ANNEX 1

RIDS-Switzerland - Mohari Village Modular Pico-Hydro Project
FINAL Project Progress SUMMARY Picture Report – January 2020

(REPIC participatory funding Contract No.: 2017.14)

Pic. 1: A panorama view of Mohari Village in the month of June with the planted patatoes and buckwheat fields. Mohari Village (37 families, 247 people) by day with its Eastern Part (right) and Western part (left) and the power/community house of the modular pico-hydro power plant in the middle on a slightly elevated hill, built on land provided by the local people. Mohari, in the North-East of the Jumla District, lies at 29° 20’ 07” North Latitude, 82° 22” 28” East Longitude and at an Altitude of 3’150 meters (10’335 feet) above sea level. See in the last picture, picture 47, how Mohari village looks now by night with the modular pico-hydro power plant generating uninterrupted power/electricity for the people and the various “smart dump” loads

Pic 2: The penstock pipe line is surveyed several times

Pic. 3: The last part of the penstock has a high drop of 20 meters

Pic. 4: Clearing the HDPE penstock pipeline path from large rocks

Pic. 5: Digging the canal for the undergound power and communication cables

Pic. 6: Layed copper power cable and communication cable before buring them

Pic. 7: Joining the 200mm HDPE penstock pipe with the heating plate (220° C)

Pic. 8: Welding on the 45° elbow HDPE has been particualr a challenge

Pic. 9: The steep penstock drop is anchored and secured with cement

Pic. 10: Bringing the steep sloped HDPE penstock pipe into place

Pic. 11: Joined HDPE penstock ready for pressure test before being covered

Pic. 12: Succesful pressure test of each of the 90 joint-wleded HDPE penstock pipes

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Pic. 14: Securing the sedimentation tank and water intake with gabon wires

Pic. 15: Gabon wire boxes protection for the sluice gate and sedimentation tank

Pic. 16: Sluice gate, sedimentation tank, penstock intake, washout, overflow

Pic. 17: Buildng the power house ground walls with stones and mud mortar

Pic. 18: Mohari pico-hydro power plant trubine house with penstock and outflow pipes

Pic.19: Building the water canal for the 6 Pelton Turbines inside the turbine house

Pic. 20: Building the water canal for the 6 Pelton Turbines inside the turbine house

Pic. 21: With no roads the 6 Pelton Turbines and all equipmnet had to be carried

Pic. 22: 2” PVC piping installation to connect all the 6 turbines to the HDPE penstock

Pic. 23: PowerSpout Pelton turbine, generation 1.2kW at 40m head and 4 L/s water

Pic. 24: Emergency, 8 kW resistor water heater in the turbine house

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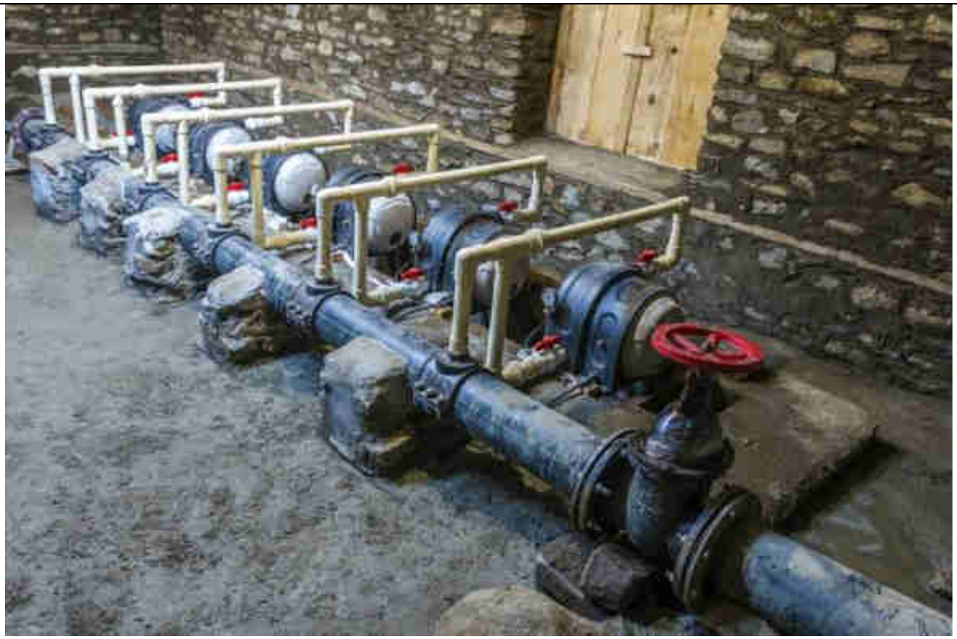
Pic. 26: Operator training for correct O&M of the power system in the power room

Pic. 27: Operator training: Correct start & stop of the power system is crucial

Pic. 28: Lights in a Mohari family home, uninterrupted on since the 30.11.2018

Pic. 29: Lights in the Community Center for teaching and education for all people



Pic. 30: Modular Pico-Hydro Power with 6 PowerSout Pelton Turbines installed

Pic. 31: 6.6 kW Power generation with 6 turbines at 47 m head and 20 L/sec = 72%

Pic. 32: A women in Mohari with her child. One of the 37 families now with electricity

Pic. 33: Children of a Mohari family now able to study in the evening with light

Pic. 34: Power/community house of the modular pico-hydro power plant with the power room, all DC to AC equipment, the battery bank and the AC distribution

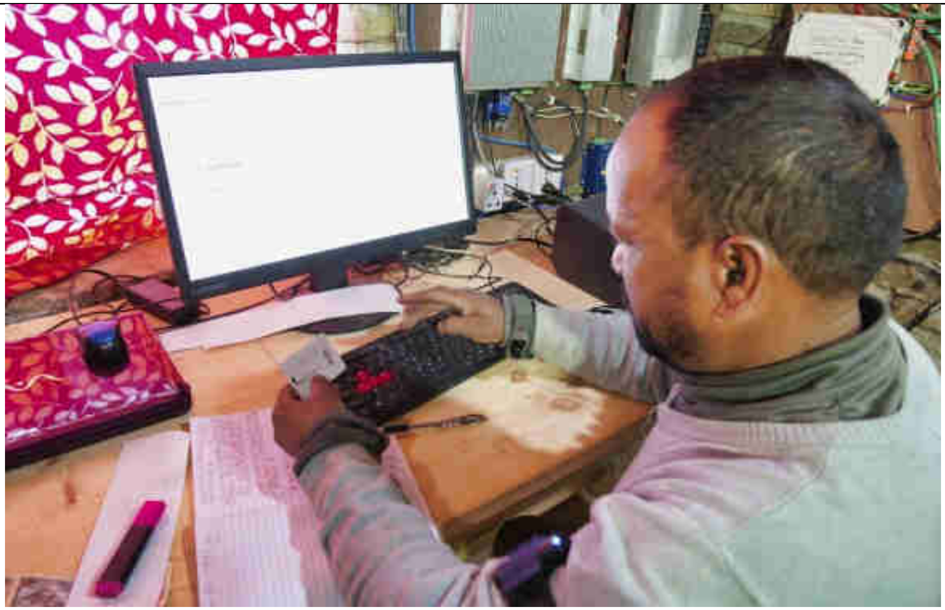
Pic. 35: Monthly greasing of each turbine while continuing generating electricity

Pic. 36: Hot water shower, one of the several "smart dump" loads in the system

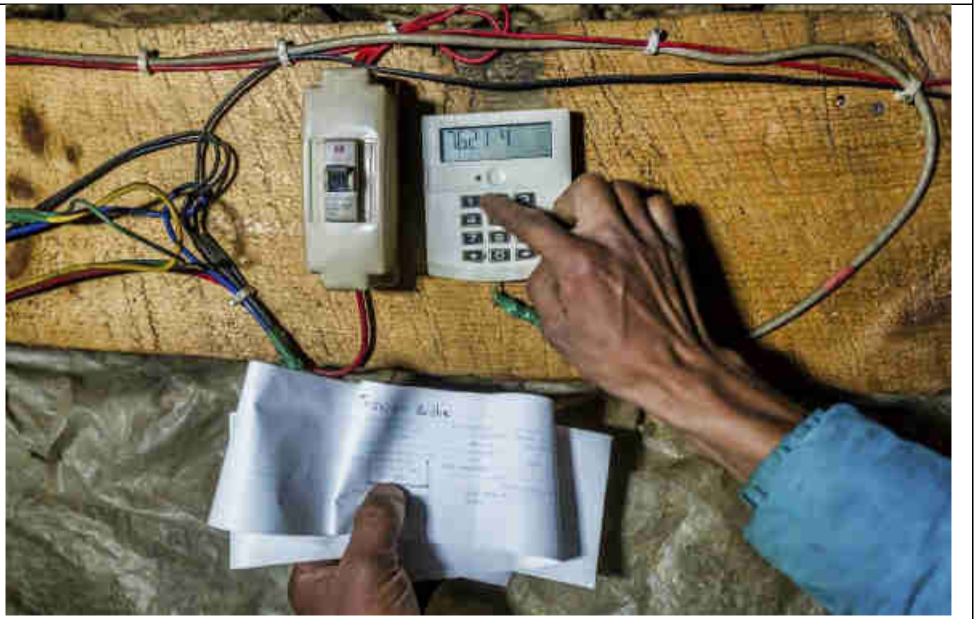
Pic. 37: Hot water shower for imporved personal hygiene, one "smart dump" load

Pic. 38: Checking the hot water tank of the village warm/hot shower center

Pic. 39: Monthly payment/family of NRs 150 for 3kWh electricity for LED lights



Pic. 40: The pre-payment PAYG PC based system for the monthly payment for power



Pic. 41: Pre-paid token number is input in the user's home display to add electricity

Pic: 42: Inauguration of the Mohari modular pico-hydro power plant on 21st June 2019

Pic: 43: Local political leaders at inauguration day testing the hot shower room

Pic: 44: RIDS produces awareness/teaching/learning videos in Nepali language (some in English) for illiterate local people (mainly women), to increase their awareness and participation in community development projects (https://www.youtube.com/watch?v=RiuBizO9Qqs&list=PLM5tNUriiE49lBkt4TVQScwvnfKpSCBUs&index=3

Pic: 45: Learning/Library room for local people/students in the community house with a large TV and plenty of space to show the educational RIDS videos. In the community center all rooms are heated with rod heaters, as part of the "smart dump" loads of the modular pico-hydro power plant system

Pic 46: First start-up of the Moudlar Pico-Hydro Power Plant on 28th November 2018. Succesful joint project partnership between the Mohari village community and RIDS

Pic 47: Mohari Village by night with the Modular Pico-Hydro Power Plant generating electricity for all demanded energy services of the village and power/community center

ANNEX 2

Mohari Village Electricity Photo Report December 2020 (all pictures taken in Mohari village December 2020)

Pic. 1: Stone walls protect the created pond and sedimentation tank (left of stone walls) from boulders rolling down the river, especially during the rainy season.

Pic. 2: Between the built stone walls flows the rushing river water into the created pond (pic. 3) to calm down and separate the gravel through gravity.

Pic. 3: Behind the built stone walls flows the water into the purposely built pond to calm down and to be cleaned from gravel and other large impurities before it flows through the gate valve into the sedimentation tank (pic. 4). All around the pond stone walls have been built for protection of the water intake system for the pico.

Pic. 4: Hiralal, one of the two trained pico-hydro power plant operators from Mohari, adjusts the gate valve to let water flow slowly into the sedimentation tank from the pond, so that all the sand and impurities can fall out, before the water is led into the penstock.

Pic. 5: A Ø200 mm HDP pipe with over 1’600 holes with Ø8mm in the sedimentation tank prevents any small debris to be sucked into the 470 m long penstock. That protects the 6 Pelton turbines in the turbine house (pic. 7 & 10).

Pic. 6: The sedimentation tank has an overflow, so that the HDP pipe (pic. 5) is always under water and no air can get into the penstock.

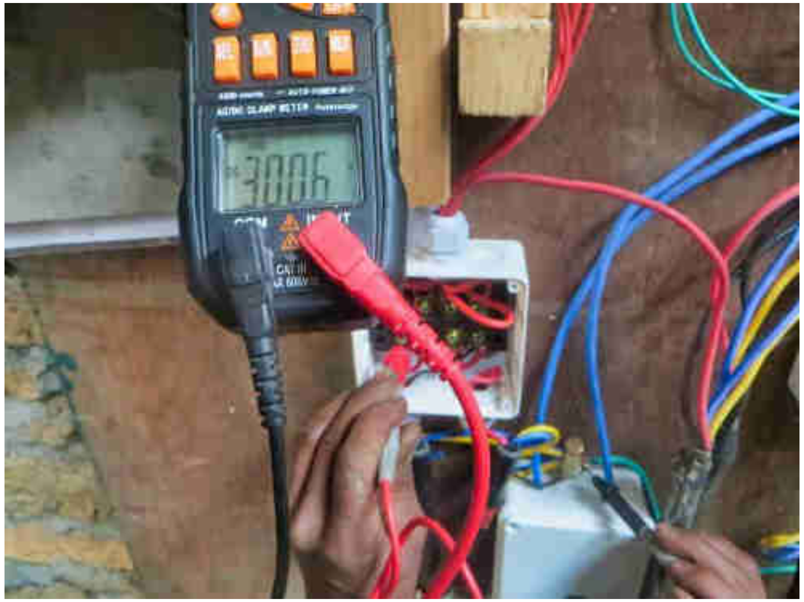
Pic. 7: The underground buried and with boulders covered, 470 m long Ø200mm HDP penstock, leads direct into the Mohari Modular Pico-Hydro Power Turbine house. Gross head is 47m, with a max. water flow of 25 L/sec for all 6 turbines.

Pic. 8: After the turbines the water is flows back into the river through a 20 m long Ø220mm HDP pipe. In summer this has become an attractive playground for the children, while in winter amazing icicles structures are created.

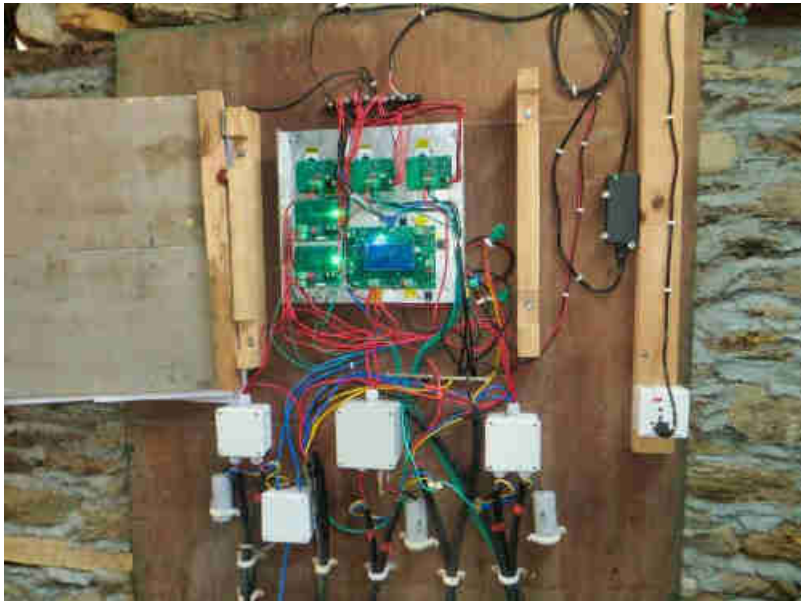
Pic. 9: Hiralal during the monthly periodical maintenance of the pico-hydro power plant. Here he is greasing of each of the 6 Pelton turbines' generator axes.

Pic. 10: RIDS-Nepal staff Mansingh cleaning the drainage valve from any leftover sand and small debris which made it into the penstock.

Pic. 11: RIDS-Nepal staff measuring the electricity generation of Turbine No. 2 generating 300.3 Volt DC.



Pic. 12: RIDS-Nepal staff measuring the electricity generation of Turbine No. 3 generating 300.6 Volt DC.



Pic. 13: Mother board and DC power cable connection in the turbine house, to get the 300 VDC power transmitted via the 300 m long, 60cm underground buried, armored cable transmission line, to the village.

Pic. 14: 48 VDC battery bank in the village's power house. The battery bank allows the DC/AC inverters to provide 3-phase AC power with up to 30 sec. 12 times the power plant's rated output power e.g., to start a motor.

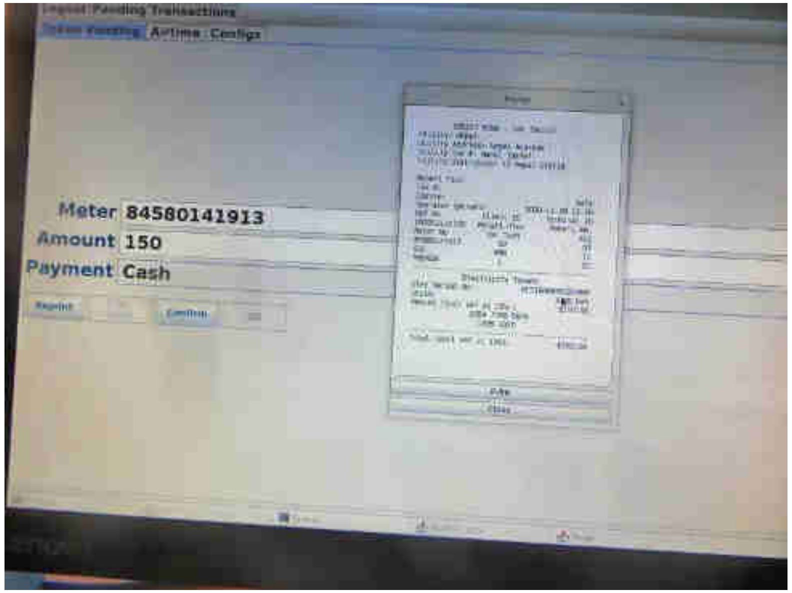
Pic. 15: Two of the six Pelton turbines, at 40m gross head and ~7.5 L/sec water flow generate 2.13 kW AC in the village. That results in a system efficiency from water to AC electricity of around 72%. The battery bank is close to max. voltage at 54.3 VDC.

Pic. 16: Power house room where the 300 m long underground transmission line from the turbine house enters. Here is all the DC-AC power conversion equipment and battery bank. The PC serves for data monitoring/recording and issuing the monthly pre-paid codes for each user.

Pic. 17: A Mohari women is cleaning the electricity distribution box in the village.

Pic. 18: A Mohari women is cleaning the smart meter/recharge in her house.

Pic. 19: Mohari women in RIDS-Nepal office to purchase their monthly pre-paid electricity recharge cards with 3 kWh for NRs.150, lasting for a month.



