to argue, if someone has to step back from privileges. This might not be true for electricity.

In cases of hardened fronts, it could be wise, to first develop the drinking water system without IHP (even though it is technically feasible). After one or two years, as soon as there is established a certain institutional routine, the village could be approached again and efforts towards realisation of an IHP could be started.

Equity

While developing drinking water schemes, WARM-P is concerned about providing water to every member free from discrimination. Drinking water schemes are community owned and community managed. A private hydropower plant, serving only a few households would be contradictory to this approach and would not be accepted (statement of interviewed households).

However it would be socially viable to implement an IHP in a sub scheme only. Many WARM-P schemes consist of sub schemes, which are technically independent of each other, but share institutional bodies. Members of neighbouring schemes of Bada Awal (page 22) said that it would not be offending, if Helvetas would support the respective system but not their own. If affected communities are openly addressed and properly informed, there are no problems to be expected.

Ownership

Sundar Nepal has experienced that ownership is crucial for sustainability of mini grid schemes. The level of kind contribution during implementation depends on whether the beneficiaries perceive the plant as their own; same is true for proper maintenance of the scheme.

Before starting an IHP project it is important to judge, whether future beneficiaries have developed a sense for ownership or whether the initiative is coming from outside and does not target their actual needs. Ownership can be raised with efforts towards awareness building, i.e. sensitizing parents for their children's need of doing homework or for the advantage they have with smokeless lighting sources.

Experiences during field visits have been different from site to site. The motivation in Gadgaun was very proactive whereas some exponents in Bada Awal said that they rather expect electricity from the government, than from their own initiatives.

Another aspect that raises ownership is imitation (which for example enhanced the penetration of Solar Sets). IHP feasible sites are rare and it is not likely that two sites are located next to each other. Members of promising villages therefore have to be targeted from outside, as it is improbable that they start own initiatives towards an IHP.

Cultural reluctance towards IHP

All interviewed households have been asked, whether they would drink water which formerly has gone through a turbine – answers were positive throughout. As long as there is no contamination from turbine or other infrastructure, no reluctance is to be expected from future beneficiaries. Water for religious activities is often collected from sources other than the one which feeds the drinking water system.

Migration

Assurani faces problems augmenting its fund for operation and maintenance (see page 19) while the population has significantly decreased since implementation of the scheme. More than 30 % of the village's households have migrated to lower areas during a few months per year and therefore don't contribute the initially fixed monthly sum.

Varying user numbers are an imminent problem for hydropower schemes and are basically not possible to overcome. However it is possible to develop a site stepwise as for example suggested in Kitu Katuje (see page 23).

11.4. Institutional

Legal

Under the current national hydropower development policy, there is no licence required for plants below 1'000 kW. The same is true for national taxes[32]. As IHP will only be developed based on an existing WUMP, issues on local water rights are not expected to arise during implementation (as this is part of the WUMP formation)

Institutions

Drinking water related decisions are usually made by the user's committee, which are preconditioned in every WARM-P supported drinking water scheme. It is reasonable to administer an IHP scheme with the same well established institutions, which represents the village's inhabitants. Decisions to be made basically include the determination of monthly contribution, daily time of operation and maximum wattage to be consumed by every household.

Technical maintenance of drinking water schemes is carried out by a so-called village maintenance worker. Extensively trained by WARM-P, the village maintenance worker is responsible for properly maintaining the system and carry out necessary reparation.
It is reasonable to assign tasks related to operation and maintenance of the hydropower plant to the same village maintenance worker. Both contacted turbine manufacturers offer respective trainings, which enable the trainee to successfully run their plant.

Foresight

All visited sites with drinking water schemes had stopped raising funds for reparation – they only contributed a reduced sum to pay the village maintenance worker. The rational for this was simple; they augmented a fund in the first few years but could not see any application for the respective money (as the new system was properly running). However at a certain point they lost incentive to put money aside as there was no immediate demand for it.

Lack of foresight of beneficiaries clearly is a sustainability issue for drinking water systems and even more is expected to be a sustainability issue for IHP. Some electromechanical parts have to be replaced after only a few years of operation. It is crucial that beneficiaries are sensitized towards the need of funding money to repair or replace these devices in order to keep the system operating.

11.5. Knowledge

Implementation

The WARM-P team should be enabled to conduct pre-feasibility assessments of drinking water schemes with the help of the generic guideline in the annex of this report. However if there are clear indications that a site is feasible for IHP, it is wise to collaborate with experienced partners (i.e. Sundar Nepal). Especially all issues related to electro-mechanical devices (turbine, generator, grid, etc.) should be consulted with respective experts.

Operation

All components of a mini grid system can be locally maintained, both contacted suppliers of Peltric Sets confirm. An extensive training enables the respective person to properly operate the system and also provides the expertise to judge whether broken parts can be repaired or need replacement.
Hydropower plants are significantly more complex and fault-prone than drinking water schemes. An unambiguous communication channel should be established, through which the plant operator can request for support, in case of problems.

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[32] The Hydropower Development Policy, 1992/2001, Singhadurbar, October 2001 (His Majesty's Government Ministry of Water Resources)

11.6. Environment and health

Drinking water safety

All contacted turbine manufacturer confirmed that their systems either are already safe do be used within drinking water or could be adopted without major effort (galvanization of parts which are in contact with water). This anyway is only an issue if the plant is realised within and not at the bottom of a drinking water scheme.

Lightning

There are reports of lightning incidents in Nepal, which have destroyed whole mini grid schemes. According to Sundar Nepal, this problem has been tackled and solved with the help of improved lightning arrestors. However, as those lightning arrestor consist of large amounts of copper, they have been subject to thievery or were just “forgotten” to be installed. It must be assured, that those devices are in place before starting the system.

12. Conclusion and recommendations

12.1. Conclusion

Combination of rural drinking water schemes and hydropower is technically possible. Upscaling potential limited.

The preconditions for hydropower schemes particularly differ from drinking waters schemes in terms of necessary flow. Statistical analysis indicates that approximately 10 % to 15 % of the DWS realised by WARM-P have enough perennial source discharge to make a combination with hydropower feasible. Respective hydropower plant manufacturer are able to supply customized hydropower systems and assure availability of spare parts after sale.