Meter 84580141913
Amount 150
Payment Cash

Pic. 20: The PC in the power house checks the user identify and issues the monthly token and ID number to input into the smart meter for NRs.150.

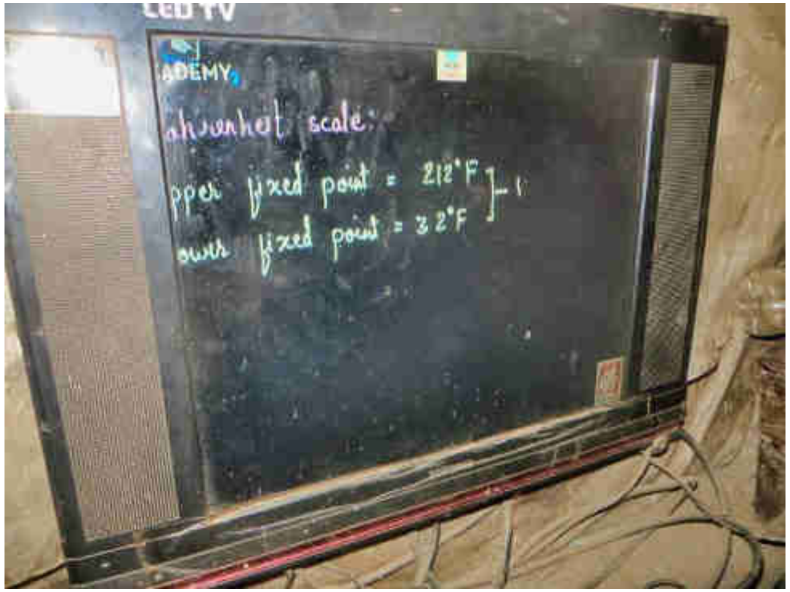
Pic. 21: Monthly electricity token is generated through the PC via specially installed Internet line for each household after pre-paying the monthly fee.

Pic. 22: RIDS-Nepal staff, Mansingh is helping a woman to recharge her meter box with the 20-digit number on the token issued by the pre-payment system.

Pic. 23: Hiralal, one of the two trained operators, is recharging a meter box.

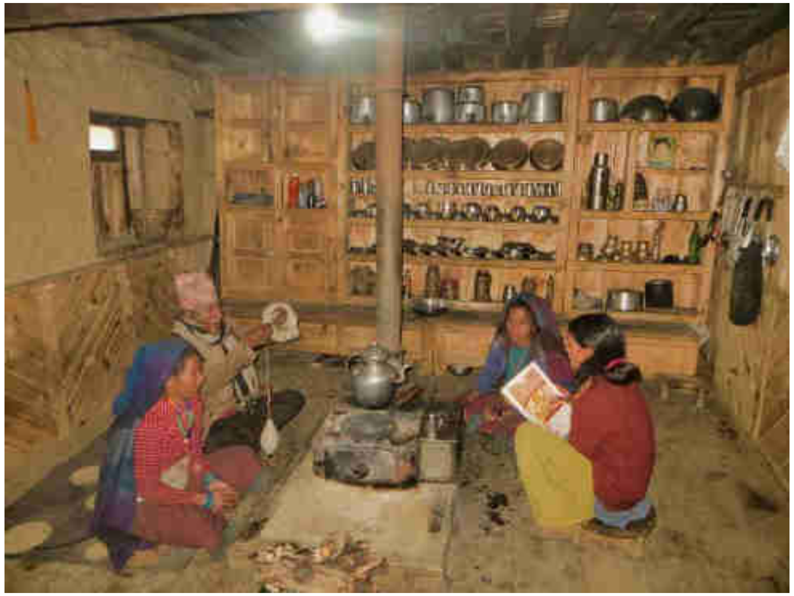
Pic. 24: The smart meter displays the electricity units left (here 30.7 kWh).

Pic. 25: Mohari Children are attending television broadcasted program due to COVID-19. This is only possible because each household has now electricity.



Pic. 26: Mohari Children are watching television broadcasted program due to COVID-19. Online-education, one of the great opportunities due to electricity.

Pic. 27: Mohari children are able to read and write till late into the night because of the availability of electricity in each house in Mohari village.



Pic. 28: A Mohari family able to spend valuable family time together till late into the night as they have now as much electricity in their home as they need.

Pic. 29: With electricity and a smokeless metal stove, the Mohari the students are able to read, write and study till late into the night, to the joy of their parents.

Pic.30: Electricity, clean indoor air, clean drinking water, clean and nutritious food, all important parts of a holistic community development village project.

Pic.31: Over the course of 20 years life has dramatically improved in Mohari village for all families through long-term holistic community development.

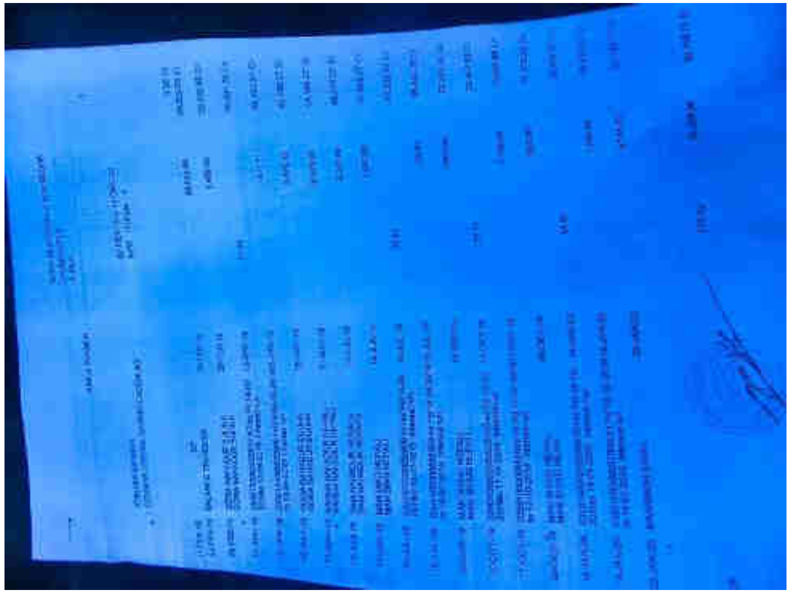
Pic.32: Electricity enables family members to work even in the evenings. The RIDS-Nepal designed Slow Sand Water Filter provides clean water for all.

Pic.33: Because of electricity, Mohari women are able to do their household chores also in the evening easy and efficiently.

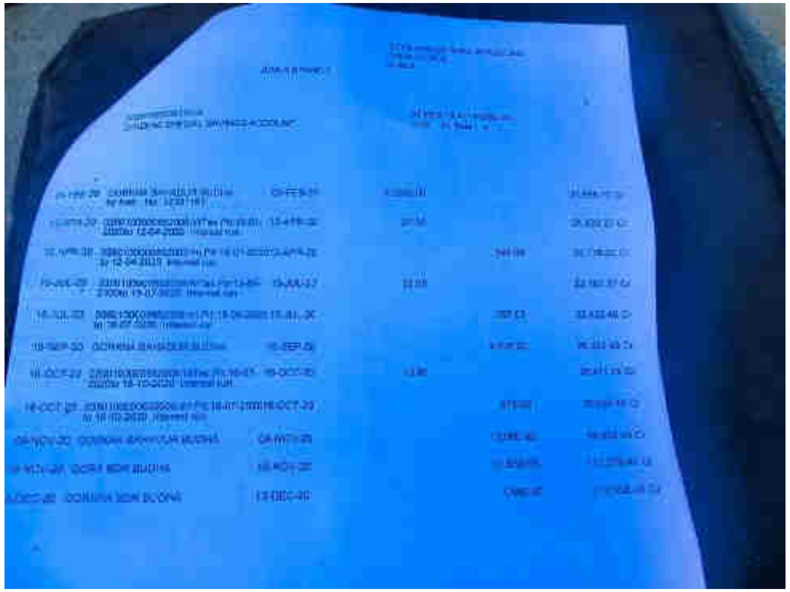
Pic.34: RIDS-Nepal Jumla Program Coordinator Haripal Nepali after taking a hot water shower, part of the "smart dump load" of the pico power plant.

Pic.35: Clean indoor air and room, possible through the RIDS-Nepal Smokeless Metal Stove, Slow Sand Water Filter and uninterrupted electricity.

Pic.36: Only if one saw this Mohari family's kitchen in 1998, when RIDS first came to Mohari, and compares it to today, one sees the HUGE improvements.



Pic.37: bank statement showing the monthly deposits of the Mohari families' electricity fees collected since December 2018.



Pic.38 The bank statement shows the total deposit of NRs. 112,938.- (~US$ 990.- equivalent), gathered from the monthly electricity fees.

Pic 39: Mohari Village (40 families, 250 people) by day with its Eastern Part (right) and Western part (left) and the power/community house of the modular pico-hydro power plant in the middle on a slightly elevated hill, built on land provided by the local people. Mohari, in the North-East of the Jumla District, lies at 29° 20’ 07” North Latitude, 82° 22” 28” East Longitude and at an Altitude of 3’150 meters (10’335 feet) above sea level.

Pic 40: Mohari Village by night with the light of the stars above and the Modular Pico-Hydro Power Plant generating the electricity for all demanded energy services of the village and power/community center on the ground.

ANNEX 3

Modular Pico-Hydro Power System for Remote Himalayan Villages

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Abstract

This paper describes the key learnings made during the final design and construction of a pilot modular pico-hydroelectric project described earlier in Zahnd, A., et al, 2017, pursued due to its ability to grow dynamically with the user demand and ability to pay as they learn to use and value electricity. The paper discusses practical experience from the operation of the system since it was commissioned in November 2018, data collected from the integrated monitoring system, and feedback from local users and the local system operators. Recommendations for future systems based on this modular approach are also discussed.

Keywords: RAPS, Rural, Electrification, Pico-hydropower, Hybrid Power System, Utilization Factor, Community Development, Prepay Electric Meter, PAYG, STS, Renewable Energy, Technology, off-grid, power generation

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1. Introduction

Pico-hydro and micro-hydro power (MHP) systems in remote regions of Nepal have had limited long term success due to seven reasons outlined in Sturdivant, R., et al., 2017. A whole new modular approach was envisioned and outlined in Zahnd, A., et al., 2017 to address all seven reasons, and a pilot system using this approach was completed in the Fall of 2018 in the village of Mohari in the Jumla District of Nepal. RIDS-Nepal's new approach addressed the seven reasons of system failure or under-performance outlined in Tab. 1.

Tab.1: Seven Reasons for Failure of Past MHP and Pico-Hydro Power Systems

Feature or Equipment	Traditional Approach	RIDS-Nepal Approach
Water Canal	Exposed Canal: Susceptible to destruction from small surface landslides common in the region	Buried Pipe/Penstock: Delivery of the water to the turbines with protection from the elements and surface landslides. Increases reliability. Farmable land can remain in service.
Modularity	Single Turbine: Offers no system redundancy and it's difficult to add additional turbines due to phasing issues.	Modular turbines, battery storage, and inverters: Allows redundancy to increase reliability and sustainability, lower replacement cost if one fails, system continues to provide power, and the ability to expand capacity as the village's electrical demands and economic vitality increase.
Generator Drive	Belt Drive: Belts usually break within 0.5 to 3 years and are expensive to replace. Without an economic system, a belt failure can doom the entire system.	Direct-Drive: Each turbine is directly connected to its own generator. Eliminates risk of belt failure, increasing system reliability. Use of permanent magnets increases overall efficiency.
Transmission Lines	Overhead Transmission Lines: Uses very soft wood from local dead trees which rot since they are not treated to resist moisture. Alternatively, metal posts are used which often cannot support high wind and snow loads, or heavy wet clothing draped on transmission lines to dry. Support failure results in line fault.	Buried Armored Transmission Lines: Removes the risk of rot and failure of above-ground supports. Transmission lines are protected from mischief and the elements, and energy theft is much more difficult. Reduces deforestation and all negative impacts which come along with it (increased landslides, soil loss, increased time and risk for women to collect firewood etc.).
Surge Capability	No Surge Capability: Peak demand over generator capacity results in brown/black out, or requires load shedding.	Battery Surge Capability: A small bank of batteries allows the system to deliver peak power in excess of generator capacity, important for starting motors needed to drive economic development.
Economic System	No Financial Plan: No economic plan to support maintenance and operations. No plan for collection of fees.	Use Prepay (Pay-As-You-Go) Meters: The system will only deliver power if you have pre-paid into a maintenance and operations fund.
Excess Energy	Dumped To Exit Water: Excess power is dumped into the exit water stream as heat. Utilization rates of only 10% or lower are achieved.	Excess Energy Utilized In The Village: Excess energy can be dissipated in ubiquitous water heater elements to heat shower water for improved hygiene and biogas slurry for improved production. It can also be dissipated in air heater elements to heat buildings such as a community center.

A video of the project can be found at RIDS-Nepal, 2019b.

This paper describes the key learnings made during the final design and construction of this pilot project, practical experience from the operation of the system since it was commissioned in November 2018, data collected from the integrated monitoring system and feedback from local users and the local system operators.

It should be stressed that this is a research project to investigate the modular concept, especially its ability to grow dynamically or alongside the village's increasing power demand over time. This includes reducing the number of operating turbines to better understand the energy needs of villages with first-time access to electricity; or operating all turbines in parallel to verify the system can run smoothly when summing power from all turbines, and to understand the maximum power capability of the system.

2. Design and Construction

This section describes the design and construction of the system, including key learnings observed during the construction phase of the project.

2.1 Intake

The water intake was constructed in the Spring of 2018. To reduce the wear and tear on the turbines, two levels of sedimentation were used as shown in Fig. 1. First, gabion walls were used to divert most of the river flow to a pre-existing channel which is especially important during the monsoon season, forming a settling pond behind the gabion walls. Additional gabion walls formed the overflow for this pond. The flow of water through this first settling pond is not adjustable. A second settling pond constructed with cement and a locally manufactured sluice gate provides additional settling. The sluice gate is used to adjust the water flow into the second, three-dimensionally shaped pond as shown in Fig. 2 to achieve an even slower flow rate for improved sedimentation, but sufficient to provide all the water needed by the turbines.

Fig 1: Two Levels of Sedimentation Tanks

Remote areas such as the Himalayas are already being impacted by global warming, resulting in higher than usual river flows. Gabion walls have been constructed to withstand more than the normal flood levels.

Fig. 2: Three Dimensionally Shaped Settling Pond

2.2 Penstock

The penstock, 490m long, was constructed with 5 m sections of HDPE pipe manufactured in Nepal. 180mm diameter PN2.5 pipe was used closer to the intake where pressure is low, then 200mm diameter PN4, then 200mm diameter PN6 closer to the turbines where the pressure reaches its peak at $5 * 10^5$Pa (5 bar). The 5 m sections of pipe were thermally welded using a jig and a plate heated by electricity from an 1800W generator as shown in Fig. 3. Even though the plate worked well, properly aligning adjacent pipes proved to be a challenge, especially the PN2.5 sections which were not entirely round, and had thin walls that required more precise alignment. In spite of the difficulties of 98 thermal welds, the penstock was created without leaks.

Fig. 3: Thermally Welding the Penstock

We had planned to bury the entire length of the penstock, but this turned out to be impossible because too many large boulders blocked the path of the relatively inflexible large diameter HDPE pipes needed to supply water to all 6 turbines. Furthermore, the inflexibility of the penstock made it difficult to follow the contours, so sections of the penstock are buried, while others are elevated on stone walls as shown in Fig. 4. Still, the whole penstock was either buried or covered with mud and stones to protect it from the elements and to continue to use the fields for agriculture. In the future smaller diameter HDPE pipes delivered on rolls pose a realistic alternative. These pipes are much more flexible, allowing them to better follow trenches that have been dug to avoid the boulders. Fewer turbines will be fed by one pipe to reduce the losses due to the smaller diameter, so multiple smaller pipes will have to be laid instead of one large diameter pipe.

Fig. 4: Elevated Section of Penstock

2.3 Turbines

Fig 5: Six Turbines, Saddles, and CPVC Supply Lines

Fig 6: PowerSpout PLT-HP Turbine

The penstock is connected to a 200mm gate valve in the 'turbine house' where six turbines are mounted on a concrete exit channel as shown in Fig. 5. Six HDPE saddles were placed on a 5m section of 200mm HDPE pipe downstream of the gate valve. The two nozzles of each turbine were connected to this pipe via 50mm CPVC pipes and a CPVC Tee.

PowerSpout Pelton PLT-HP turbines from Ecoinnovation were used (Powerspout 2019), shown operating in Fig. 6. These turbines appear to be nearly optimal for remote systems because they are light enough (~20 kgs) to be carried on a single person's shoulder, removing the need for helicopter transport; they can be repaired by local personnel in the village using very economical parts; and they are much more efficient than the crossflow turbines commonly used. Our performance monitoring showed an overall efficiency of 72% from water flow to electricity available in the power room, which is quite high compared to the 45% provided by the typical crossflow turbine in a pico or micro-hydro power plant.

The pilot system can generate 6.6kW at 47m net head, with approximately 20 Liter s^{-1} flow, when all 6 turbines are running. Power output can be reduced to just 1.1 kW with only one turbine running to serve the initial power needs of a small village just being introduced to electricity. For example, the village of Mohari, with approximately 40 households consuming power almost exclusively for LED lighting, can easily be served by just 1 turbine.

Good quality grease must be used with any turbine's bearings. The first batch of grease we used was counterfeit. One container actually had a chili in it! Grease should be ordered only from an SKF agent.

Fig 7: Unwinding Armored Transmission Cable from the Spool

The PowerSpout turbines come with an integrated 3-phase bridge rectifier to produce DC, allowing multiple turbines to be wired in parallel to feed each charge controller in the village.

2.4 Transmission Lines

Buried armored transmission lines, 300m long, were used to send the DC power to the power room in the village. Generators operate at 300VDC, allowing the use of smaller diameter transmission lines. This was chosen partly for cost savings, but mostly to simplify transport and construction. The cables came on large rolls as shown in Fig. 7, and even these reduced diameter cables were extremely difficult to manage by a large number of local people since there are no forklifts or trucks available in the village.

2.5 Power Electronics

Fig. 8: Power Room

The power electronics including the charge controllers, battery bank, and inverters are housed in the power room in the village shown in Fig. 8.

Studer Innotec provided three VS-70 charge controllers (Studer Innotec, 2019b), three Xtender XTM-4000 4000W inverters (Studer Innotec, 2019a), and various accessories for the project. The system was very easy to set up to generate 3-phase power to the village. The MPPT algorithm in the VS-70 charge controllers is designed for solar applications, and is unstable with hydro turbines. However, the VS-70 supports a fixed-voltage "Upv-fixed" MPP mode which maintains the input at a specified voltage. This works very nicely with hydro because the operating conditions are quite constant. A manual search of the MPP is sufficient when the project is commissioned. The Upv-fixed MPP algorithm proved to be extremely stable.

Four ubiquitous N-200 truck batteries were used in the system. The truck batteries are recommended over deep cycle batteries because they stay charged due to the continuous power generation, and they have a much higher maximum charge current rating than deep cycle batteries, allowing them to accept all available power from the turbines.

The system is set up so the VS-70s always accept all available power from the turbines to keep them from spinning too fast and creating voltages that could damage the system. A battery-side diversion load controller keeps the battery from being overcharged as described in Section 2.8.

One subtle configuration setting is needed to ensure every VS-70 in the system accepts all power available to it. Each VS70 will determine its own charge state independently if its setting 14036 is set to 'No'. Although this sounds innocuous, in some cases this causes a single VS-70 to accept less than the full power available to it, even though its battery charge voltage setting is much higher than the current battery voltage. This causes the turbines to spin faster, creating potentially damaging voltages. VS-70 setting 14036 must be set to 'Yes' so every VS70s will synchronize its charge state to the state determined by the overall Xtender system.

Other types of renewable energy sources, e.g. wind and solar, can have their own VS70 charge controller to supply power to the batteries without affecting the operation of the turbines.

2.6 Distribution System

Fig 9: Junction Box with 3-Phase Buss Bar and Prepayment Meters

Two three-phase spines are routed through the village, one to the East of the power room in the center of the village, and one to the West. Single phase lines are connected to the three-phase buss bars at 12 locked junction boxes distributed through the village to minimize the length of these single-phase lines. The boxes, shown in Fig. 9, were designed by RIDS-Nepal and manufactured in Kathmandu.

Buried armored cables are used for the three-phase spines through the village, and the single phase lines to each customer. This helps prevent energy theft, mischief, and environmental damage.

2.7 Prepay Electric Meters

Itron donated ACE9000 SSP DIN-R electric meters and Customer Interface Units for the project (Itron 2019). These meters are stored in the junction boxes to help prevent energy theft, and the customers enter 20-digit Security Token Service (STS) tokens into the Customer Interface Unit (CIU) in their homes. The STS Association (STS Association, 2019) owns the STS technology which is the dominant technology used in electric prepayment meters.

Although STS prepay electric meters are inexpensive and ubiquitous, software systems needed to vend tokens to village-level 'utilities' are not. A number of prepaid electricity vending solution providers exist for large utilities, but none have been identified that are designed for village-scale 'utilities'. The cost of support, crafted for large-scale utilities, far exceeds any amount of revenue the providers can get from these small developing villages.

The authors also believe that a nation-level business, operated by a Nepali company, could aggregate many village-scale 'utilities' and provide the vending solution and local support to them. The prepaid electricity vending solution providers could support just a few local people, educated with the necessary skills, who would then provide local-language support at a much lower labor cost to the local village-level 'utilities'. This business could serve existing pico, micro, and mini grids, so the number of meters served by the district-level business could rapidly grow to a level that would warrant interest by large-scale prepaid electricity vending solution providers. This prepay aggregation service, by itself, would probably not economically justify the creation of such a business. But this same business would likely be economically viable if it also provided design, installation, and maintenance services for a large number of village-level electricity systems. The prepay aggregation would just be the way they would guarantee a revenue stream needed to support their operation. The company iPay (iPay, 2019) was a partner on this project, providing the prepaid electricity vending solution and support.

2.8 Useful Dump Loads

Pico and micro hydroelectric systems typically use diversion load controllers to balance the consumption and generation of the system, using either PWM or phase modulation to divert excess power to the water heater resistors in the water returned to the river. This is a total waste of a valuable resource with no added valuable energy service to the consumers.

The Studer Innotec VS-70 charge controllers used in this project are configured to consume all available power from the turbines by setting its float voltage well above 54.4V. A commercial Morningstar TS-60 diversion load controller (Morningstar 2019) monitors the battery voltage to keep it at 54.4 V. If the voltage rises slightly the TS-60 will increase the duty cycle of its PWM output which drives air heater resistors in the community center. Loads in excess of the TS-60's 60A rating are driven by MOSFET based SSRs mounted to aluminum sheets for heat sinks. They are triggered simply by monitoring the PWM output waveform from the TS-60 diversion load controller, scaled down to acceptable voltages using a resistor divider.

A means to improve the utilization factor of renewable energy systems by dumping excess power to a set of prioritized loads was described in Stambaugh, M., et al, 2017. It proposed that a PWM diversion control signal could be routed to one of a set of dump loads based on priority. The highest priority load that needed additional power based on its temperature took all the excess power. Battery-side diversion was used instead of AC-side diversion because this modular pilot system can continue to operate even if the inverter driving an AC dump load is off-line for maintenance or failure. Two issues were discovered during the final design stage that led to a different solution. Both of these issues resulted from the need to use battery-side diversion operating at 54.4 VDC.

- High power resistive loads operating at 54.4VDC are expensive and far from ubiquitous.
- High currents required to dissipate all excess power at 54.4VDC cannot economically be run to remote locations in the village for convenient use.

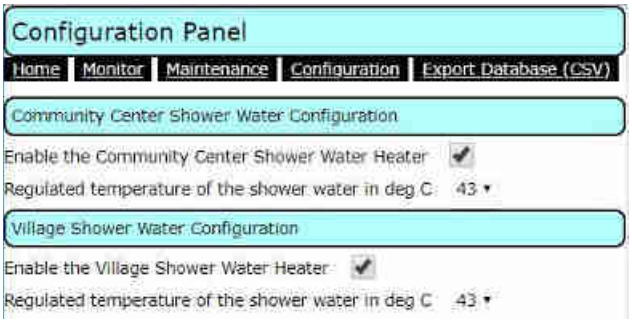
A Linux-based 3360 control computer provided by Schweitzer Engineering Labs (Schweitzer Engineering Labs, 2019) ran the code used to improve utilization, monitor the system, and provide the prepay electricity vending terminal. This ultra-high reliability computer was chosen because only a single Linux computer was used in

Fig 10: Installation of AC Relay Board and Hot Water Tank for Showers

the system, and its remote location makes replacement very difficult.

The utilization improvement code monitored battery voltage, production, and consumption to determine if there was sufficient power available to turn on useful loads such as shower water heater elements. Hysteresis was used to ensure the loads were not turned on and off rapidly. A small ‘AC Relay’ board was mounted next to each useful load as shown in Fig. 10 to monitor its temperature. It also included two 10A relays which are used under computer control to turn on or off power to the water heater resistors. 500W and 1000W resistors were used to provide 0, 500, 1000, or 1500W to the useful load depending on the availability of power. The AC Relay board incorporated an Arduino which communicated with the control PC via buried RS-485. RF communication was not used due to licensing issues in Nepal. The AC Relay board is described more fully in Yeh, J., et al, 2019a.

Any number of distributed useful loads can be placed throughout the village. The control PC provides a GUI shown in Fig. 11 that lets the operator specify the relative priority of each load, and the target operating temperature. The highest priority load gets available power if it needs it, up to 1500W. If there is any power left over the next highest priority load gets it if needed, etc. The air heater resistors in the community center, one of which is shown in Fig. 12, are the lowest priority loads, and are able to accept all generated power, e.g. if nothing else needs any.



Community Center Shower Water Configuration

Enable the Community Center Shower Water Heater ☑

Regulated temperature of the shower water in deg C 43 ▾

Village Shower Water Configuration

Enable the Village Shower Water Heater ☑

Regulated temperature of the shower water in deg C 43 ▾

Fig. 11: GUI to Set Relative Priority and Temperature of the Hot Shower Useful Loads. The GUI for Other Useful Loads is Similar

Because ubiquitous 230VAC water heater resistors are used in the distributed loads, and power is supplied through the existing village distribution system, these loads are quite economical.

The RS-485 communication cables are buried in the same trench as the armored 230VAC distribution cables. They are run in 15mm HDPE pipe to provide protection from animals.

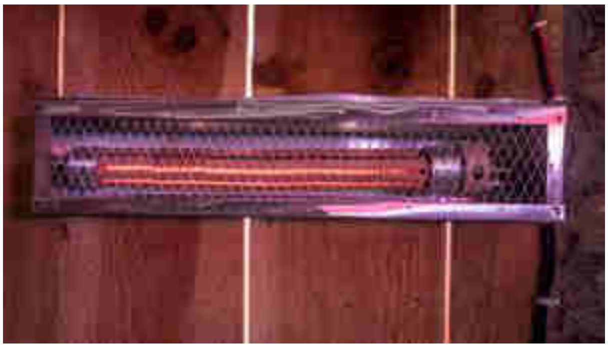


Fig. 12: Air Heater Resistor in the Community Center

2.9 Failsafe

Because we are running the turbines at 300VDC under MPP load, their output can reach about 900V if the Studer VS-70 charge controllers stop consuming all available power. Although this should never happen, Murphy’s Law says it will, so two levels of failsafe are employed in the turbine house to limit the voltage. Custom solutions were used due to the high cost of multiple (three) 600V diversion controllers capable of handling the required current.

The first is a custom PCB described in Yeh, J., 2019b, that will dump power via discrete IGBTs using PWM to a bank of water heater resistors in the output stream from the turbines. It contains an Arduino that regulates the turbine output to around 400 VDC, much lower than the 600VDC rating of the VS-70 charge controller, but much higher than the normal 300VDC operating voltage of the system. Two 230VAC water heater resistors are wired in series to withstand the higher DC voltages. The Arduino is also used in the monitoring system described in section 2.10.

The second is another custom circuit board that triggers a discrete SCR when the turbine output voltage rises to around 460VDC. It is a very simple circuit using a precision opamp comparator to quickly trigger the SCR. Once triggered, the turbine output is dumped to the same bank of water heater elements. The turbines must be turned off to reset the SCR.

300VDC was chosen as the operating voltage for the turbines to reduce the cost and weight of transmission cables while providing low losses. However, this increased the potential no-load voltage to over 600VDC, the rating of the VS-70 charge controllers. Preventing this over-voltage significantly complicated the design and cost of the system. Although cost-effective custom solutions were created for the pilot system, this presents yet another challenge to system replication.

200VDC would be a better choice because the no-load voltage would remain below 600VDC, allowing the elimination of the custom over-voltage regulation circuitry and the dump load resistors in the turbine house. Dropping the operating voltage to 200V would increase the transmission current by 1.5x, which would increase the transmission losses by 2.25x. Either fatter conductors could be used in the transmission cable, or the extra losses could be tolerated. The 300m transmission lines each conducted as much as 6.6A at 300VDC to the power house. 4mm2 copper was used for conductors, with losses of around 5.4%. By dropping to 200VDC operation the losses would have increased to about 12.2%, which is probably a good tradeoff to eliminate the complexity and custom over-voltage protection circuitry. Alternatively, fatter conductors would be needed.

3. Operation

This section describes key learnings observed during the operation of the system since November 30, 2018.

3.1 Charge Controllers and Inverters

Studer Innotec supplied their Xtender system including three VS-70 charge controllers and three XTM-4000 inverters, as well as other accessories. The authors are very satisfied with the performance of the properly configured Studer Extender system in this modular pico-hydro-electricity application.

3.2 Air Heater Resistors

Commercial 230VAC air heater resistors were purchased in Kathmandu. They were constructed with eight sections of Nichrome wire, connected in series, on a ceramic core. The resistors as configured would consume very little power at 54.4 VDC, so they were modified so only two sections are wired in series instead of eight. As a result, the Nichrome wire dissipated the same power per section at 54.4 VDC as the original resistor did at 230 VDC.

3.3 Pressure Regulation

At one point the gate valve was partially closed to reduce pressure, or the net head, at the turbines. This was done to explore the operation of the system when power generation is close to the demand of the village. This worked fine, but the position of the gate valve moved slowly due to vibration and other factors, resulting in a gradual reduction of the pressure and generated power. This particular gate valve is not a good pressure regulating device, and we suspect other gate valves available in Nepal have similar properties. Given the modularity of the system, turning off turbines is probably a better approach to controlling the generated power.

3.4 Failsafe

Testing revealed that the PWM control of the Arduino-based custom circuit board described in section 2.9 is too slow to react before the opamp-based crowbar circuit triggers. Fortunately the VS-70 charge controllers are extremely reliable at consuming all available power from the turbines, so nuisance tripping of the opamp-based crowbar has never occurred once the VS-70's were configured correctly. Both the Arduino-based and the opamp-based custom boards are still used to provide redundant protection in case a VS-70 charge controller stops consuming power for any reason. Neither of these custom circuit boards is needed if the turbines are configured at the PowerSpout factory to be operated at 200VDC.

3.5 Prepayment System

The prepayment system was very popular with local government officials. They readily saw how important it was to the long-term success of any system. Although they were familiar with prepayment for cell phones, they had never seen prepayment meters used in an electricity system.

Several issues were observed with the prepaid electricity vending solution from iPay, but they should be attributed to operator error. This should be expected because the training model of utility-scale solutions is optimized for large utilities, not village-scale utilities whose personnel are not literate in English. Although good documentation was provided, on-site training classes are not economically viable for village-scale utilities.

The solution vended 20-digit tokens as specified by the STS standard. These were printed as roman numerals instead of Nepali numerals, but at least they were consistent with the numerals printed on the Customer Interface Unit (CIU) keys. Errors did occur when entering the 20-digit tokens into the CIUs, but the CIU reported that the token failed, and the entry was retried. In a few cases failed tokens were reported by the user after several entry attempts. In reality, they were entered incorrectly multiple times.

3.6 Prioritized Dump Loads

The availability of hot showers as shown in Fig. 13 has been extremely popular, not just to the villagers, but also to the government officials who visited the site during its inaugural celebration in May 2019. People were dancing in the showers. Although we currently do not have Pay-As-You-Showers, the goodwill this service creates significantly improves the users' willingness to pay for the operation and maintenance of the system.

The heated community center rooms are also appreciated by the village. Elder women are given seats next to the heaters, and seem to enjoy this honor immensely. Although the community center isn't heated to Western standards, it improves comfort significant enough to attract tourists and researchers in the future.

The local operator had no trouble understanding the GUI used to set priorities and the target temperature of each useful load.

Fig. 13: Hot Showers!

By heating the shower water, biogas digester, the community center, and other services that are useful to the village, 100% of the available energy can be utilized for useful loads, much better than the typical small system in Nepal. Tab. 2 compares the utilization of the pilot project in Mohari to the system serving the nearby village of Chaura using the traditional MHP approach.

Tab 2. Utilization Comparison

Daily Energy	Chaura's Hydroelectric Approach Serving 200 Households (HH)	RIDS-Nepal's Hydroelectric System Serving 40 Households (HH)
Potential Generation	20 kW * 24hrs = 480 kWh	6 kw * 24hrs = 144 kWh
Power room equipment (considered overhead, not a 'useful load')	NA	80W * 24hrs = 2 kWh
Consumption for lights	200 HH * 2 * 5W * 10hrs = 20 kWh	40 * 3 lights * 3 W * 12hrs = 4.3 kWh
Consumption for cell phone charging	100 HH * 5W * 2hrs = 1 kWh	30 HH * 5W * 2hrs = 0.3 kWh
Consumption for TV	NA	2 HH * 60W * 4hrs = 0.5 kWh
Village Shower Center	NA	1.5kW * 4hrs = 6 kWh
Community Center Showers	NA	1.5kW * 4hrs = 6 kWh
Community Center Lights	NA	20 * 7W * 15hrs = 2kWh
PCs, Laptops	NA	5 * 100W * 10hrs = 5 kWh
Community House TV for education	NA	100W * 5 hrs = 5 kWh
Heating Community Center	NA	112.9 kWh
Total utilized for useful loads	21 kWh (4.3%)	144 kWh (100%)

4. Participation

4.1 Planning

The local community and government officials participated throughout the planning phase of the pilot project through periodic information and discussion meetings to define the location and scope of the power plant.

Fig. 14: Building Elevated Penstock

4.1 Construction

The village committee decided that each household in the village had to donate 100 days of work toward the construction of the modular pico-hydroelectric project and the community center in order to connect to the electricity system. For each day not worked the household had to pay 500 Nepali Rupees (approximately 4 € or 4.5 USD in July 2019). Only two households, about 5%, did not connect because they were absent from the village for the duration of the project. Otherwise almost everybody participated, examples of which are in Fig. 14-16.

Fig. 15: Laying Penstock in Steep Section

Fig. 16: Just About Everyone Participated!

The village community also gathered and processed local building materials such as wood, stone for walls, and sand for concrete.

4.3 Financing Operations and Maintenance

Each household pays 150 NRP (approximately 1.2 € or 1.36 USD in July 2019) per month to connect to the electricity system, and this includes 3 kWh per month. Because high efficiency LED lighting was installed throughout the village, 3 kWh is usually sufficient for basic lighting and cell phone charging, but not enough for a TV. Additional energy costs 50 NRP (approximately 0.4 € or 0.45 USD) per kWh. Although any off-grid system will cost more than a grid-tied service, the rate paid in Mohari is not that much higher than the average residential rate for grid-tied energy in Hawaii (0.33 USD per kWh). Half this revenue pays a salary for the operator, a resident of the village. The other half goes into a maintenance fund to pay for any needed repairs or maintenance.

This financial commitment seems small by western standards, but is significant for subsistence farmers. Some of the villagers wanted the connection fee to be reduced to 50 NRP/month. Their request is understandable since there is no monthly fee for most other systems in the area. Considerable time was spent educating the villagers that the lack of a monthly fee is one of the reasons these neighboring systems often fail early in their lifecycle. Additional time was spent educating them on the value of electricity for education and economic development to give their children opportunities in this ever-changing world. The final solution was that 150 NRP/month connection fee would be collected for each household, which includes 3 kWh per month, but the more affluent residents would help pay the connection fee for the poorest ones.

5. Data Collected

5.1 Monitoring System

A wide range of operational parameters of the system are captured every 15 minutes and exported daily to the RIDS-USA.org website. They can be viewed via the web at http://mohari.rids-usa.org/monitor.php (RIDS-Nepal, 2019a). An improved presentation which will be accessed using the same URL is under development as of July 2019.

The monitoring system stores data from several sources. The power electronics from Studer Innotec provides many parameters dealing with energy production and consumption, as well as battery status. Examples include battery voltage, temperature, and state of charge; output kVA and kW from each inverter; and input voltage and power to each charge controller. Various water and air temperatures in the system, including the temperature of the shower water, are sampled by the custom PCBs mentioned earlier in this article. The monitoring system also captures how much power is being delivered to heat the water for the two showers.