As a consequence of low perennial source flow, the available power output is not sufficient to satisfy any other end use than lighting and charging services. However, energy efficient lighting devices are locally available. 40 W are stated to be the targeted power supply per household and should enable illumination of the whole house including yard (minimum: 20 W).

Individual feasibility

The feasibility of a site depends on various factors and cannot be assessed from salient features only. A proper assessment includes consideration of topography, available energy in relation to number of households, indication of ownership of future beneficiaries and many more. For this report only four sites have been assessed in detail – all results must be understood in this context.

Limited synergies

The motivation to combine two applications within one scheme clearly comes from the idea to share infrastructure and use further synergies. For the case of rural drinking water schemes in Nepal, it turned out, that only few parts of the necessary technical infrastructure are viable to be collectively used (intake and upper waterway). Reservoir and penstock, which both represent significant cost factors, cannot be shared in most cases.

However institutional synergies during implementation and operation are expected. Especially survey, design, awareness building and other activities during implementation of both applications do partially overlap and allow usage of synergies. The same is true, once the scheme is in operation – maintenance and operation can be done by the same person in charge.

Sustainability issues

Lack of ownership has turned out to be the major risk of failure for mini grid schemes in Nepal (Sundar Nepal). Similar experiences have been made with drinking water schemes supported by WARM-P. It is possible but not very probable, that the combination of two applications raises ownership and therewith sustainability. However as this problem is identified it is worth focusing on it during implementation.

Technical wise, all electronic devices, including generator and electronic load controller, are generally weak spots of a hydropower system. It is therefore all the more important to properly train respective operators and establish efficient communication channels.

Cost aspects

The cost structure for IHP does not significantly differ from larger hydropower schemes, as only a small part of the infrastructure is collectively used. Necessary investments are expected to range between NRP 15'000 and NRP 25'000[33] per household, which is comparable to those of Solar Sets. Monthly expenditures for maintenance and operation are roughly estimated to be at the range of NRP 50 to NRP 100, which is within the willingness to pay of villagers.

The required investments per household are expected to majorly depend on two factors; number of households and available head within the system. Costs for most of the required infrastructure are subject to a strong economy of scale effect; required investments per household fall, with larger systems and growing numbers of beneficiaries.
As expenditures for piping material rise over proportional with growing pressure resistance, it is beneficial to have a site with high flow rather than a site with high head.

Carbon financing

The size of inline hydropower plants in rural Nepal is too small as those schemes could qualify for any carbon financing program. Neither clean development mechanism (CDM), the program of activities (PoAs) nor payments for environmental services (PES) are suitable for those schemes.

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[33] Those investments reflect the additional costs only (without investements for DWS)

Inline hydropower in Switzerland

Inline hydropower seems to be a success in Switzerland. However the situation in the two countries is different with respect to two factors. First of all, there is no site developed where expected power output is below 10 kW, as smaller systems would not be financially viable. Secondly, the energy production cost of IHP in Switzerland is way higher than the actual energy value. Nevertheless the systems are heavily subsidized, as they are perceived to produce energy of high ecological value.

12.2. Recommendation

Approximately 10 % to 15 % of WARM-P drinking water schemes fulfil basic technical requirements to be theoretically feasible for IHP. The actual feasibility, which includes financial and social aspects, could not be assessed quantitatively but is expected to be lower. Bearing in mind that WARM-P annually realises about 25 schemes, it is fair to assume that no more than one or two IHP schemes could be realised with current resources.

Three recommendations are made based on the author’s experience during this assignment.

1. There is no reason to immediately invest into building up hydropower capacities within the WARM-P team.
   Pre-feasibility checks, which allow a preliminary assessment of drinking water schemes, can be done based on the generic draft. Once the site is judged to be promising for hydropower, it is necessary to collaborate with experienced agencies and consultants.

2. Initiation of a promising site in order to gain experience.
   Development of a site helps to test the results of this study and could point out the difficulties to combine the two purposes. Expected results are:

   - detailed information on costs, especially those, which could only roughly be rated (cost for development, awareness building, management)
   - procedure and amount of subsidies
   - time requirements from first idea to realisation
   - identification of main hurdles and obstacles

   The respective site should be developed with support of Sundar Nepal and an experienced engineering company. If it turns out to be a success, the scheme clearly can serve as a flag-ship project for promotion of Helvetas’ WARM-P program.
   Of the four visited schemes, Gadgaun is the most feasible site, as it comes with the most favourable preconditions in terms of energy and ownership of village inhabitants. Gadgaun however is located in Doti district, which currently does not belong to the target districts of WARM-P.
   The topography of Kitu Katuje in Pipalkot VDC is highly feasible and should be taken into consideration as second priority. At this time the WUMP in Pipalkot is under development and there are source conflicts to be solved before starting any initiatives towards an IHP.

3. Collect information on sustainability of conventional mini hydro schemes in Nepal.
   All hydropower involved agencies, NGOs or manufacturers stated that a majority of their schemes are successfully operating. None of the organisations had numbers or reports to support those statements.
   The author of this report believes that there are sustainability problems, but they are not disclosed (because none of the involved parties has interest in publishing them and therewith compromising its business).
   Unfortunately AEPC has not signalized to disclose information in this direction. Still it is worth assigning a WARM-P team member to reserve one to two weeks for further investigations in this direction.

13. Acknowledgement

I'm grateful to the whole Helvetas WARM-P team which not only supported me with regard to the actual assignment but also put an effort to make our time in Surkhet a good time. Special thanks go to Madan Raj Bhatta, Mohan Raj Bhatta, Bikram Rana Tharu and Prakash Ayer. But above all my deepest thanks yields to Brigitte Landolt my dear partner, which has accompanied me during the whole mission.

The below list – of course incomplete – includes those, who have contributed to this report.