5.2 User Feedback

The village users and the local and regional political leaders are all very happy with the system. Thanks partially to its modular nature, it has been running non-stop since it was commissioned in Nov 2018, aside from very brief interruptions for normal maintenance and enhancements, as compared to traditional systems in the area that are turned off for long periods of time each day and often live a very short life. The additional loads in the village also help everyone realize the power of electricity, even before the village economy grows by utilizing it.

6. Summary

Based on the operation of this pilot system for one year, RIDS-Nepal's modular approach to pico and micro-hydroelectric systems appears to have solved many of the problems seen with the traditional approach used in remote regions of Nepal. The use of buried penstock, transmission, and distribution lines reduces maintenance and deforestation, preserves farmland, and helps prevent energy theft. The modular use of smaller more contextualized Powerspout direct-drive turbines result in high system reliability through redundancy. Repairs are more economical to small remote systems incorporating prepayment meters to ensure a modest revenue stream. Its surge capability will be useful in starting motors needed for economic expansion. And finally, the full use of the produced power has increased the value of the system, making the end users more willing to pay into the economic system enforced by the prepay meters.

This pilot project was created to explore and verify the operation of the system with different configurations simply by turning the modular components on or off, for example to operate a single turbine, or all six. It was scaled to run as many as 6 turbines, supplying over 6 kW, which is much larger than that needed by a small village being introduced to electricity. Most early adopters of electricity will need only one or two turbines, and won't need 3-phase transmission at first. Replicated systems also won't need quite as extensive monitoring, but will need enough to enable remote support by more educated personnel. Another project is planned to explore the costs of a minimum system needed to support a reasonable sized village just being introduced to electricity.

The end goal of this project is the broad replication of this approach which will require design and installation guides, finding ways to manufacture some of the components in Nepal, creation of an ecosystem needed to support the projects, and working with the Nepali government's AEPC (Alternative Energy Promotion Center) by recommending policies needed for broad replication. Some of these tasks are currently being pursued.

7. Acknowledgments

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- REPIC, Renewable Energy, Energy and Resource Efficiency Promotion in Developing and Transition Countries, An interdepartmental platform of the Swiss Federal Government
- Itron provided the ACE9000 SSP DIN-R STS prepay meters.
- iPay provided the prepaid electricity vending solution.
- Studer Innotec provided the Extender system.
- Schweitzer Engineering Labs provided the ultra-high reliability computer systems.
- Aurora Power and Design, Boise, ID, USA provided most of the miscellaneous equipment needed in the project, as well as a heavy dose of technical advice.
- Ecoinnovation, New Plymouth, NZ, provided the turbines and valuable advice.
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8. References

iPay, 2019, http://ipay.co.za/ (accessed 25 July 2019)

Itron, 2019, https://www.itron.com/-/media/feature/products/documents/brochure/ace9000-ssp-dinr.pdf (accessed 28th July 2019)

Morningstar, 2019, https://www.morningstarcorp.com/products/tristar/ (accessed 28th July 2019)

PowerSpout, 2019, https://www.powerspout.com/collections/pelton-plt (accessed 28th July 2019)

RIDS-Nepal, 2019a, http://mohari.rids-usa.org/monitor.php (accessed July 28, 2019)

RIDS-Nepal, 2019b, "Modular Pico-Hydro Power Plant Prototype Project in Mohari Village, Jumla, Nepal", RIDS-Nepal youtube channel with videos for illiterate people and education, https://www.youtube.com/playlist?list=PLM5tNUriiE49lBkt4TVQScwvnfKpSCBUs (accessed 26th July 2019)

Schweitzer Engineering Labs, 2017, https://selinc.com/products/3360/ (accessed 25 July, 2019)

Stambaugh, M., et al, 2017, "Improving the Utilization Factor of Islanded Renewable Energy Systems", Proceedings of the ISES Solar World Congress 2017, DOI: 10.18086/swc.2017.16.04

STS Association, 2019, http://www.sts.org.za (accessed 25 July 2019)

Studer Innotec, 2019a, https://www.studer-innotec.com/en/products/xtender-series/ (accessed 28ty July 2019)

Studer Innotec, 2019b, https://www.studer-innotec.com/en/products/variostring-series/ (accessed 28th July 2019)

Sturdivant, R., et al, 2017, "Pico-Hydro Electric Power in the Nepal Himalayas", IEEE Green Technologies Conference (GreenTech), 2017, DOI 10.1109/GreenTech.2017.40.

Yeh, J., et al, 2019a, "Prioritized Load Control System for Pico-Hydroelectric Power in the Nepal Himalayas," submitted to IEEE Green Technologies Conference (GreenTech), 2020.

Yeh, J., et al, 2019b, "Programmable Turbine Failsafe System for Pico-Hydroelectric Power in the Nepal Himalayas," submitted to IEEE Green Energy and Smart Systems Conference, 2019

Zahnd, A., et al, 2017, "Modular Pico-Hydro Power System for Remote Himalayan Villages", World Renewable Energy Congress XXVI. DOI 10.1007/978-3-319-69844-1_45

ANNEX 4

Pico/Micro Hydroelectric Policy Recommendations to AEPC

Current Situation

Nepal's current electrification strategy is to connect all of Nepal to the macro-grid based on a conversation with AEPC mini-hydro team leader British Singh. This approach has many merits including higher capacity to satisfy a small community's peak loading, and higher utilization of available energy generation resources by sending excess energy to the macro-grid.

Australia's electrification policy is essentially the same, and generally works well for them. However, the cost to maintain the transmission lines to remote communities proved to be very high. So high that it made sense to remove some of the existing transmission lines and install islanded solar electric facilities to serve some remote communities, which is what happened (https://www.pv-magazine.com/2019/10/04/australias-horizon-to-replace-overhead-network-with-solar-and-batteries/). Although it could be argued that the distance between communities in Australia's Outback is larger than that in Nepal, their terrain is much gentler on transmission lines than Nepal's. RIDS-Nepal is wary of any solution that fits all situations. We believe Nepal will experience similar if not worse costs if they continue to follow a broad policy of connecting all communities to the macro-grid.

Furthermore, macro-grid reliability relies on a network of multiple redundant transmission paths, but this redundancy won't happen throughout remote Nepal for many years, if ever.

Nepal has attempted to build islanded micro-hydro and pico-hydro electricity grids in remote Nepal, with limited success due to seven reasons presented in "Pico-Hydro Electric Power in the Nepal Himalayas" by Sturdivant et al .

Table 1: Reasons the Existing Pico/Micro-hydroelectric Approach has Limited Success (*text in italics is added for better understanding*)

Exposed Canal: Susceptible to destruction from small surface landslides common in the Nepal Himalayan regions due to increasingly heavy monsoon rains owing to climate change and the constant subducting of the Indian tectonic plate under the Eurasian tectonic plate in the North. *In contrast, the Modular Pico-Hydro Power Plant concept includes underground buried HDPE pipes as penstock which are far more protected from the natural elements*.
Single Turbine: Offers no system redundancy and it's difficult to add additional turbines due to phasing issues. *Single turbine micro-hydro power (MHP) plants have to be greatly oversized, so that they cover the next 10 – 20 years load demand growth of the user community. Thus, usually the first 10 years the MHP plants are far too costly to operate and maintain, as the users use only a tiny fraction of the power generated as they learn to live with electricity, but are burdened with the maintenance costs of a mature system. Further, the cost per unit (kWh) electricity is usually heavily under paid, making it impossible to operate and maintain the MHP. That results very often in a premature breakdown of the MHP system, leaving the user community without electricity and a negative experience. In contrast, with a modular pico-hydro power plant concept, the first few years only one turbine is installed to cover the initial user demand which is usually very low. Once the user community has learned the value of electricity and can operate and maintain the small system*

through realistic unit price, additional turbines can be installed according to the user community's load demand growth and ability to pay for the system.
Belt Drive: Belts usually break within 3 years or less and are expensive to replace as they have to be imported from abroad, usually from Switzerland. *In contrast, the Modular Pico-Hydro Power Plant concept includes only direct driven turbines, eliminating the need for drive belts*.
Overhead Transmission Lines: Used dead trees which rot since they are not treated to resist moisture. Support failure results in line fault. The already huge deforestation and loss of important and valuable forests, is further increased due to the need to replace the rotted poles every 3-5 years. *In contrast, the Modular Pico-Hydro Power Plant concept includes underground buried armored cables, designed with to carry the future maximum anticipated generated power with multiple turbines added over the life cycle of the power plant. In this way no trees need to be cut at all and the transmission lines is as well much more protected from the elements and safer for the users, as now open cables go through the village*).
No Surge Capability: Peak demand over generator capacity requires load shedding. *In contrast, the Modular Pico-Hydro Power Plant concept, which generates high voltage DC electricity, in order to join all the additional turbines added in the future in parallel, includes a small battery bank and sufficient large designed inverters to provide high quality AC power to the users. In this way, short term peak demands, such as when e.g. an AC motor is started for an income generation task such as a carpentry workshop, can easily be provided by increased power delivery from the battery bank and converted by the inverters.*
No Financial Plan: No economic plan to support maintenance and operations. No plan for collection of fees*. In contrast, the Modular Pico-Hydro Power Plant concept includes a pre-paid PAYG system which allows each consumer to keep control over his/her power usage accordingly what they can afford to pay. The costs per unit (kWh) is based on a power plant life cycle cost analysis and agreed to be paid by the user community. That teaches the users from the start to be wise with the electricity consume as each one has to pay as much as they use.)*
Dumped to Exit Water: Excess power is dumped into the exit water stream as heat. Utilization, and therefore the value of the system, is very poor (*commonly between 5% - 10%*). This low value makes it difficult for a community to justify the high cost of maintaining the system until it is connected to the macro grid and its utilization improvements. *In contrast, the Modular Pico-Hydro Power Plant concept includes "smart dump loads" in the systems. That means, when additional power is available from the power plant, additional useful electricity consumers, such as hot water heating systems for personal hygiene (showers), and room heaters, heating of bio-gas digesters etc. all for a defined user cost, are included in the power plant. In this way the utilization of the Modular Pico-Hydro Power Plant concept can be up to 100%, making the power plant much more economical feasible and realistic.*

RIDS-Nepal has built a pilot modular pico-hydroelectric system in Moharigaun, Jumla district, addressing all of the above causes of limited success.

Table 2: How the Mohari Village System Addressed Reasons for Limited Success

Buried Pipe: Delivery of the water to the turbines with protection from surface landslides. Increases reliability.
Multiple Turbines: Allows redundancy to increase reliability and sustainability, lower replacement cost if one fails, system continues to provide power, and the ability to expand capacity as the village's electrical demands and economic vitality increase.

Direct-Drive Turbines: Each turbine is connected to its own generator. Eliminates risk of belt failure which increases reliability.

Buried Transmission and Distribution Lines: No supports are needed, which removes the risk of transmission and distribution line failures, preserves valuable forest resources, and protects the lines from the elements and mischief.

Battery Surge Capability: A small bank of batteries allows the system to deliver peak power in excess of generator capacity.

Use Smart Pay-As-You Go Meters: The system will only deliver power if you have already paid.

Excess Energy Utilized In The Village: System heats green house, community bathing water, and biogas digester.

RIDS-Nepal respects AEPC's strategy of eventually connecting electric systems to the macro-grid. Mohari village's modular system was constructed so that it can eventually be connected to the macro grid, or islanded when the connection to the macro grid is disrupted.

The system has been running non-stop, utilizing 100% of the available energy, since the 30th November 2018 (~18'000 hours running non-stop by the 18th December 2020, and around 20'000 hours by around the 12th March 2021). Based on this success, RIDS-Nepal staff Mr. Muni Raj Upadhyay submitted the following policy change recommendations to address the electrification of small isolated communities in the Nepal Himalayas to the Executive Director of AEPC, Mr. Madhusudan Adhikari, on the 22nd January 2020. A second meeting with the Executive Director of AEPC, Mr. Mark Stambaugh, Mr. Muni Raj Upadhyay and Dr. Alex Zahnd, to deepen the discussion and explain the recommended policy changes, was planned for the 27th March 2020. However, this meeting had to be cancelled due to the strict look-down of Nepal and the inability for Mr. Mark Stambaugh and Dr. Alex Zahnd to enter the country for the planned spring 2020 project field trip and meeting with AEPC.

Policy Recommendations Applicable to All Pico/Micro-Hydro Systems

Improvements outlined in this section are applicable to any Pico/Micro-Hydro system, including ones built using the traditional single large spinning generator.

Buried Penstock and Transmission Lines

Future pico/micro-hydroelectric systems should use buried penstock and transmission lines to prevent the failure of these components due to either mischief or exposure to the elements, and to preserve valuable farm land and timber resources.

Prepaid Electric Meters

Future and existing pico/micro-hydroelectric systems should incorporate prepay electric meters to guarantee the revenue stream needed to support an operator's salary and maintain the system. Furthermore, a prepayment system ensures that the electrical resource is consumed equitably among its customers to maintain harmony in the community. This is done through:

1) economic penalty for using incandescent light bulbs and large loads, and
2) by programming each meter to limit the peak load of each user much like an MCB.

Policy Recommendations Applicable to a Modular Pico/Micro-Hydroelectric System

The following requirements are technically and economically achievable. RIDS-Nepal recommends them for adoption by AEPC.

Requirement	Justification
Modular approach	The system must be able to expand as the communities' needs and ability to pay increase. The use of multiple turbines and other components allow the system to continue operating even if one piece of equipment fails.
Direct-drive turbine-generators	This eliminates the need for an unreliable and expensive drive belt, and reduces the overall weight to ease transportation costs and increases end efficiency.
Turbine/generator efficiency >= 60%	The incorporation of a permanent magnet alternator (PMA), along with an efficient turbine design, achieves this efficiency specification. This is much better than any turbine using a traditional generator, allowing the community to generate as much power as possible from available water resources.
Light enough for a single Nepali to carry	This is very important for remote villages where the turbines must be carried for multiple km or even days. The turbines used in the RIDS modular pico-hydro power plant weighs a total of 23 kg, which can easily be carried by one person for hours. Additionally, it reduces transportation costs.
Overall annualized cost of ownership must be bearable by the community served	Any power generation plant has to be paid for, including the salary of an operator and other expected operation and maintenance costs, largely ore completely by the users' pre-payment for the consumption of electricity. Therefore, the unit (kWh) cost has to be based on a simple life-cycle costs analyses of the planned power generation plant.
A field-serviceable repair kit for the turbines must be included in the original system cost	The traditional turbine and generators of MHP plants (~10- 100 kW) need to be shipped back to Butwal or where they have been manufactured in the Terai, often via air and land-transport, to be repaired or reconditioned. This results in considerable cost which is never included in a traditional MHP plant's original economic analysis. It also results in significant system down-time. A field-serviceable turbine/PMA, along with a turbine repair kit, will eliminate the cost, and return the turbine to service in hours instead of weeks.
System must be capable of delivering for 30 seconds 2x the power provided by the turbine/generators	Traditional pico/micro-hydroelectric turbine/generators are sized to meet future surge demand. Motors present a surge demand at startup approximately 3 time their normal rated demand, traditionally requiring largely oversized turbines and generators just to meet this short-term demand surge. The use of a small battery bank and appropriately designed inverters allows the system to start motors without bearing the cost of oversized turbine/generators. The use of a battery bank also provides a DC summing point which vastly simplifies the addition of multiple turbine/PMAs (no costly and technical complicated AC synchronization needed) as well as any other hybrid renewable energy resource such as wind and solar.

AEPC Support for an Ecosystem

The specifications listed above imply a system that would technically challenge personnel available in many developing communities. Beside the annual in person project visits by the project developers (Mr. Mark Stambaugh and Dr. Alex Zahnd) to train the operators and users (except in 2020 due to the completely, country wide look-down), an engineer in the USA and one in Switzerland have used remote monitoring, email, and Skype meetings since November 2018 to support the Mohari village project. The system has operated since it initial start end of November 2018 till to date continuously, proving that the technology gap can be addressed. However, while for a prototype/research project such volunteer support is feasible and needed, it cannot be broadly replicated for future commercial power generation plants. Therefore, some means of support must be available as a Nepali-run business to design, construct, and operate these systems. This issue will have to be brought forth to and discussed with AEPC to add to, or integrate into, their already available policies.

Such a business would be funded by the pre-pay system in each community served. Its technology support should be structured as follows:

Operator in the community served	• Performs routine maintenance such as cleaning intake filters and greasing turbine bearings. • Performs diagnostic and simple repair tasks as directed by higher trained technical staff. • Operates a vending station in the community to fill pre-pay meters
Electrician in the District Center	• Directs and educates the operator of each system • Travels to the site to monitor the system, educate the operator and community members, and perform any diagnostic and repair tasks the operator cannot perform. • Works with local communities to identify upcoming system expansions of established and running systems due to load demand increase in the user community and good prospects for future new systems and prepare the community for its arrival. • Performs site surveys & works with engineers in Kathmandu to develop new modular pico-hydro power plant systems. • Project manager on new construction
Engineer in Kathmandu	• Design of new modular pico-hydro power plant systems based on site surveys performed by district electricians. • Remotely monitor systems. • Educate the electricians in each district. • Direct the electricians.

There's a 'chicken and egg' situation here. An ecosystem is needed to build and operate these systems, but the ecosystem isn't viable until there are a number of systems built. Two things can help alleviate this.

1. A pre-payment system can be deployed in existing pico- and micro-hydroelectric systems. This business can use that income to pay a local operator to maintain that system and provide funds for the ecosystem business overhead. The ecosystem business can also upgrade the legacy pico/micro-hydro systems to a modular approach if it makes sense.
2. A combination of donor, government, and entrepreneurial funding can provide the seed capital to start such a business and operate it until a sufficient number of systems can be built to maintain that business.

ANNEX 6

RIDS-Switzerland - Mohari Village Modular Pico-Hydro Project
4th Project Progress Picture Report for REPIC – January 2020
(REPIC participatory funding Contract No.: 2017.14)

Pic 1: Mohari Modular Pico-Hydro Power Plant Turbine house with the 6 Pelton turbines during the winter 2019/2020

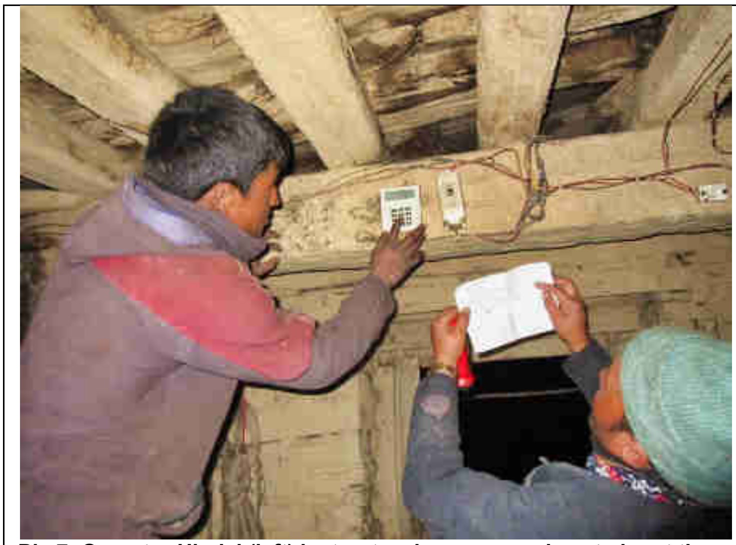
Pic 2: Pelton Turbine 1 of 6 forming icicles un der the nozzle ball valve. The river water temperature is just under 1° Celsius

Pic 3: A closed turbine nozzle ball valve caused the water to freeze inside the valve, cracking the hard plastic ball valve body

Pic 4: When a turbine is halted for maintenance and cleaning during winter a small stream of water flow has to occur to prevent the water from freezing inside the ball valve keeping it safe

Pic 5: Periodical cleaning and check-up of all 6 Pelton turbines of the Modular Pico-Hydro power plant in Mohari village. This is during the winter even more important than during the other seasons as the way below freezing ambient temperatures cause very harsh conditions for the materials and power plant to run

Pic 6: All 6 Pelton turbines have been running non-stop, 24/7 since the 30th November 2018. That means that by around the 22nd January 2020 the Mohari village Modular Pico-Hydro power plant has been running for 10’000 hours. Thus, a first milestone towards sustainability has been reached



Pic 7: Operator Hiralal (left) instructs a home owner how to input the digital code for his monthly pre-paid electricity units for his home

Pic 8: Input panel (left) for the code for the monthly pre-paid electricity units plus the security fuse (right) inside the home for safety

Pic 9: Cleaning the LED lamp inside the home

Pic 10: Family sitting around the warm smokeless metals stove in bright light without any smoke form cooking or indoor lighting

Pic 11: Electric light inside the home, power by the pico-hydro power plant brings so many advantages and improvements in health, ability to work inside after sunset and social life

Pic 12: Cooking with light inside the home is so much easier and healthier, especially for the women and children who spend the most time indoors

Pic 13: Cooking the evening meal with light inside the home, sitting around the warm stove while the winter night is freezing cold is so much better than ever before. The Mohari families are all very much aware of the manifold improvements in their lives

Pic 14: A warm and bright home allows as well some tasks and income generating activities in the evening along with the family.

Pic 15: A family during evening cooking time with some activities which can be done due to the bright light inside the home

Pic 16: Education and doing the home work is another huge benefit of having bright lights inside the home powered by the modular pico-hydro power plant

Pic 17: Women in particular enjoy the bright indoors as they are the ones who spend most the times of any family member indoor

Pic 18: The Modular Pico-Hydro Power Plant Turbine house with the 6 Pelton turbines inside generating 24/7 up to 6.6 kW electricity when all 6 turbines run at their maximum power output (47 meters head and ~3-liter water per second per turbine)

Pic 19: Water overflow HDPE pipes of the sedimentation tank are being check and made sure they are not blocked by the ice building up all around by the operator

Pic 20: HDPE water filter pipe in the sedimentation tank which cleans the water running down the 460 meter long HDPE penstock to the Pelton turbines from any debris which could damage the turbine runners

Pic 21: Periodical cleaning of the surface water from leaves and sticks in the sedimentation tank by the operator

Pic 22: Periodical cleaning of the surface water from leaves and sticks in the sedimentation tank by the operator

Pic 23: With sub-freezing temperatures outside during the harsh 4 winter months in Mohari village it is wonderful to sit in front of the “smart dump load room heaters” to warm up

Pic 24: Warming up in front of the “smart dump room heaters” in one of the rooms in the Mohari village Community/power house before heading back out again for work

ANNEX 7

RIDS-Switzerland - Mohari Village Modular Pico-Hydro Project
3rd Project Progress Picture Report for REPIC - June 2019

(REPIC participatory funding Contract No.: 2017.14)

Pic 1: Mohari Village by night with the Modular Pico-Hydro Power Plant generating the electricity for all demanded energy services of the village and power/community center

Pic 2: Mohari Village (42 families, 250 people) by day with its Eastern Part (right) and Western part (left) and the power/community house of the modular pico-hydro power plant in the middle on a slightly elevated hill, built on land provided by the local people. Mohari, in the North-East of the Jumla District, lies at 29° 20’ 07” North Latitude, 82° 22” 28” East Longitude and at an Altitude of 3’150 meters (10’335 feet) above sea level.

Pic 3: Power/community house of the modular pico-hydro power plant with the power room, all DC to AC equipment, the battery bank and the AC distribution

Pic 4: Turbine house of the modular pico-hydro power plant with the 6 PowerSpout Pelton turbines. 47 m Net Head, ~20 L/sec flow, 6.6 kW power generation = ~ 72% eff.

Pic 5: The modular pico-hydro power plant's turbine house with the 6 Pelton turbines is located at the bottom right, connected via armored underground cables to the 300 meters away located village and power/community house where the generated power is managed and distributed to the village and the various smart dump loads.

Pic 6: The 6 PowerSpout Pelton turbines in the modular pico-hydro power plant turbine house. A 490 m long, 200 mm HDPE penstock pipe, half a meter underground buried, brings the clean water from the sedimentation tank down to the turbines. The DN200 16 bar Gate Valve is adjusted to the needed head (max. 47m) and water flow (max. 20L/sec) to regulate power generation. The modular pico-hydro power plant can generate from 300 W (one turbine at 30%) to 6.6 kW (6 turbines 100%), based on the village's power demand. Thus initially one turbine is sufficient, with additional turbines added, "growing dynamically" with the village's increasing power demand over the years.

Pic 7: There is place, sufficient water and cable capacity for additional 2 turbines

Pic 8: Every individual turbine can be shut down for inspection, maintenance or repair by simply closing its two ball valves (red handles) to cut the water flow to the two jets of the Pelton turbine. The other turbines continue to produce electricity.

Pic 9: Monthly each turbine is greased as part of the periodical maintenance while the turbine is running producing its expected power output

Pic 10: Monthly greasing of each turbine while it is continue to generate electricity

Pic 11: Monthly inspection of the Pelton turbine

Pic 12: PowerSpout Pelton turbine running with its two jets

Pic 13: Monthly inspection and maintenance of each turbine and piping system

Pic 14: Periodical inspection and cleaning of each turbine, valve and piping system

Pic 15: End cap of the 490 m HDPE penstock with a maximum Net Head of 47 m. Analog and digital pressure gauge are mounted to monitor the net head

Pic 16: With a Net Head adjusted to 3.4 bar (34m), the 6 turbines generate 4 kW. The blue ball valve is the flush out valve to clean the penstock once a month

Pic 17: Periodical cleaning of the emergency power dump load in turbine house

Pic 18: Cleaned emergency power dump load (up to 8 kW) in turbine house

Pic 19: 6.6 kW maximum power generation of all 6 turbines a 47 m, ~ 20 L/sec, resulting in an overall ~72% Power Conversion Efficiency (in AC) in the village

Pic 20: Maximum net head of 47 m (4.7 bars). Based on the village's and power & community house based power demands this pressure is adjusted for power generation

Pic 21: Daily cleaning of the sedimentation tank at the sluice gate and intake tank

Pic 22: Daily cleaning of the HDPE intake filter at the sedimentation tank

Pic 23: Daily cleaning of the sedimentation tank at the intake

Pic 24: Cleaned HDPE intake filter at the sedimentation tank and overflow pipes

Pic 25: Power/Community house hot water shower (part of the regulated "smart" dump load, based on the power generation and the village's power demand)

Pic 26: Power/Community house hot water shower room and toilet, both with access to hot water as part of the various "smart" dump load energy services

Pic 27: Inside the Power/Community house hot water shower room. The shower temperature can be adjusted from 10 °C (50°F) during no use and winter, up to 55 °C (131 °F) through the Configuration site (http://www.mohari.rids-usa.org/config.php)

Pic 28: The hot water us monitored via: http://www.mohari.rids-usa.org/monitor.php

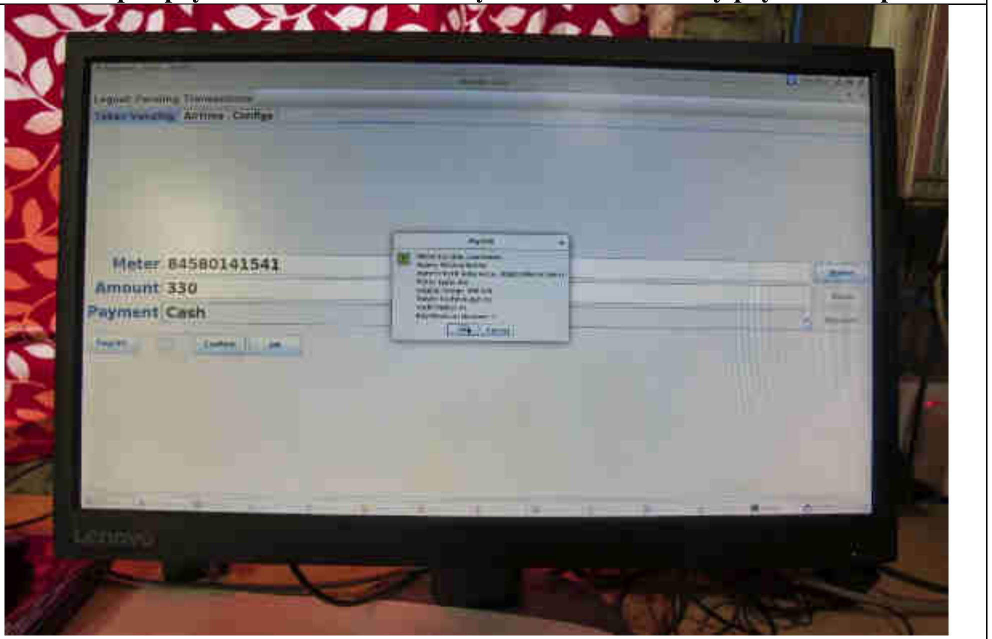
Pic 29: Once a while a hot shower improves the local peoples' hygiene an health

Pic 30: No question, a warm/hot shower for 10 NRs/person is very much appreciated

Pic 31: Installation of the smart meters in the various junction boxes in the village

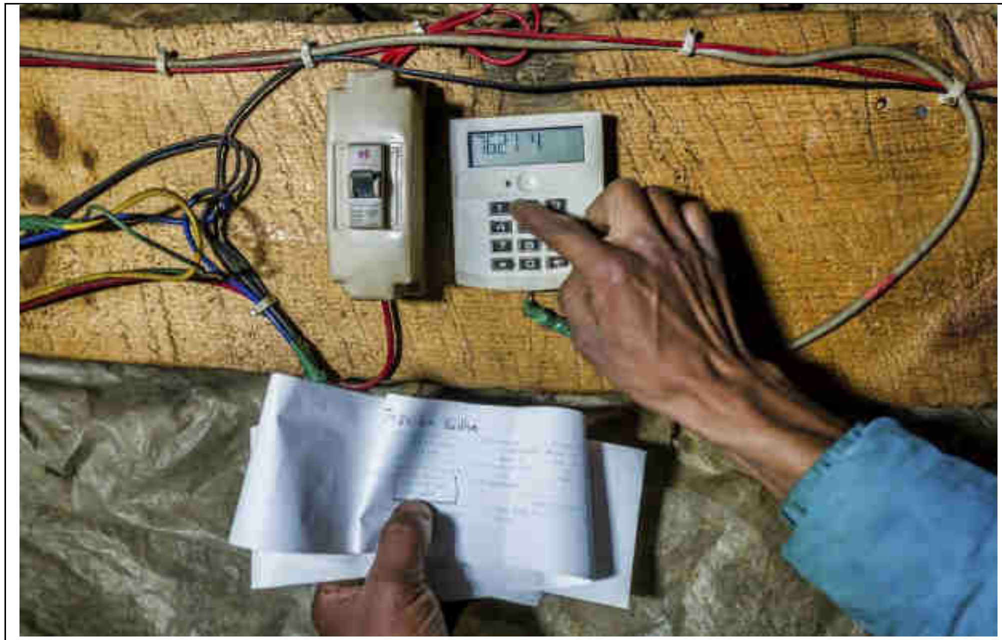
Pic 32: The pre-payment PAYG PV based system for the monthly payment for power

Pic 33: At least once a month each family has to pay a minimum of NRs 150 for the basic connection fee and 3 units (kWh) energy for their 3-4 LED lights an one phone



Meter 84580141541
Amount 330
Payment Cash

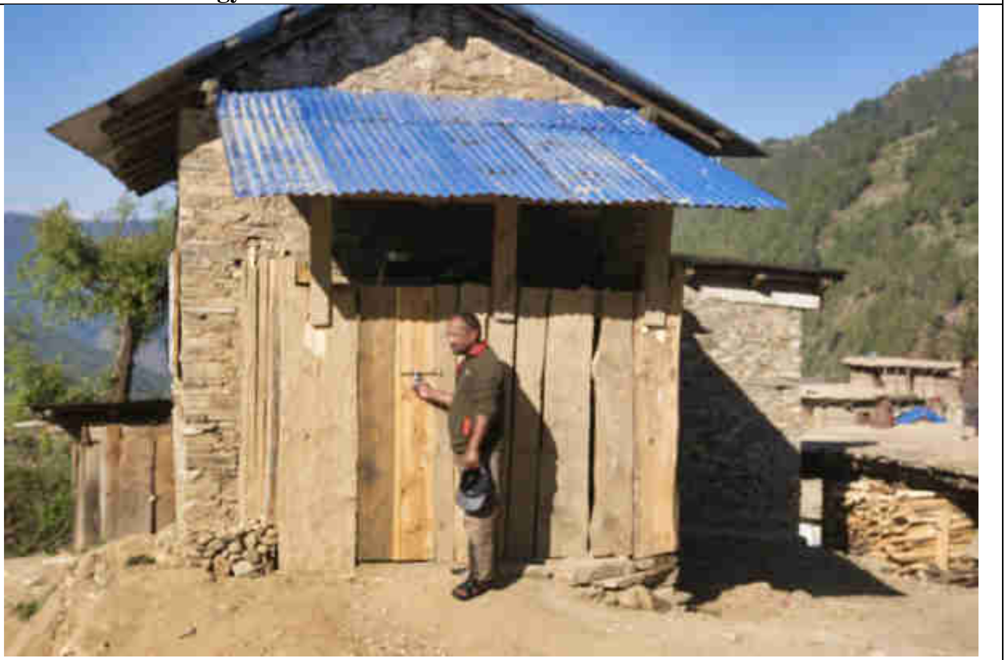
Pic 34: Each family is registered in the PAYG system and has a unique user number which is checked before their monthly pre-payment is processed and the token printed



Pic 35: The unique printed token number for their paid monthly energy is input in the user's home display, connected to the dedicated smart meter to add energy units

Pic 36: Once the token number issued by the PAYG system is accepted, the display shows the new energy the user has left.

Pic 37: The smart meter registers all energy use and displays the energy left



Pic 38: Village based warm/hot shower center with the hot water tank room in view

Pic 39: Checking the hot water tank of the village warm/hot shower center

Pic 40: Checking the intake ball valve of the hot water tank warm/hot shower center

Pic 41: Installation of the shower head in the village based warm/hot shower room

Pic 42: Installation of the shower head in the village based warm/hot shower room

Pic 43: Hot shower running in the village based warm/hot shower room

Pic 44: Hot water tap in the village shower room for operator to cleaning the shower

Pic 45: Net Head (x) – Power Generation (y) Curve for 6 PowerSpout Pelton turbines

Pic 46: Inauguration of the Mohari modular pico-hydro power plant on 21st June 2019

Pic 47: Inauguration of the village warm/hot shower center in Mohari on 21-06-2019

Pic 48: Local political leaders checking out the Mohari village warm/hot shower center

Pic 49: RIDS-Nepal Jumla coordinator Haripal Nepali is explaining to the local political leaders the Mohari modular pico-hydro power room and its role & functions

Patarasi Rural Municipality

Office of Rural Municipal Executive

Dillichaur ,Jumla

Karnali Province, Nepal.

Letter of Appreciation

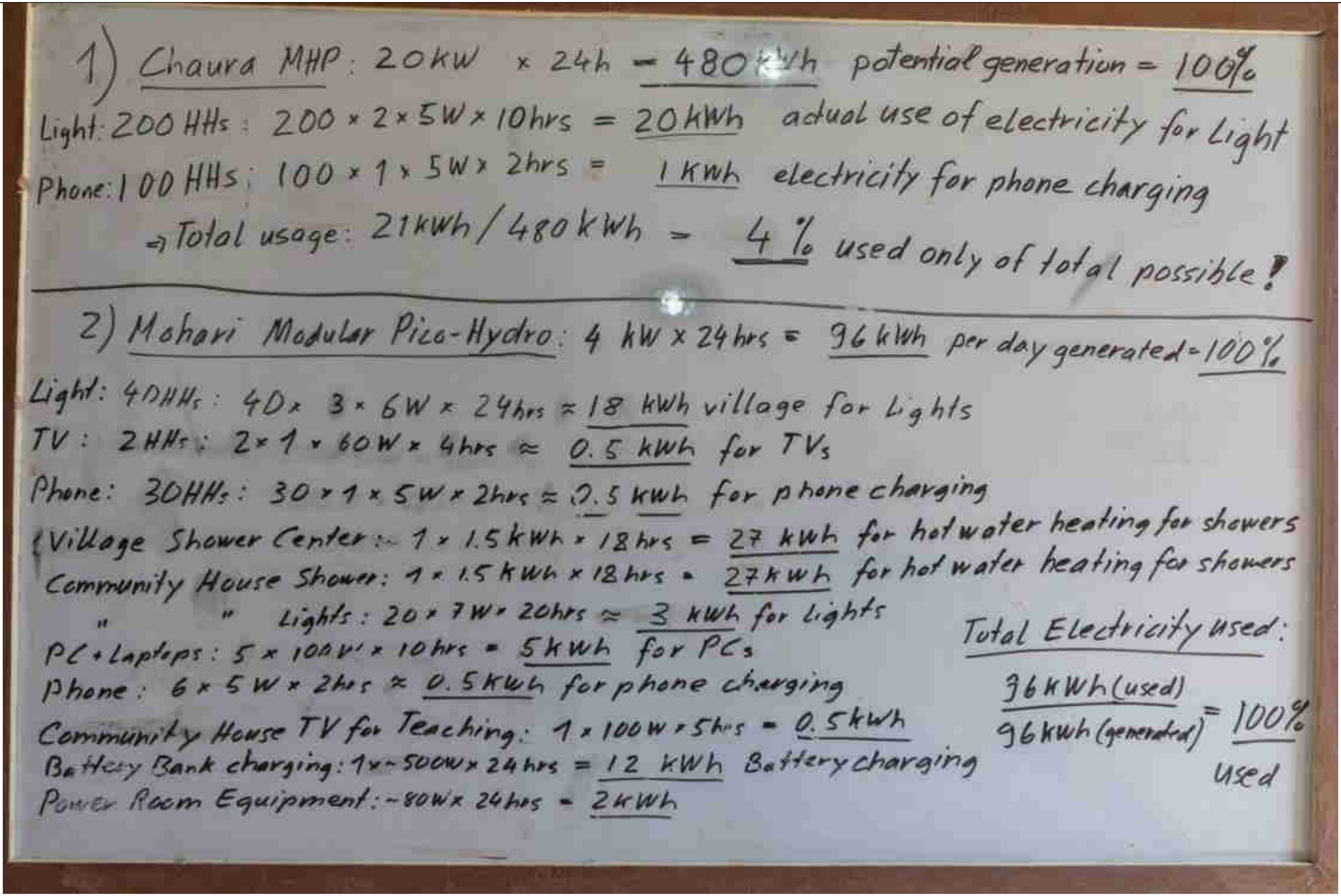
As decision made by Office of Executive, Patarasi Rural Municipality, Dillichaur, Jumla dated on 20 May 2019 would like to provide appreciation letter awarded to Dr. Alex Zahnd for the outstanding contribution to this Municipality through Rural Integrated Development Service (RIDS) Nepal, for the Development of Agriculture, Health, Sanitation and Renewal Energy Sector in this Municipality. We are highly appreciated for your kind contribution, with many thanks.