Agnes Montangero - Alex Zahnd - Anup Rana - Bal Kunwar - Bernhard Hiller - Bhim Malla – Brigitte Landolt - Jürg Merz - Lea Zanola - Marc Müller - Martin Bölli - Martin Dietz - Martin Mächler - Max Ursin - Niraj Acharjy - Reinhold Metzler – Robert Gröli - Sanjay Nidhi – Thakur Thapa - Thomas Finsterwald

Moritz Güttinger
Surkhet, September 2012

Annex

A.1 Lighting solutions available in Surkhet in September 2012

Table 7: Lighting solutions available in Surkhet bazaar in September 2012

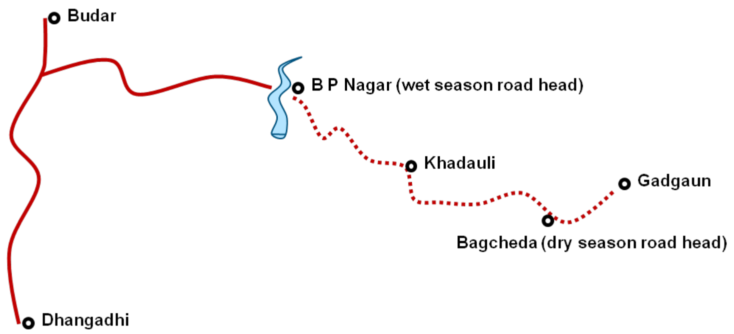
Category of bulb		*Suppliers*							
Wattage	*Type*	*Jwala trader*		*Manikej*		*Himalayan trader*		*Bheri bijuli*	
		NRP	*Producer*	*NRP*	*Producer*	*NRP*	*Producer*	*NRP*	*Producer*
1	LED	200		360					
2	LED	250		360					
3	LED	275		360					
5	CFL	150	premire			190	Euro	250	Himstar
7	CFL	150	premire					252	Himstar
9	CFL	150	premire	210	powerpack	210	Euro	280	Himstar
10	CFL	150	premire						
11	CFL	150	premire	230	powerpack			280	Himstar
15	CFL	160	premire	250	powerpack	250	Euro	300	Himstar
18	CFL	160	premire			320	Euro	370	Himstar
20	CFL	160	premire	320	powerpack				
22	CFL	160	premire			340	Euro		
23	CFL			360	powerpack			390	Himstar

Note: Though rates are included, LED bulbs have not been available in Surkhet market in September 2012, but could be obtained on pre-order.

A.2 Details of sites visited

Gadgaun

Figure 18: Location of Gadgaun, Lanakedareswor - 6, Doti district



MONSOO SEASON	**Dhangadhi > B P Nagar:** Vehicle: 4 h	**B P Nagar > Khadauli:** Trekk: 5 h	**Khadauli > Gadgaun:** Trekk: 7 h
DRY SEASON	**Dhangadhi > B P Nagar:** Vehicle: 3 h	**B P Nagar > Bagcheda** Vehicle: 3 h	**Bagcheda > Gadgaun:** Trekk: 3 h

Figure 19: Existing Drinking Water Scheme in Gadgaun (44 HH)

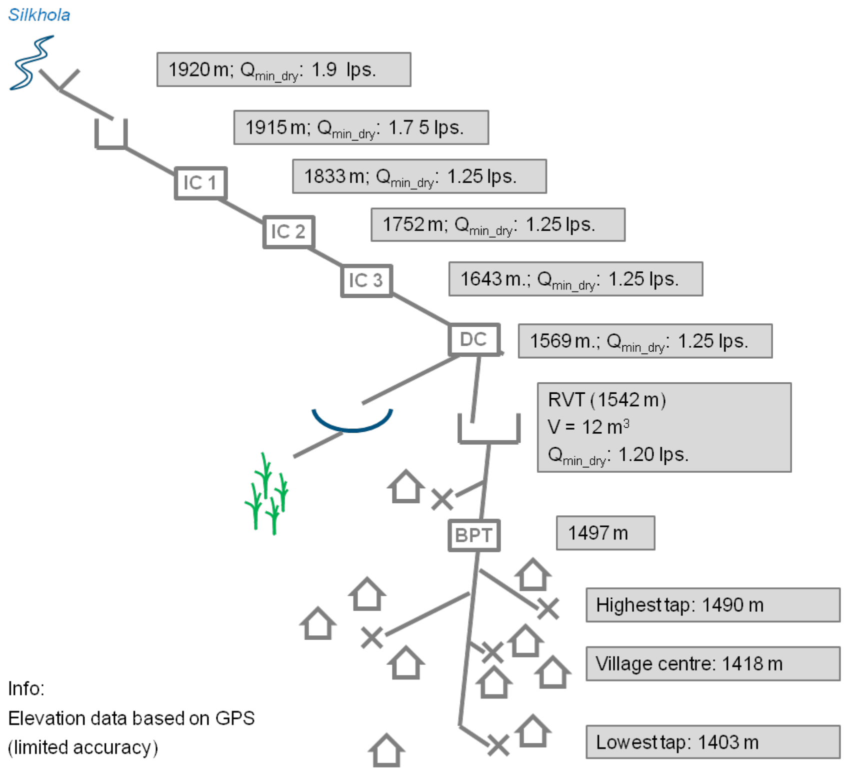
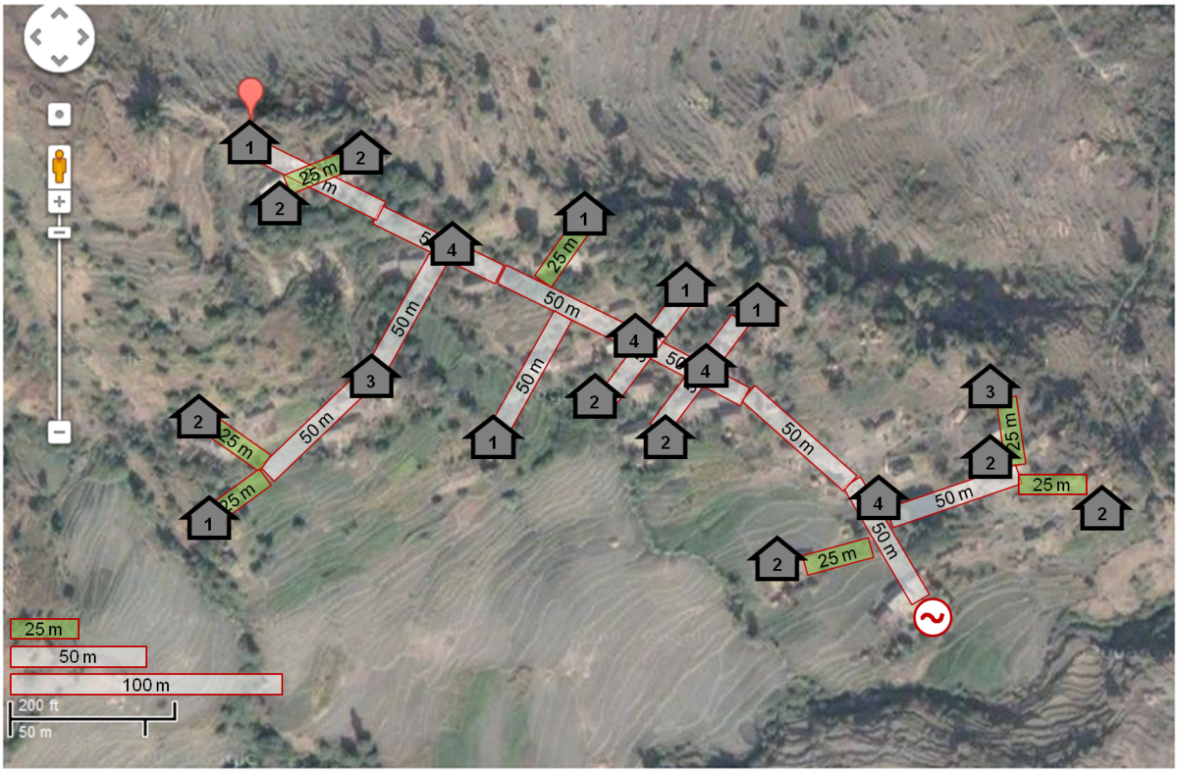