Wish you a wonderful and successful professional carrier ahead.

Chief of Administrative Officer

Chairperson

Pic 50: Award from the local political leadership for RIDS-Nepal's innovative modular pico-hydro and community development project in Mohari village and wider area



1) Chaura MHP: 20kW × 24h = 480kWh potential generation = 100%

Light: 200 HHs: 200 × 2 × 5W × 10hrs = 20kWh actual use of electricity for Light

Phone: 100 HHs: 100 × 1 × 5W × 2hrs = 1 kWh electricity for phone charging

⇒ Total usage: 21kWh / 480kWh = 4% used only of total possible!

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2) Mohari Modular Pico-Hydro: 4 kW × 24hrs = 96kWh per day generated = 100%

Light: 40HHs: 40 × 3 × 6W × 24hrs ≈ 18 kWh village for Lights

TV: 2HHs: 2 × 1 × 60W × 4hrs ≈ 0.5 kWh for TVs

Phone: 30HHs: 30 × 1 × 5W × 2hrs ≈ 0.5 kWh for phone charging

Village Shower Center: 1 × 1.5kWh × 18hrs = 27 kWh for hot water heating for showers

Community House Shower: 1 × 1.5kWh × 18hrs = 27kWh for hot water heating for showers

" " Lights: 20 × 7W × 20hrs ≈ 3 kWh for lights

PC + Laptops: 5 × 100W × 10hrs = 5kWh for PCs

Phone: 6 × 5W × 2hrs ≈ 0.5kWh for phone charging

Community House TV for Teaching: 1 × 100W × 5hrs = 0.5kWh

Battery Bank charging: 1 × ~500W × 24hrs = 12 kWh Battery charging

Power Room Equipment: ~80W × 24hrs = 2kWh

Total Electricity used:

$\frac{96\text{KWh(used)}}{96\text{kWh(generated)}} = 100\%$ used

Pic 51: Comparison of the utilization factor (actually used electricity/energy services in kWh per 24-hour over the total potential kWh possible to generate per day for a defined hydro-power plant) of a traditional MHP (Micro Hydro Power) plant (with no smart dump loads, no underground cabling, no pre-payment PAYG smart meters, etc.), such as in neighboring Chaura village with a 20 kW MHP plant (with a max. utilization factor of ~3- 8%), and the new, RIDS developed, modular pico-hydro power plant, with 100% utilization of the max. daily energy generated for defined "energy services" such as light, phone charging, hot water, room heating etc. through electricity.

Pic 52: Mohari village fully electrified through armored underground cables into each home, saving precious Himalayan pine trees for poles. That not only increases the security for uninterrupted electricity through snow, storms, floods and rains, but actively fights the fast increasing deforestation Nepal faces nationwide.

Pic 53: Power/Community (P/C) house serves as learning, research and tourist center

Pic 54: RIDS's office and staff center in the Power/Community house

Pic 55: The office serves as control center with Internet access for data transfer

Pic 56: National/International students come to conduct their research/dissertations

Pic 57: The Community Learning Center serves as awareness and teaching center for the local people to learn more about community development through lectures/videos

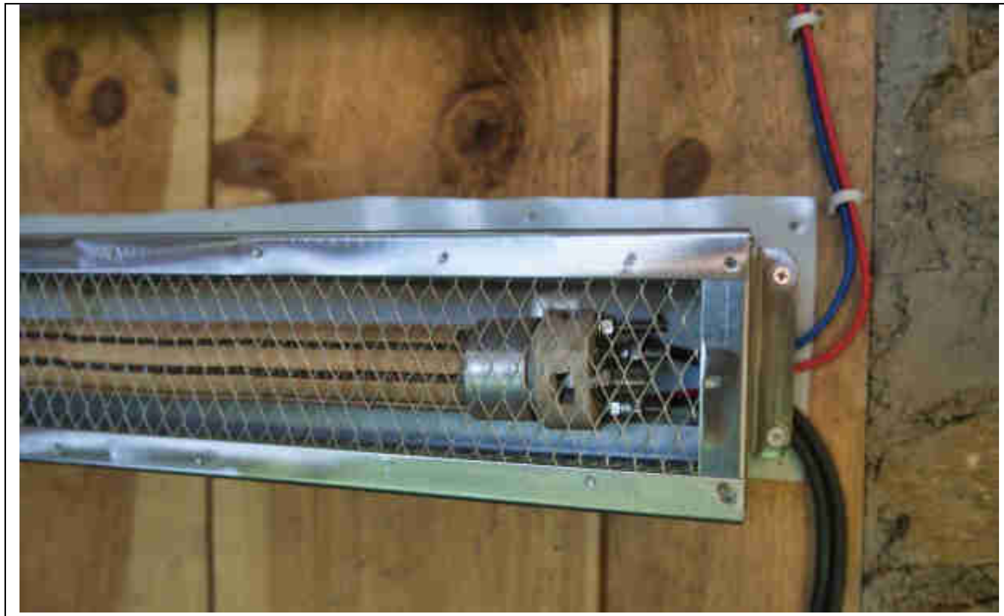
Pic 58: RIDS produces awareness/teaching/learning videos in Nepali language (some in English) for illiterate local people (mainly women), to increase their awareness and participation in community development projects (https://www.youtube.com/watch?v=RiuBizO9Qqs&list=PLM5tNUriiE49lBkt4TVQScwvnfKpSCBUs&index=3)

Pic 59: Learning/Library room for local people/students in the community house

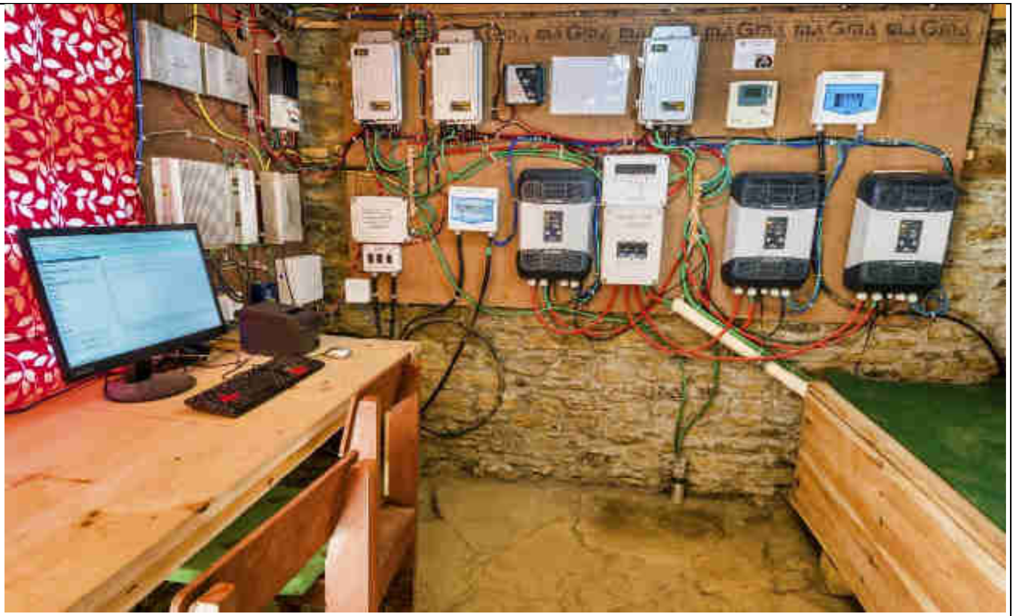
Pic 60: Kitchen to cater for all people staying and working in the community house

Pic 61: Dining room in the Power/Community house for all he RIDS staff, national/international students and visitors/tourists to Mohari village

Pic 62: Room heating (one of the various “smart dump loads”) to increase the indoor room temperature during the cold 10 months in the P/C house for improved comfort



Pic 63: The "smart" dump load room heaters are 48VDC resistive heaters which use power not immediately needed by the village but generated by the modular pico-hydro plant. The pico-hydro power plant's PC software allocates the various power demands, set based on different user energy service demand priorities, in real time



Pic 64: The modular pico-hydro power plant's power room in the P/C house with the village power distribution, DC/AC conversion and battery bank, able to provide e.g. for AC motor start starting time (<5sec) up to 15 kW power from a 6.6 kW hydro power plant. That enables income generation activities such as a carpentry workshop

Pic 65: Mohari Village with its 40 families (250 people) with the Modular Pico-Hydro Power Plant providing 24/7 all its increasing power and energy demands. All electrical lines are buried underground, providing maximum security and safety against the elements (snow, rain, storms etc.), saving precious local trees which would need replacement about every 3 years (as the Himalayan pine tree is a very soft tree that rots quickly if exposed to the elements).

ANNEX 8

RIDS-Switzerland - Mohari Village Modular Pico-Hydro Project
Project Progress Picture Report for REPIC - December 2019

(REPIC participatory funding Contract No.: 2017.14)

Pics. 1-3: Nepal Himalaya Mountain range and Mohari Village (42 families, 250 people). Mohari, in the North-East of the Jumla District, at 29° 20’ 07” N Latitude, 82° 22” 28” E Longitude, Altitude 3’150 meters (10’335 feet) above sea level. Left: Power house in middle of Village, Turbine house at bottom. Right: Power house

Pics. 4-6: The Mohari Village Modular Pico-Hydro Power Plant with 6 x 1kW PowerSpout Pelton Turbines running in series at 50m head and 24 L/s water.

Pic. 7-9:Shortly after starting up the Mohari Village Modular Pico-Hydro Power Plant the Mohari families had to come and see their new power plant.

Pic. 10-12: After the heavy and long monsoon season from June - October (10 years height!) the built water pond was covered with boulders and tree logs. However the sedimentation intake was fully protected. In 2019 six more protective Gabon Wire cages will be built to protect the sedimentaion tank and pond even more.

Pic. 13-14: After cleaning up the boulders and wooden logs the pond, intended to slow down the water flow for increased sedimentation of water, sand and silt is again working as intended. In that way the sedimentation tank and the pond in front of it provide very clean water to feed into the penstock to power the 6 Pelton turbines.

Pics. 15-17: Covering the 460 m long HDPE 200mm diameter penstock with stones and mud for increased protection from the elements and farming activities.

Pics. 18-20: Covered, protected 460 m long, 50 m head, HDPE penstock pipe which carries 24 liter water per second to power the 6 PowerSpout Pelton Turbines.

Pics. 21-23: All the Equipment, such as the turbines, inverters, charge controller, PAYG system etc. which RIDS imported from New Zealand, Switzerland and Hungary respectivley, had to be transported by truck on a 1000 km road trip from Kathmandu to Jumla bazar, once all was released from custom after 3 months.

Pics. 24-26: From Jumla bazar all the equipment and material had to be loaded on a 4-wheel drive tractor to transport it in a one day trip from Jumla bazar to Mohari village on mountain dirt and stone roads.



Pics. 27-29: All main and house cabling is through armoured, undergroung cables, so the Mohari families had to dig trenches for all cables to reach the homes.



Pics. 30-32: At least one man and one woman from each family in Mohari village has been working with RIDS in all work for the Modular Pico Hydro Power Plant.

Pics. 33-36: From Mohari Village all the equipment and materials had to be carried by the Mohari people to the power plant site as there is no road or path beyond the village.

Pics. 37-39: Several local Mohari people have been trained by the RIDS staff in how to install the housewiring system, the cables, the LED lights, MCB (maximum current breaker) and switches.

Pics. 40-42: RIDS staff training and supervising local Moahri people in the house wiring installations.

Pics. 43-45: House wiring equipment for each of the 42 homes in Mohari village. 20 m red and black cables, 4 LED lights (3 x 3watt and 1 x 5 watt), 4 bulb connectors and switches, PAYG meter, 2 Ampere MCB and insulation tape, is made available for each household to be picked up before the installation.

Pics. 46-48: House wiring equipment for each of the 42 homes in Mohari village ready to be picked up. A detailed account is kept and signed by each user once picked up so that all users are listed for the collected material.

Pics. 49-51:Installation of the 11 different distribution boxes in the village (left) with the PAYG meters for each household. Installation of each MCB and pre-payment display box in each home (middle and right).

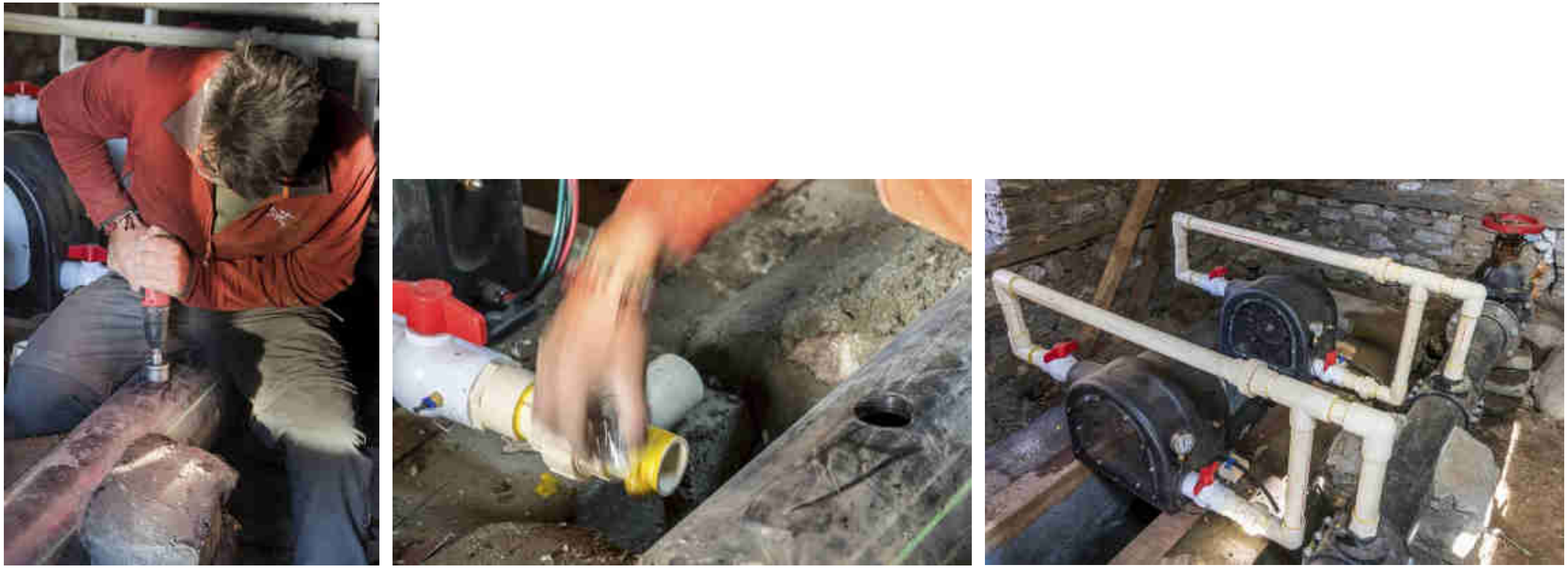
Pics. 52-54: All the local available materials such as stones, sand and wooden logs are collected and prepared (sand washed, stones cut and wodden logs cut and plained), by the local families from Mohari village as part of their voluntary participation in the modular pico-hydro power plant project.

Pics. 55-57: Inside the Pico Hydro Power Plant Turbine house. The last piece (of total 92) of the 5m long HDPE PN6 200 mm diameter penstock is installed and the water canal, to install the 6 Pelton turbines, is built. The 6 PowerSpout Pelton Turbines are installed (screwed on) on top of seasoned hard wood which is resistant to water for 20 years.

Pics. 58-60: The 6 PowerSpout Pelton Turbines, each generating about 1 kW at the defined location (50 m head and 4 Liter water per second per turbine) are carried from Mohari village to the turbine house.

Pics. 61-63: Building the water canal for the 6 PowerSpout Pelton Turbines to be screwed on top of the seasoned hard wood. The purposely built stone wall is cemented so that it lasts for years to come and so that it is leveled for the PowerSpout Pelton Turbines.

Pics. 64-66: Cementing the water canal for the 6 PowerSpout Pelton Turbines and layout of the penstock and turbines.



Pics. 67-69: Preparing the six, 2” holes in the HDPE penstock pipe in the turbine house to install the 6 saddles to connect the 2” PVC pipes to the Pelton turbines.

Pics. 70-72: 2” PVC piping installation to connect all the 6 Pelton turbines to the HDPE penstock.

Pics 73-75. Connecting new, armoured cables to the Pelton turbines so that the cables can be put underground inside the tubine house. Each PowerSpout Pelton turbine has 48 stator fingers with a rotor with 48 permanent magnets. Each PowerSpout Pelton turbine generates at 50m head and 4 L/s water 320 Volt DC, which is sent via underground, armoured copper cables (4 x 2mm2 size) to the 300 meter away Power House.