Figure 20: Schematic design of suggested mini grid in Gadgaun



http://maps.google.com/maps?hl=en&q=29.055000N,+80.938333E&bav=on.2,or.r_gc.r_pw.r_qf.,cf.osb&biw=1051&bih=633&um=1&ie=UTF-8&sa=N&tab=wl

Table 8: Option B for IHP at Gadgaun village

Synergies	
Shared infrastructure	*Intake, transmission line*
Additional infrastructure	*Transmission line (partially), forebay, penstock, HPP, wiring*
Salient features	
Power output (head & discharge)	*2'360 W (130 m, 3.6 lps.)*
Daily hours of operating	*4 h*
Power per HH	*~ 40 W (totally 44 HH)*
Charging station	*200 W*
Losses	*20 % (unqualified assumption)*

Bada Awal

Figure 21: Option A (rejected) in Bada Awal

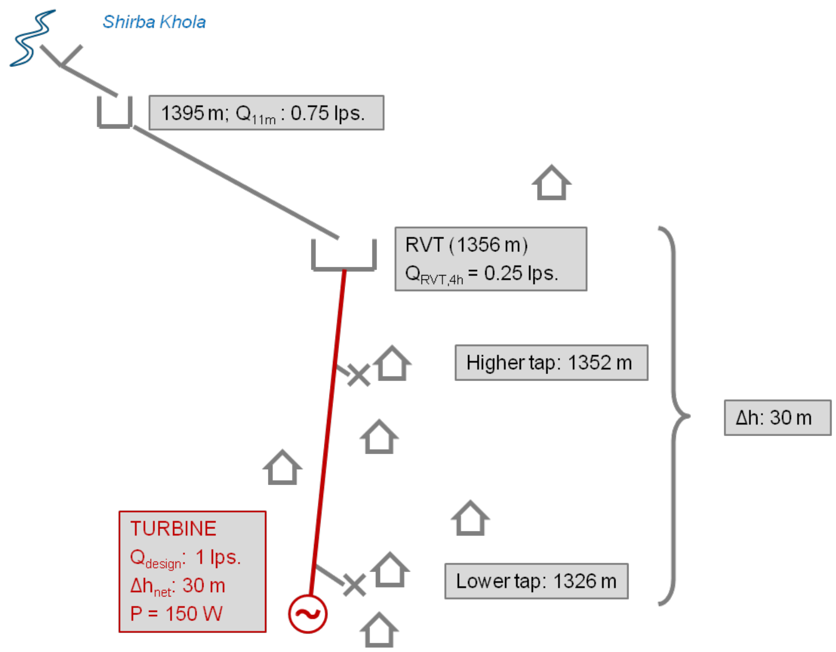
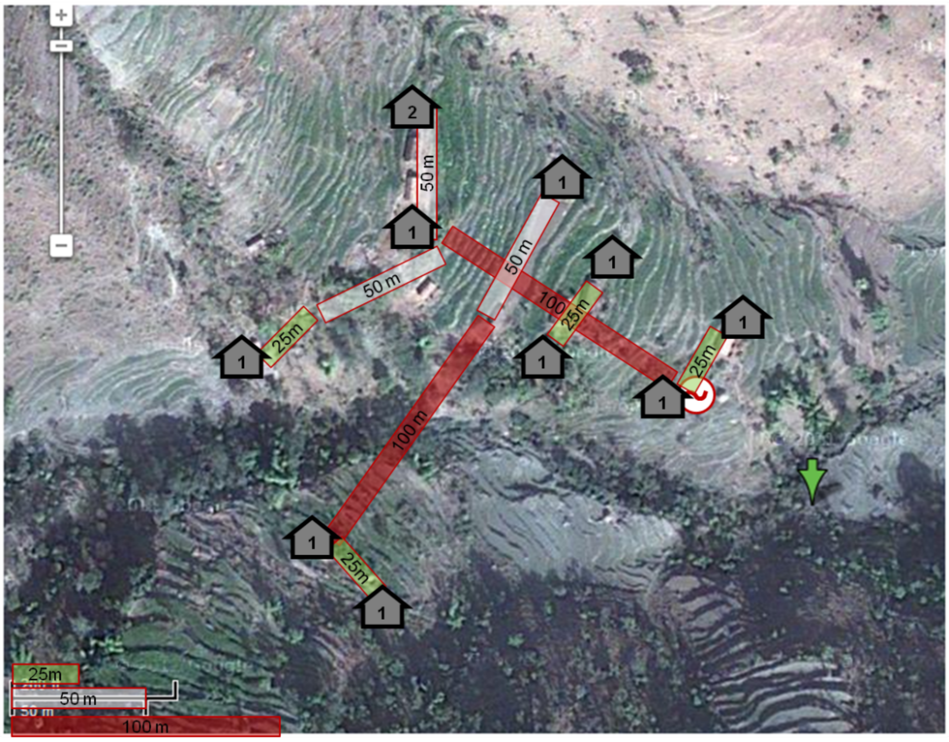


Figure 22: Schematic design of suggested mini grid in Bada Awal



http://maps.google.com/maps?hl=en&q=28.666667N,+81.750000E&bav=on.2,or.r_gc.r_pw.r_qf.,cf.osb&biw=1051&bih=633&um=1&ie=UTF-8&sa=N&tab=wl

Table 9: Option B for IHP at Bada Awal village

Synergies	
Shared infrastructure	Intake
Additional infrastructure	Transmission line, forebay, penstock, HPP, wiring
Salient features	
Power output (head & discharge)	650 W (50 m, 2.3 lps.)
Daily hours of operating	4 h
Power per HH	~ 40 W (totally 11 HH)
Charging station	100 W
Losses	20 % (unqualified assumption)

Kitu Katuje

Figure 23: Schematic design of suggested mini grid in Kitu Katuje

http://maps.google.com/maps?q=29.1001667N,+81.525E&hl=en&ll=29.098965,81.523404&spn=0.021749,0.038581&sll=29.055,80.938333&sspn=0.348135,0.617294&t=h&z=15

Table 10: Option for IHP in Kitu Katuje village (Pipalkot VDC, Dailekh district)

Synergies	
Shared infrastructure	Intake, transmission line, forebay, penstock
Additional infrastructure	Distribution lines need pipes of higher pressure resistance (which are more expensive), HPP, wiring
Salient features	
Power output (head & discharge)	1’530 W (160 m, 1.9 lps.)
Daily hours of operating	4 h
Power per HH	~ 40 W (totally 25 HH)
Charging station	200 W
Losses	20 % (unqualified assumption)

Khamohale

Table 11: Option for IHP in Khamohale village (Chalsa VDC, Achham district)

Synergies	
Shared infrastructure	Intake
Additional infrastructure	Transmission line, forebay, penstock HPP, wiring
Cost	
No detailed cost estimation has been done, as site is not feasible for IHP. To reach the necessary power output of 890 W, a reservoir tank of 60 m^3 volume had to be built. The same area is exposed to a potential landslide.	
Salient features	
Power output (head & discharge)	890 W (30 m, 5.9 lps.)
Daily hours of operating	3 h
Power per HH	~ 40 W (totally 16 HH)
Charging station	100 W
Losses	20 % (unqualified assumption)

A.3 Collected field data

Table 12: Overview on collected data during field visits. The interviewee's statement are made within a specific context, numbers must therefore not be used out of this context.

ID	Village	Date	Khet	Bari	Cash Saving	Income Source	Income Amount	Depts	Health costs	Education costs	Alc./Tobacco costs	Solar Invest	Since	Problem	WTP	Mobile Phone	Cost	Since
GG01	Gadgaun	12.07.2012	2	1	1'000			2'000	2'000	2'000		13'000	2012	charging	100	Head of HH	4'000	2012
GG02	Gadgaun	12.07.2012	1	2		India	8'000		20'000	none		5'000	2012	no	50	Head of HH	4'800	2012
GG03	Gadgaun	12.07.2012	2	2						10'000				bigryo	50	Father & Son	6'000	2012
GG04	Gadgaun	12.07.2012	5	5					500	5'000					100	Son in India		
GG05	Gadgaun	12.07.2012	0	0		Road constr	18'000	100'000		5'000					50	Son in India		
GG06	Gadgaun	12.07.2012	1	0	8'000	sewing	70'000	15'000	200	5'000						Son		
GG07	Gadgaun	12.07.2012	1	1				8'000	10'000						50	no		
GG08	Gadgaun	12.07.2012	3	4	10'000	teacher	30'000	8'000	15'000	20'000		13'000	2011	no	100	3 members	4'000	2011
GG09	Gadgaun	12.07.2012	2	1	-			8'000				13'000			50	2 sons		2012
GG10	Gadgaun	12.07.2012	0	0.5												no		
B01	Bada Awal	20.07.2012	1.5	2.5		India	10'000		40'000	12'000	3'600	12'000	2007	no	50	3	2'000	2010
B02	Bada Awal	20.07.2012	1	2		India	10'000	5'000	1'200	8'000	6'000	10'000	2011	no	50	1		2008
B03	Bada Awal	20.07.2012	2	4					4'000	8'000	5'000	14'000	2012	no	25	no		
B04	Bada Awal	20.07.2012	1	2		India	10'000	25'000	16'000	20'000	5'000	14'000	2012	no	100	2	3'500	2011
B05	Bada Awal	20.07.2012	0	2		India	26'000	40'000	5'000	7'000	15'000	14'000	2011	no	60	no		
P01	Kutu Katuje	08.08.2012	9	9	-	Milk	30'000	50'000	200'000	120'000	-	10'000	2009	no	60	1	3'000	2011
P02	Kutu Katuje	08.08.2012	1.5	3	-	"no income"		-	-	-					15	no		
P03	Kutu Katuje	08.08.2012	2	5	-	"zero"	-	30'000	-	1'000					60	no		
P04	Kutu Katuje	08.08.2012	0	0	10'000			10'000	6'000	6'000		2'600	2011	no	300	1	6000	2011
(P05)	Kutu Katuje	08.08.2012																
P06_spare	Kutu Katuje	08.08.2012	14	0		Sale of Cattle	10'000	35'000	-	10'000	7'000	13'000	2007	bigryo	100	2	2'500	2009
KH01	Khamohale	10.08.2012	5	2	-	India	40'000	100'000	20'000	-	-	2000 (subs)	2010	no	50	no		
KH02	Khamohale	10.08.2012	2	2	-	India	40000	25000	50000	12000	6000				200	1	4000	2012
KH03	Khamohale	10.08.2012	3	2	-	Veget. & Ghatta	35'000	30'000	60'000	14'000		12'000		no	200	no		