Pics. 76-78: Emergency, 8 kW resistor water heater in the turbine house. This emergency heater is used ONLY if all the other, normal user loads and all the other "smart dump loads" (warm water bathing center, biogas digester heater and room heaters in the power/community house) are NOT in use due to a technical problem in the power transmission line from the turbine house to the power house.

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Pics. 79-81: Under the direct supervision of the RIDS staff the Mohari village famlies are digging and buidling the 30 m long, underground buried, Modular Pico-Hydro power plant water outlfow HDPE pipe (225m diameter PN2.5), to lead the water used to generate the power back into the river.

Pics. 82-84: RIDS staff training the two local operators, Aitaram and Hiralal, how to operate and maintain the sluice gate valve of the sedimentation tank.

Pics. 85-87: Improving the sluice gate and HDPE intake filter, with 1060 x 8mm holes to protect the Pelton turbines from any particulates larger than 8 mm.

Pics. 88-90: Installed new HDPE 200 mm diameter Intake water filter with 1060 x 8mm holes plus the two 180 mm diameter HDPE overflow pipes, with the sedimentation tank, shown empty and filled. The washout is at the bottom right if the sedimentation tank. It enables to flash out the collected sand and silt constantly out of the sedimentation tank, improving the protection of the Pelton turbines at the end of the 460 m long penstock HDPE pipe.

Pics. 91-94: Finished building and operating the sedimentation tank, provding the 6 PowerSpout Pelton turbines with very clean water, without any sand or silt particulates. That will increase the life expectancy of the turbines significantly.

Pics. 95-97: Building the wodden box for the 200Ah 48 VDC battery bank for the Power room. Inside the power room, installing the various power electronic equipments such as the inverters, charge controllers, computer, switches and security systems.

Pics 98-100: Building the Super-Earthing system in the Turbine house (left) and the Power Room in the Power/Community House in the village (right) to make sure the whole Modular Pico-Hydri Power Plant is protected with a correct and proper earthing system.

Pics. 101-103: Training of the RIDS staff how to start and stop the Modular Pico hydro-Power plant by Dr. Alex Zahnd. In turn, the RIDS staff is training the local Mohari operators and village elders in the Operation &Maintenance of the Mohari Modular Pico hydro-Power plant.

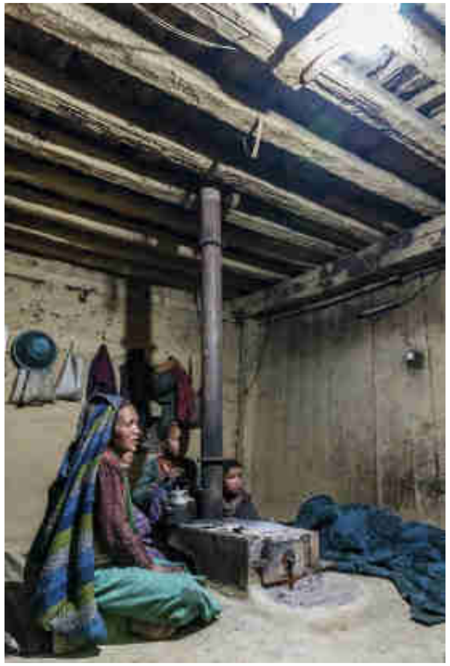
Pics. 104-106: Training of the local Mohari operators and village elders in the O &M of the Modular Pico hydro-Power plant.

Pics. 107-109: Training of the local Mohari operator Hiralal Buddha with a local woman checking out the new pico power plant. The electronic system in turbine house (right) to assure that the needed DC voltage is achieved and maintained during the operation of the 6 turbines.

Pics. 110-112: Training of the RIDS staff and operators in the use of all the equipment in the power room by Mr. Mark Staumbaugh. In turn, the RIDS staff is training the local Mohari operators and village elders in understanding what all te pieces of equipment mean and indicate of the Modular Pico-Hydro power plant.



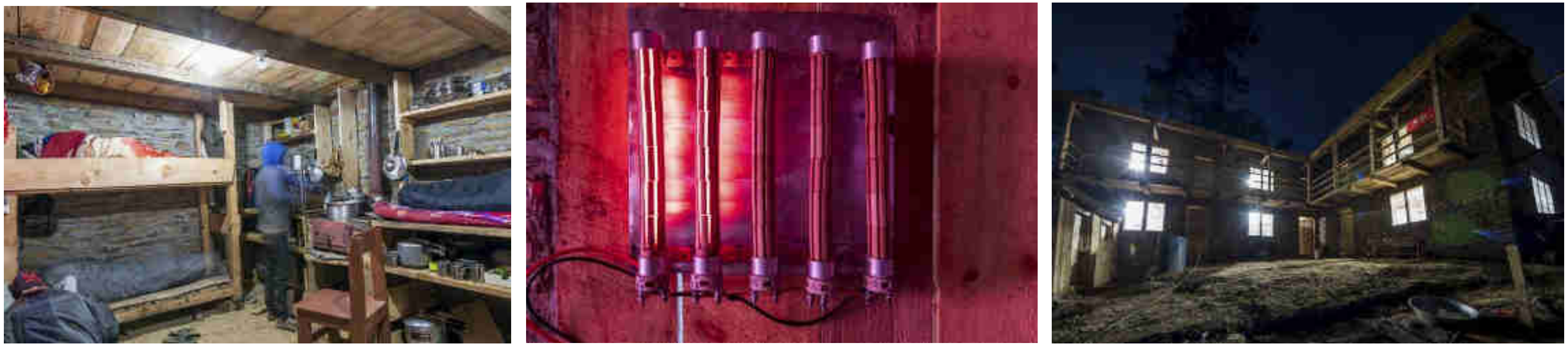
Pics. 113-115: Light (LED bulbs 3- max. 9 watt each in the power/community house) in all the rooms and kitchen (right) of the power/community house.



Pics. 116-118: Light (3 LED bulbs 3 and 1 LED max. 5 watt) in each of the 42 Mohari family homes. Also, each house already has a smokeless metal stove in their home and a pit latrine for eac family.

Pics 119-121: Lights are now on since the 30.11.2018, 24/7 in the homes of the Mohari families.

Pics. 122-124: Pre-payment display and 2 Amps MCB (left) and light inside 3-4 rooms in each of the Mohari family home.



Pics. 125-127: Power/community house kitchen (left), “smart dump load” resistor 48 VDC room heater (middle) and the 2 floor, power/Community house with light in each room.

Pics. 128-130: Different users and “smart dump loads”. Left: Warm water heating bathing system (inside 60 °C water with the inside drum lid with ice as the night temperature was around -5 to -8 °C). 2nd to left: charging of a mobil phone in one of the Mohari family homes. 3rd from left: Resistor (48VDC) room heater in the power/community house office. Right: Cooking with the RIDS developed smokeless metal stove and a LED light (3 watt) in the kitchen.

Pics. 131-133: Some of the 250 people from Mohari village. The Modular Pico-Hydro Power plant will provide in particlar long-term benefits to the young generation.

Pics. 134-136: Left: Modular Pico-Hydro Power on the 30th Nov. 2018. Middle: 5.61 kW Power generation. Aim was to achieve 5 kW, so aim fulfilled! Right: First movie and slide evening with over 120 local people taking part and enjoying the first community hall evening in the power/commnity house.

Pics. 137-139: People from Mohari village very happy to have now 24/7 light in their homes.

Pics. 140-142: Sunset over Mohari village and a girl saying NAMASTE (greeting in Nepali).

Pics. 143-144: Succesful joint project partnership between the Mohari village community and RIDS (28th November 2018) and sunset over Mohari Village.

ANNEX 9

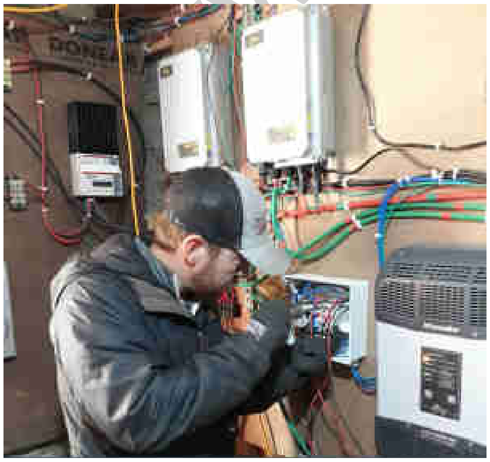
PowerSpout
WATER GOES IN POWER COMES OUT

PLT Case Study 10 – 7kW multiple PLT installation in Mohari Village (remote Nepal)

ecoInnovation

December 2018

CONTENTS



1. Background

A PowerSpout Gold Dealer Derek Jackson of Aurora Power in the USA was approached by the Swiss Charity RIDS for a hydro solution in a very remote Nepalese village at 10,000ft (3,000m) above sea level.

Powerspout turbines are an ideal solution for modern rural electrification projects based on a modular approach using multiple turbines, and battery storage to optimise energy usage.

Michael Lawley of EcoInnovation (makers of PowerSpout turbines) and Derek Jackson volunteered to assist with the installation that follows.

For a fascinating gallery of the surveying and construction of the intake civil works, the penstock pipe, powerhouse and buried cabling, see this link.

1.1. Prior technology

Nepal has many rivers and streams and many remote villages are already supplied by larger AC-direct turbines that typically exploit low head and high flow sites as shown in the picture below.

These schemes have often been put in by overseas donors. Limited power for lighting and small appliances is often provided free of charge with the local villagers responsible for ongoing maintenance costs.

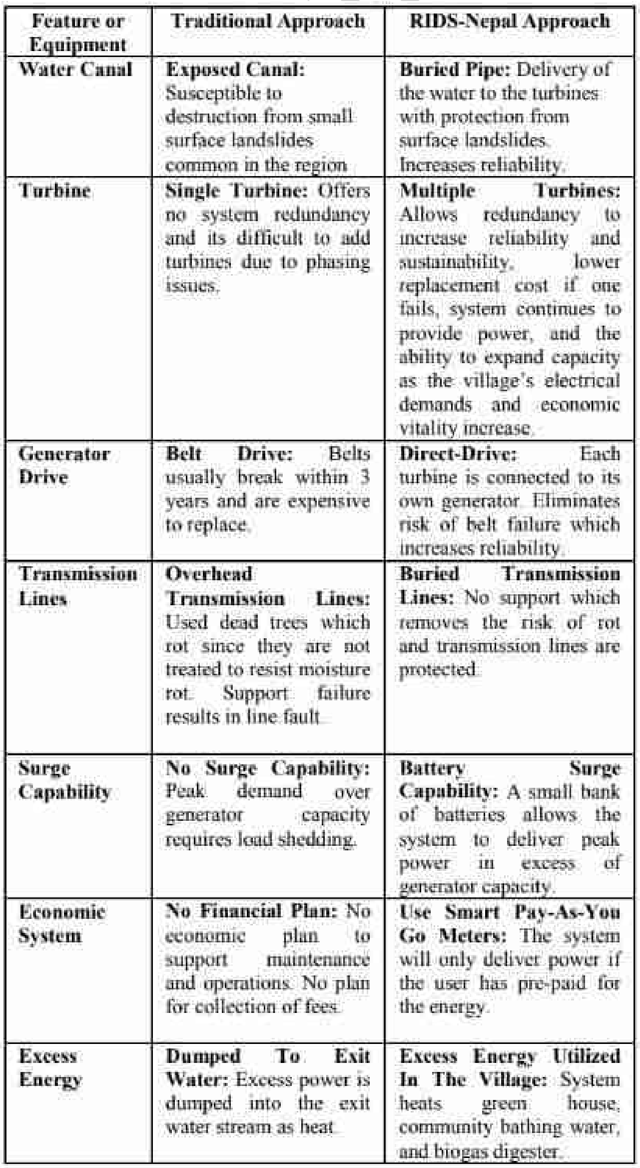
The success of these schemes is variable. The main issues are outlined in the table below in contrast to the battery-based solution used here.

1.2. The new approach

RIDS have been working out a new design approach to hydro power projects in the area, based on learning from the shortcomings of the previous projects.

The key features of the new approach are summarised on the right, and the full details are in these documents online:

- Pico-hydro Electric Power in the Nepal Himalayas
- Improving the Utilization Factor of Islanded Renewable Energy Systems



Feature or Equipment	Traditional Approach	RIDS-Nepal Approach
Water Canal	**Exposed Canal:** Susceptible to destruction from small surface landslides common in the region	**Buried Pipe:** Delivery of the water to the turbines with protection from surface landslides. Increases reliability.
Turbine	**Single Turbine:** Offers no system redundancy and its difficult to add turbines due to phasing issues.	**Multiple Turbines:** Allows redundancy to increase reliability and sustainability, lower replacement cost if one fails, system continues to provide power, and the ability to expand capacity as the village's electrical demands and economic vitality increase.
Generator Drive	**Belt Drive:** Belts usually break within 3 years and are expensive to replace.	**Direct-Drive:** Each turbine is connected to its own generator. Eliminates risk of belt failure which increases reliability.
Transmission Lines	**Overhead Transmission Lines:** Used dead trees which rot since they are not treated to resist moisture rot. Support failure results in line fault.	**Buried Transmission Lines:** No support which removes the risk of rot and transmission lines are protected.
Surge Capability	**No Surge Capability:** Peak demand over generator capacity requires load shedding.	**Battery Surge Capability:** A small bank of batteries allows the system to deliver peak power in excess of generator capacity.
Economic System	**No Financial Plan:** No economic plan to support maintenance and operations. No plan for collection of fees.	**Use Smart Pay-As-You Go Meters:** The system will only deliver power if the user has pre-paid for the energy.
Excess Energy	**Dumped To Exit Water:** Excess power is dumped into the exit water stream as heat.	**Excess Energy Utilized In The Village:** System heats green house, community bathing water, and biogas digester.

2. The system design

2.1. Choice of Power conversion equipment (PCE)

The project benefits from the support of the Swiss manufacturer Studer, who make PCE and who offered the necessary charge controllers and inverters at a substantially discounted price.

VS-70

MPPT solar charge controller

Upv max: 600V
Pnom: 4,2kWp
I batt: 70A
Ubat: 48V
Eff: 98%
MPPT eff.: > 99.8%
Self-consumption: < 1W
IP-54

2.1.1. Overvoltage protection

Most modern GTI's (grid-tied inverters) and a few MPPT charge controllers can operate at up to 600V (maximum DC input limit). This limit applies to the Studer Variostring charge controllers used here. We normally advise the use of 200V PowerSpout turbines so that the Voc of the turbines will not exceed 600V. This avoids any need for voltage protection measures at remote sites. This equipment increases system complexity.

We have published a guide to using the VarioString range of controllers here. We have limited experience the Studer VS-70. We had used one before for a job in Laos that worked well for a <1.5kW hydro site.

In this case (with a 500m cable) it was impractical to try to work the turbines at around 200V, which is the bottom of the VS controller's operating range. 300V was needed to get full output from these VS controllers, and hence voltage protection equipment would be needed.

These turbines were therefore designed to operate at 318V with a predicted Voc close to 1000V DC.

To operate safely and without problems, the turbines needed over-voltage protection including two elements:

- A shunt regulator using PWM control of load resistors to limit the voltage and keep the turbines on load without excessive voltage arising.
- A "crowbar" that short-circuits the turbine output in the event of the above failing. This is safe, but has to be manually reset before any power can be generated.

It is safe to short circuit the PowerSpout alternator as it has inherent current limiting but the controller input capacitors must not be shorted. This can be solved using a blocking diode but in this case it was solved by shorting into a resistive load to limit the current.

PowerSpout offer a suitable over-voltage protection unit including both elements (PWM and crowbar with blocking diode), called the PowerClamp.

It has been tested and is quick to install, but the project team preferred to design a new protection circuit, building and testing it for the first time on site.

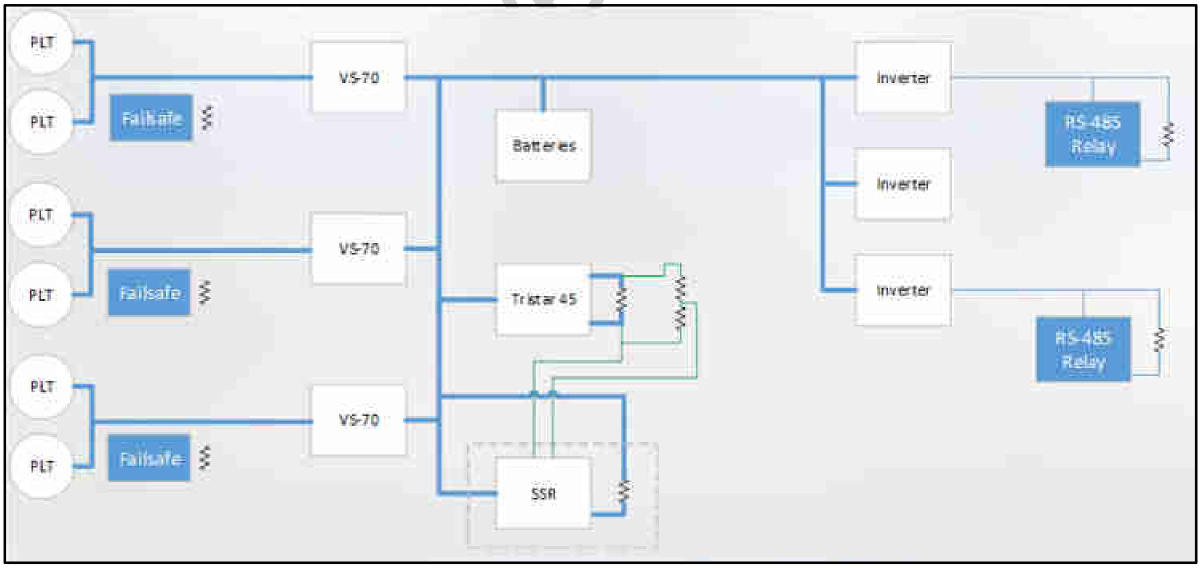
2.2. Online calculation

The online calculation tool was used as always to find the best solution and to optimise the turbine design. You can find the calculation online here.

Units: Metric
Used Flow: 24.1 lps
Pipe Head: 51.0 m
Pipe Length: 455 m
Pipe Diameter: 169 mm
Number of Powerspouts: 6
Nozzles: 2
JetDiameter: 10.0 mm
Pipe Efficiency: 94 %
Speed: 1149 rpm
Output per turbine: 1001 W
Total Output at turbines: 6005 W

Electrical
Output Voltage: 327 V
Cable Length: 500 m
Load Voltage: 300 V
CableMaterial: Copper
CableSize: 12.0 mm^2 (note: 4mm^2 for each of three pairs of turbines)
Cable Current: 18.4 A
Cable Efficiency: 92 %
Actual Total Output: 5506 W

2.3. Electrical system block diagram



3. Turbine installation

Just prior to our arrival on site the 6 x PowerSpout PLT HP 300V turbines had been installed. The picture opposite shows final tightening of the large pipe saddles onto the 200mm OD MDPE pipe.