A.4 Material and labour cost

Table 13: Cost for penstock material and excavation labour based on information of WARM-P team September 2012

Pressure kg/cm2	Outer Diameter mm	Cost NRP/m
HDPE 4	90	250
HDPE 4	110	350
HDPE 6	90	350
HDPE 6	110	520
HDPE 10	90	524
HDPE 10	110	773
GI pipe	90	1107
1m of excavation for pipe (NRP/m)		193

A.5 List of contacted manufacturers, advisors and agencies

Table 14: Overview of manufacturers and turbine solutions

	NEPAL YANTRA SHALA	KATHMANDU METAL INDUSTRIES	MANIKEJ	DLLD, imported by WATT & VOLT	GAUTAM
	Patan, Kathmandu	Kathmandu, Bhaktapur	Surkhet	Kathmandu	Butwal
Flow	min: 3 lps.	0.5 - 6 lps.	1 lps.	3 - 4 lps.	0.7 - 2 lps.
Head	min: 50 m	20 - 200 m	20 m	10 - 15 m	20 - 200 m
Turbine	Pelton (bronze or cast mild steel)	Pelton (Δh < 80m: aluminium, Δh > 80m: bronze)	Pelton (plastics)	Turgo (plastics)	Pelton (metal and plastics)
Power	1 - 5 kW	600 W - 5 kW (down to 100 W)	100 W	200 W	100 - 500 W (Fam. Set) 1 - 5 kW (Peltric)
Prices (w/o VAT)	1 kW: NRP 95’000 5 kW: NRP 205’000	600 W: NRP 60’000	NRP: 15’000	NPR: 40’000	100 W: NRP 16’000 500 W: NRP: 32’000
Weight		30 kg, can be dismantled	< 10 kg	< 5 kg	~ 20 kg
Guarantee		1 year, bring-in		spare parts available (orally confirmed)	1 year
Statement	focused on larger units, annual output: 3-5 sets	experienced supplier annual output: 100 sets	poor reputation	Maintenance work difficult as know-how abroad	about 200 of these “Laltin & Family” have been sold till now

Nepal Yantra Shala

Founded in 1976 with strong bounds to Switzerland, NYS is one of the most experienced manufacturers in Nepal. The power output of their (predominantly crossflow) turbines ranges from 1 to 100 kW. Peltric Sets are offered but only 1 – 5 sets are sold annually.

As minimum flow of their smallest system is at 3 lps. and as NYS has a clear focus on larger units, they are not listed as promising suppliers of plants for drinking water schemes.

Manikej Energy, Surkhet

Manikej is a local supplier of electrical goods in Surkhet (Birendranagar). He gave a quick presentation of the 100W-device on 26th of April 2012 (turbine not in operation). Runner and generator are fixed on the same shaft, no electronic controller or ballast heater is installed. The robust casing with inlet pipe and nozzle are locally manufactured, runner and generator are imported from India.

Figure 24: Pictures of Manikej's hydropower solutions

Experience

According to the supplier, there are a few sites, where the power plant runs successfully (but he could not make precise statement of the exact place). Manikej has a poor reputation in the hydropower sector (customers and advisors say); no cooperation is recommended.

Watt & Volt, Kathmandu

Imports, sells and maintains electrical goods in Kathmandu. They import a small 200 W plant from a Chinese entrepreneur who runs a factory in Vietnam (DLLD). Documents which can be found on internet indicate, that DLLD is only producing in China, but W&V representative confirmed that they are importing from Vietnam.

The system (turbine, generator, load converter) arrives as one unit; no further assemblage is done by Watt & Volt. An electric ballast heater is installed within the turbine casing, to divert the surplus energy.

Experience

Watt & Volt offers the 200 W device since one year. After-sales services are not provided, thus they are not in contact with buyers and neither do know where the plants are installed. Responding to the question, whether spare parts are available, they said that there is no demand until now, but confirmed that spare parts are available from manufacturer.

Figure 25: Pictures of Watt & Volt's hydropower solutions

Contact

Mr. Buskar (junior), Dillibazar, Kathmandu, +977 1 4411330 / 4429330, watt@ntc.net.np

Centre for Rural Technologies Nepal, CRT

Figure 26: Pictures of CRT's hydropower solutions

Contact

Lumin Kumar Shrestha, Director of CRT, lumink@crtnepal.org, +977 15537556

MD Engineering

MD Engineering is a distributer of Peltric-sets in Kathmandu. According to their sales agent, MD Engineering only assembles equipment based on the customer's specification. The company cannot be found in the list of recommended HPP manufacturer published by AEPC.

MD engineering has realised "a lot of schemes" (Surya Neupane) in the districts around Kathmandu but also in western parts of Nepal.

Contact

Surya Neupane, naupanesurya17@yahoo.com, +977 9849955039

Sridhar Devkota

Sridhar is a veteran in the small HPP business. He held several management positions in various organisations in the small hydropower sector. Being retired now, he didn't seem very interested in any collaboration with Helvetas.

Contact

Sridhar Devkota, sridhar.devkota@gmail.com

Bhim Malla, Advisor

Bhim formerly a staff member of RVWRMP also worked for the UMN, he has started his own advisory business. Bhim has sound experience in the small hydropower sector and knows well which manufacturer is reliable and which has to be considered doubtful.

His main statements are:

- KMI / Nakarmi is an experienced company, which especially is a good choice if new solutions have to be designed.
- Gautam Energy Engineering produces high quality goods. His strength more lies in marketing than in developing new plants.
- Bhim does not recommend collaborating with Manikej, Surkhet. Manikej has only little experience in small hydropower and rumour has it that he has not always been correct.
  This statement is in line with the experience that has been told by the representatives of Kadoorie. Manikej has not delivered the improved water mill to their satisfaction and now has to rework the order.

Contact

Bhim Bahadur Malla, bhim.malla@gmail.com, +977 14104217, +977 9808241020

Household Energy Network (HEDON)

HEDON is a UK based knowledge sharing and networking NGO. Focusing on household level energy solutions in developing countries, they maintain an informative website with recent information on the hydropower sector in Nepal.

Contact

http://www.hedon.info/Micro-hydroDevelopmentInNepal?bl=y

Kadoorie Agricultural Association British Gurkhas Nepal KAABGN

KAABGN is the Nepal field team of Kadoorie Charitable Foundation, which is funded by Ghurka Welfare Trust (GWT). Their activities aime to support ex Ghurka soldiers and their relatives; hence they operate in the district where these soldiers are recruited from. Amongst others KAABGN runs a program which implements micro hydropower plants. The power output of the supported schemes generally ranges between 5 kW and 100 kW[34]. They have not realised schemes where drinking water is combined with electricity production.

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[34] Kadoorie also promotes improved Ghattas and is therefore in contact with Manikej Energy.

Contact

Contact Person: Major Judbahadur Gurung: +977 9804132238, judgurung@hotmail.com, www.gwt.org.uk

Rural Integrated Development Services Nepal RIDS

The NGO's activities in three VDCs of Humla district cover four main issues: drinking water, pits, improved cooking stoves and lighting. Besides several hundred PV sets they have also supported a small hydropower plant in Kholsi. At this site RIDS implemented LED lighting systems, which only need a few Watt per bulb. Three bulbs per HH were given and according to a RIDS-program manager, the whole scheme is still in good condition after being in operation since December 2006.

Lighting solutions

Figure 27: Lighting solutions developed and implemented by RIDS. Power demand 2,4 W (round), 1.8 W (longish).

Contact

www.rids-nepal.org,

A.6 Calculation details of annual income from CDM

i. CDM hydro projects in India receive between 0.8 CER and 1 CER per 1 MWh (depending on which grid they feed[35]).
Assumption is made that a hydropower project in Nepal receives 1 CER per MWh.

ii. Value of European emission reduction Future at EEX is comparable low and currently[36] traded at around 3 €/tonCO_2 (1 tonCO_2 is equal to 1 certificate). The value of CDM certificates is always below European certificates. But as markets have been higher in previous years, the number of US$ 7 per certificate is still widespread in literature. Hence for this estimation US$ 7 is taken as reference.

iii. For IHP in the context of Nepal, the power output of a single IHP is set at 1'500 W. It is assumed that the plant runs smoothly all year round with operating hours of 4 h/d (annual hours of operation: 1460 h/a). This results in an annual energy production of 2.2 MWh for a single 1.5 kW.

iv. 2.2 MWh are equal to 2.2 certificates (see i.). If those certificates can be sold at US$ 7, income of US$ 15 can be expected per year for every IHP.

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[35] Strengthening the CDM capacity in Orissa, Climate Change and CDM, Ashok Kumar Singha Managing Director-CTRAN Consulting

[36] 2.9 €/ton$CO_{2,}$ European Energy Exchange EEX, 15.08.2012

A.7 “Generic Design”

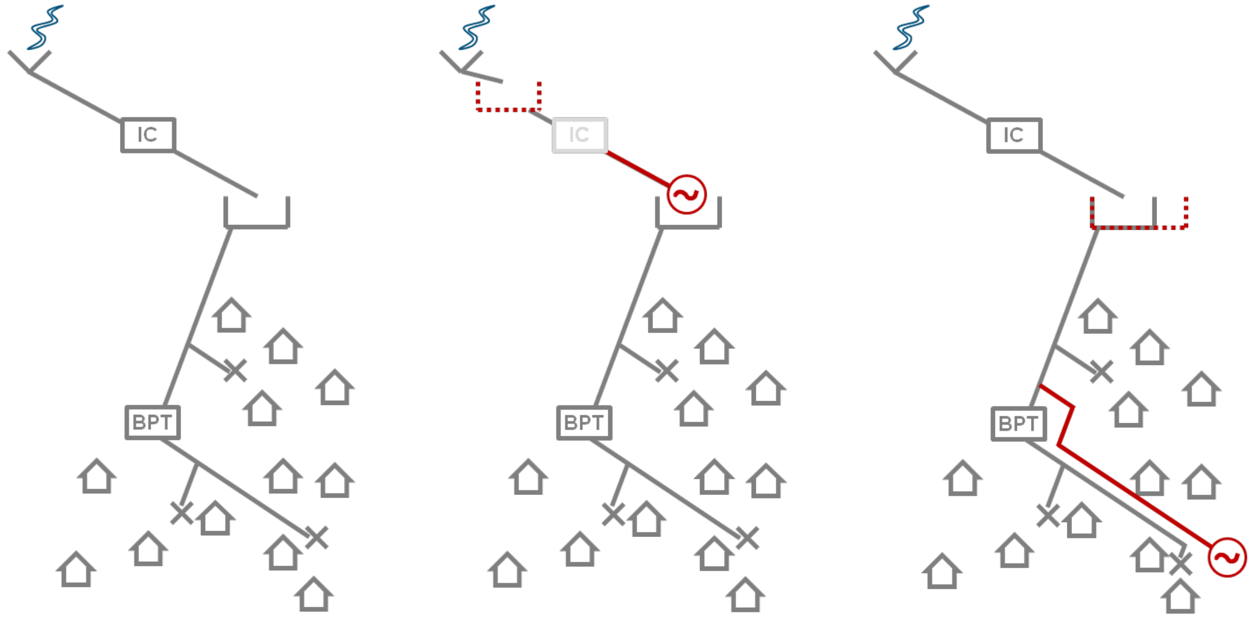
Concept of IHP

Inline hydropower is understood as a system, which serves two purposes: provision of drinking water and production of electricity. The hydropower part itself does not fundamentally differ from common mini hydropower schemes, which are numerously realised in rural Nepal. What makes it special is the idea to collectively use infrastructure, which anyway has to be build for either one of the applications.

Concept variations

Starting with a drinking water scheme, there are principally two ways how to make it an IHP scheme (see Figure 1). In the first option a hydropower plant is located amid the system. Potential energy is used but the water then is given back to the system in order to further convey to the tap stands. The second option is to locate the turbine at the end of the DWS. As the water afterwards leaves the DWS it is not dispensable for domestic use anymore. Still water is ready for irrigation of paddy or commercial crops.

Concepts of inline hydro power schemes (DWS without IHP: left, IHP concept 1: middle; IHP concept 2: right)



Intake

An intake which is designed for drinking water schemes clearly is feasible to be used for hydropower and needs no further adjustment. Water anyway is collected from sources that are free of turbidity or any sediment. Just the same is essential for the turbine, which is sensitive to any particles carried in the water.

Gravel traps or settling basin, which are commonly necessary for larger hydropower schemes, are not required for inline hydropower schemes.

Head race

The waterway between intake and reservoir chamber basically is practical to be used for both applications. Depending on the applied IHP concept, it is necessary to adapt the pressure resistance of the respective pipes.

Reservoir or forebay

Reservoir tanks for drinking water schemes are usually build as closed type. In almost all cases inline hydropower schemes also require reservoir tanks, as the actual source discharge is too little. The reservoir’s volume has to be designed so that appropriate power output can be achieved with the available head.

Reservoir chambers exceeding 15 m^3 are reasonable to be built as open type; however the actual design, size and type have to be chosen based on the site specific conditions. In the case of Gadgaun for example it is reasonable to reactivate the existing irrigation pond, which currently is not in operation. Whereas it is suggested to collectively use a closed ferro-cement reservoir tank in Bada Awal.

Penstock

Usage of the same waterway to convey water for hydropower (penstock) and for drinking water is only suggested if the power plant is applied in the upper part of the system (concept 1). The pipe system of a drinking water scheme below the reservoir tank is designed in such a way that between 5 m to 20 m are applied at the tap stands. Even though tap stands theoretically are able to withstand much higher pressure, their lifetime would only be reduced. That is why it is recommended to build separate infrastructure for penstock and distribution line.

Powerhouse and tailrace

Location of the turbine and therewith the powerhouse should be as close as possible to the settlement. If the water leaves the system after having gone through the turbine (concept 2) it is wise to place the power house in such a way that water can be used for irrigation.

Generation

Turbine and generator which are appropriate for the respective site are customized by manufacturers based on head and discharge. With prevailing small discharges at IHP sites only Pelton turbines come into consideration.

Distribution

The distribution of electricity to the point of use requires a mini grid. The grid design follows the approach to use as little wiring material as possible, which comes up to a starlike design with ramifying ends.

Guideline for pre-feasibility assessment of IHP

A simple procedure to check sites (with or without DWS) for their IHP feasibility follows the steps described below.

1. Killer criteria

Question: Is perennial discharge above 0.5 lps.?

Hydropower schemes at sites with less than 0.5 lps., require reservoir volumes which exceed 20 m^3 by far. Those high volumes have to be filled during the day and therewith water would not be available for drinking water purposes. It is expected that even many schemes with higher discharge are not feasible for IHP; however the threshold of 0.5 lps. allows identification of a majority of the unfeasible sites.

Task: Assess whether site passes above criteria.

2. Rough estimation of power output

Question: Does power output meet demand for lighting?

- Head: difference between highest source and lowest household
- Flow: perennial discharge at source
- Efficiency of generation: 50 %
- Available power output:
    - Power = head [m] x flow [lps.] x 10 x efficiency [-]
- Power demand:
    - Per household demand: 40 W
    - Demand = number of HH x HH demand
- Assumption: water can be stored for 8 h to triple the flow at turbine
    - If power output is multiplied by three it should exceed the power demand

Task: Assess whether triple power output is larger than power demand.

3. Estimation of power output based on a concept design

Question: Is there an IHP concept applicable, which is able to meet power demand?

- Draft sketches of different options for an IHP scheme, choosing option 1 or option 2 or a combination of them (see figure above).
- Place the hydropower plant accordingly – ether at the end of the transmission line before the reservoir tank or within the village. Depending on the village's arrangement it is either possible to use the distribution line as penstock too (see example of Kitu Katuje) or it is necessary to design two separate waterways (see example of Gadgaun).
- Reservoir location and volume have to be chosen, so that the water flow at turbine is sufficient to produce the required power demand.
- Operation regime: daily operation time of 4 h is recommended.
- Calculate power output based on the above formula (head loss within penstock is negligible at this stage)

Task: Assess whether triple power output is larger than demand.

4. Rough investment estimation of those schemes which are technically feasible

- Cost estimation of civil work (labour and material) with WARM-P approach
- Costs for generation:

Indication on required investment for generation (only use for rough estimation, numbers based on Gautam quotation, August 2012)

Power output	500 W	1’000 W	1’500 W	2’000 W	2’500 W	3’000 W
Investment	NRP 120’000	NRP 150’000	NRP 190’000	NRP 210’000	NRP 240’000	NRP 260’000

- Cost estimation for distribution and lighting:
- Transmission / distribution: NRP 2’500 per HH
  - earthing set: NRP 9’000
  - bulbs: NRP 1’000 per HH
- Expenses for engineering services, WARM-P management, etc.: NPR 85’000
- Expected subsidies: NRP 97’500 pro kW
- Summarize required investment.
- Expected expenses for operation and maintenance per year: 4 % of initial investment.

Task: Assess, whether investment and operational expenditures are acceptable compared to the willingness to pay (compare chapter 11.2).

5. Further proceeding if site is perceived to be IHP feasible

- Collaborate with Sundar Nepal for cost estimation
- Contact manufacturer for quotation
- Assign an engineering company to conduct a feasibility study