3.1. Voc testing

Prior to the connection of the turbines to any power conversion equipment (PCE), Voc tests were done as follows. Click on links below to watch the video of each test:

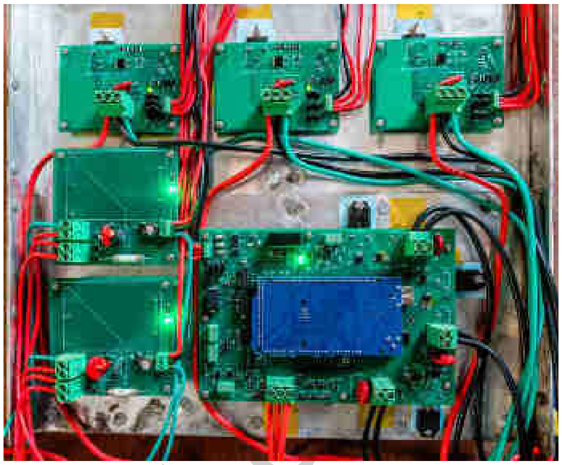
Fast start all turbines (gate valve)	= 1013 Voc
Slow start all turbine (gate valve)	= 796 Voc
Fast start 1 turbine both jets (ball valve)	= 840 Voc
Fast start 1 turbine 1 jet (ball valve)	= 757 Voc

You will note that the highest Voc was obtained when we did a fast start of all turbines by opening the large gate valve as fast as we could. This result may seem odd at first. It is due to the fact that the pipes are full of air when the large valve is closed and the small turbine valves are all open.

When the large valve is opened quickly, the air can easily vent out of the jets much faster than water would, so the water in the penstock accelerates until all this air has escaped. We then observed a pressure spike as the exhaust air runs out and the flow is sharply reduced by the constriction of the jets. This water cannot exit the jets as fast as the air, so the flow in the penstock is restricted (decelerates sharply) and we observe conversion of this kinetic energy to pressure energy, which in-turn increases water jet velocity and hence turbine Voc above the normal values for startup with a flooded manifold. Slow starting the turbines in the same manner resulted in a 20% reduction in Voc.
Always slow start hydro turbines.

This Voc testing was done to gather information so that we could lower the Voc to <600 V by changing the PMA stators should that option be desirable to avoid the need/cost of Voc protection for attached PCE equipment.

3.2. Voc protection



Opposite can be seen the prototype Voc protection board and 3 crowbars (1 for each PLT pair). This was designed in the USA but had not yet been field tested.

The crowbars worked fine (shorting the PMA through a water cooled load resistor if 400v was ever reached), but the PWM voltage regulator did not work as planned. This was ultimately due to a lack of suitable soldering equipment on site.

It took almost a day to wire it in, and then it failed to prevent the crowbar from tripping when the voltage rose for any reason.

One of the following tried and tested solutions may have been a better option in such a remote location.

- Installing 3 x PowerClamps
- Operating the turbines at <600 Voc (with Studer VS-70 600v)
- AC coupling each turbine pair with a 5kW 3-phase (1000V) Solis GTI
- AC coupling all turbines (in threes) with an 8kW 3-phase (1000V) Solis GTI

3 x PowerClamps would have added $1500US to the equipment cost. Lowering the operating voltage from 318 to about 240 V would have increased cable losses a little for no extra turbine cost. (It could have been tricky to select a stator that kept the operating voltage within the range required for the VS-70's to safely work, given the additional factor of voltage drop in the transmission cable.) It is likely that one of the above options could be implemented in future rework if necessary. The team are confident that the original plan can be implemented once the teething troubles have been overcome during a future visit.

Meantime, in order to get the job working, the following procedure was needed to ensure start up without tripping the protective crowbar:

- Start turbine slowly while watching volt meter
- Hold turbines at just over 200V until the Studer VS-70 600v MPPT's have time to wake up and track in P&O mode.
- Open up turbines to < 350V

This procedure is workable with care, and the custom-built PWM voltage regulator circuit will be brought into action later, making the system simpler to keep in operation without tripping off.

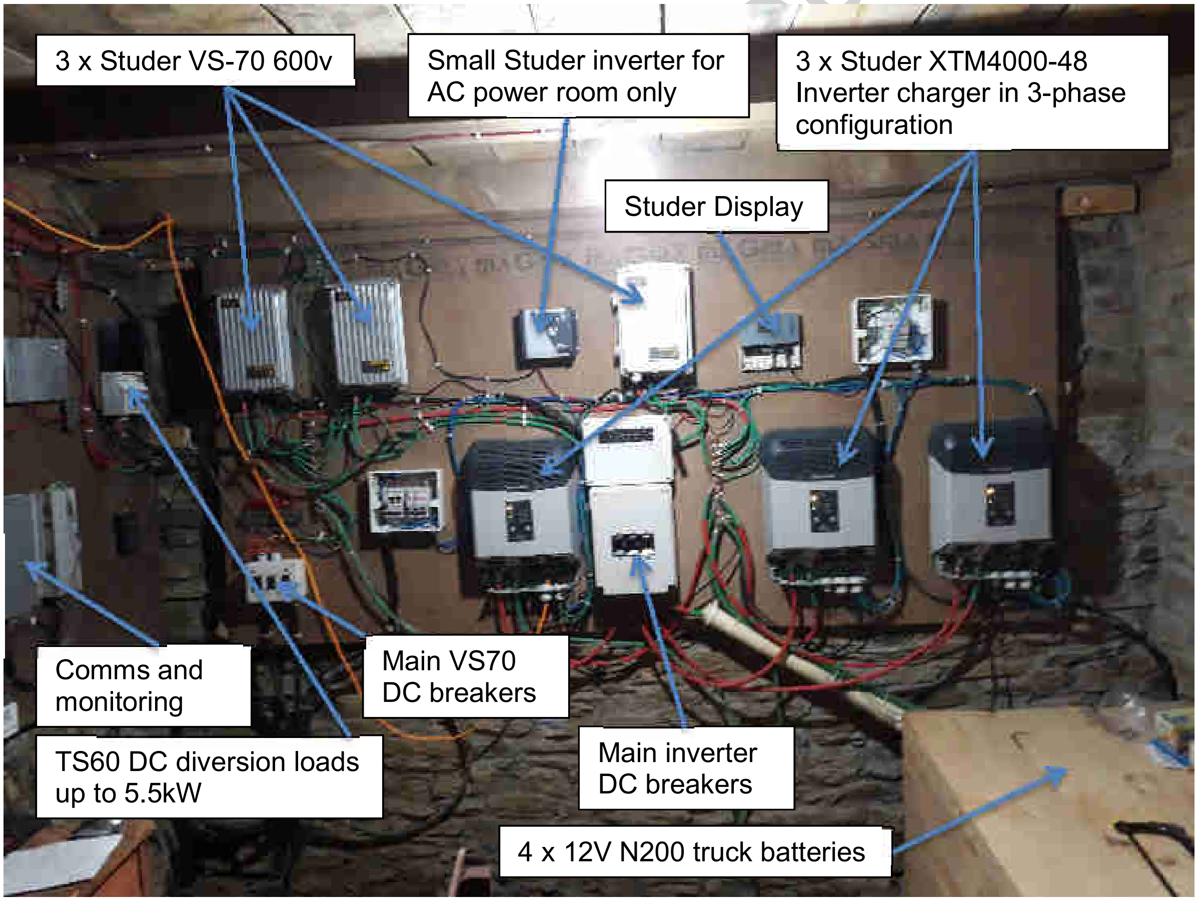
3.3. Power diversion

A Morningstar TS60 PWM charge controller was supplemented by the addition of 2 x Crydom D1D60 solid state relays (triggered by the TS60's load). This combination was able to divert up to 5.5 kW to air heaters.

In addition to the air heaters there was a 1.5kW water heater and a 2kW heater in a bio-digester project.

The priority control of all these heaters was still ongoing at the time of our departure from the site. But the basic concept proved successful to prevent overspeed or tripping of the turbines and to make fruitful use of the surplus energy when available.

3.4. PCE equipment layout



Wiring was later tidied up to cover all exposed connections.

4. Commissioning issues

4.1. Intake

The intake consisted of the following:

- Flow control gate
- Settling chamber
- Pipe screen made from 200mm PE pipe about 0.5m long and drilled with 100's of small holes

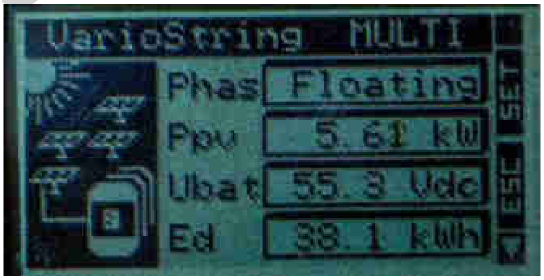
Testing 1-2 turbines went fine, and the pressure drop in the pipe system was minor.

But when all 6 turbines were turned on, the pressure at the turbines would not rise above 25m head (50% being lost in the pipes).

This pressure drop was due to the intake filter not being large enough. With the intake removed there was little pressure drop on subsequent testing. A new filter 3-4 times larger was being made at the time of our departure.

4.2. Studer VS-70

Initial testing went very well. A single turbine would reach 1.2kW at 50m head at about 320V. This test implied that 7kW was obtainable on the site.



VarioString MULTI
Phas Floating
Ppv 5.61 kW
Ubat 55.3 Vdc
Ed 38.1 kWh

However, on operating all turbines we discovered an issue. Once the main valve was opened up to give more than 38m head of pressure (with output reaching 5.61 kW) the VS-70s would not hold down the input (turbine) voltage.

Voltage is held down by drawing current from the turbines but the controllers would only draw a certain, limited maximum current. Given more input power they would let the voltage rise well above the Vmp (maximum power voltage) and risked triggering the crowbars. Hence we were unable to apply full system pressure and flow. We believe that this rise was due to the controllers not being willing or able to handle the full power for some reason, but the exact reason is as yet unclear.

The system was allowed to run overnight and all went well. The VS-70s did not seek a new Voc. (If they had the crowbars would have triggered). Attempts were made to adjust the VS-70 tracking modes from P&O, to solar, to fixed voltage - but this issue remained.

Large AC resistive loads were applied to drop the battery voltage (in case battery charge control was the issue) but the behaviour continued.

Time ran out and we had to leave the site leaving others to contact Studer to see if the matter could be resolved. It appeared to us that each VS-70 would not deliver >30 amps output despite all programmed settings being checked and VS-70 temperatures being only warm. We are confident that the matter is relatively minor and likely to be a setting in the VS-70 in need of adjustment. Either it's related to the fan operation, or some setting associated with the battery capacity driving the current limit.

4.3. Greasing

4 x 0.5 kg grease tubs were sent to site, having been purchased in Nepal.
On opening one grease tub there was a chilly pepper in the grease, and general inspection of the grease revealed it to be of questionable quality, despite two of the tubs having the Castrol logo on them. We suspect the grease available in Nepal is all pirated brands, so we did not take the risk of using it in the turbines. It is our advice that grease of a trusted brand should be brought in from outside Nepal in the near future.

We have recently had an issue with 2 turbines in Indonesia where we suspect similar low quality contaminated grease had been used.

4.4. Videos

For a video of the turbine hall click here
For a video of the power room click here

5. Work that followed our departure

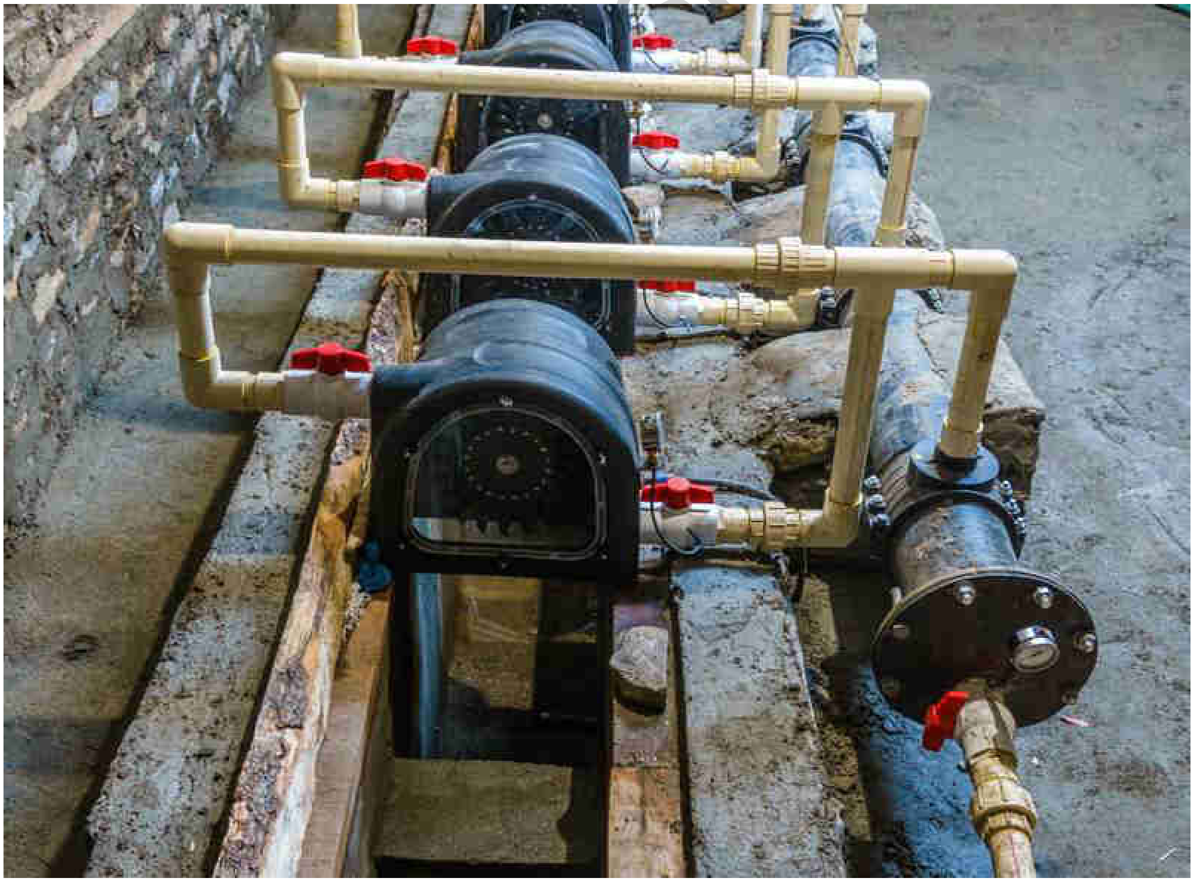
Significant work followed our departure from site, I will let the pictures tell this story.

5.1. Upgrade of intake strainer size

5.2. Covering the floor with flat rocks (limits dust & protects underground cables)

5.3. Mortar point walls (inside and out) and floor

5.4. Concrete edging to ensure exhaust water is fully contained



6. Power to the village for the 1st time

7. Interesting project pictures

Turbines and equipment moved from road head (Jumla) to Mohari Village

7.1. Turbines carried to site from Mohari village

7.2. Water intake spillway

7.3. System operation instruction

7.4. Community building hot water tank

7.5. Burying penstock to protect from damage and freezing

8. RID-Nepal Acknowledgements

Rural Integrated Development Service-Nepal (RIDS-Nepal) is a Social Non Government organization (NGO). It was registered in the calendar year 2005 (2062) with the Government in Lalitpur, in the Lalitpur District Office and the Social Welfare Council of Nepal. RIDS-Nepal is a NON-PROFIT body and the majority of its long-term Holistic Community Development (HCD) projects and field based research projects are financed by the donations from individuals, charities, communities and INGOs.

This PowerSpout hydro installation was made possible by the RIDs (NGO), their donors and the donations of time and travel costs by all those involved to make this hydro project a reality.

RIDS work to date has also included:

Pit Latrines	1074
Smokeless Metal Stoves	998
Solar Lighting Systems	698
Drinking Water Supply Systems	5
Greenhouses	35
Solar Driers	16
Slow Sand Water Filters	70
NFE classes	13
Nutrition projects	5
Pico-Hydro System	1

ANNEX 10

RIDS-Switzerland - Mohari Village Modular Pico-Hydro Project

Project Progress Picture Report for REPIC - June 2018

(REPIC participatory funding Contract No.: 2017.14)

Pic. 1: Mohari Village with its 42 families and 250 people. Mohari is in the North-East of the Jumla District, in the remote and impoverished Karnali Anchal. Mohari lies at 29° 20’ 07” Northern Latitude, 82° 22” 28” Eastern Longiture, and at an altitude of 3’150 meters (10’335 feet) above sea level. Visit Mohari Village through the RIDS-Nepal Google Earth link: http://www.rids-nepal.org/images/google_earth/Mohari.kmz

Pic. 2: A panorama view of Mohari Village in the month of June with the planted patatoes and buckwheat fields. The women just finished their first weeding of the planted fields.

Pic. 3: Moahri Village is the last and most remote village in the North-Est of the Jumla dtsrict and lies at crossing point of the vallyes (right in the middle of the picture) and at the foot of the 6'800 meters high Kanjeroba Himal, which marks the physicla boarder between the Jumla and Dolpa district.

Pic. 4: One of the many children of Mohari for whch this "Modular Pico-Hydro Power Project" will be a life cnahing experience n the years to come, creating new opportnties in life and edcation.

Pic. 5: Another, new day beginning at Mohari Village, with the sun raising baove the snow peaked montains towards th East.

Pic. 6: Early morning afetr the sun raised at Mohari village


Pic. 7: The penstock pipe line is surveyed several times


Pic. 8: The penstock length is 455 meter long from the source to turbine house


Pic. 9: The penstock gross head is 50.5 from the intake to the turbine house


Pic. 10: The last part of the penstock has the higehst drop of 20 meters

Pic. 11: Surveying underground electrical cable from the turbines to the village

Pic. 12: Clearing the HDPE penstock pipeline path from large rocks

Pic. 13: Clearing the HDPE penstock pipeline path from large rocks

Pic. 14: Building the HDPE penstock pipeline with stone bridges etc.


Pic. 15: Clearing the HDPE penstock pipeline path from large rocks


Pic. 16: Clearing the HDPE penstock pipeline path from large rocks


Pic. 17: Clearing the HDPE penstock pipeline path from large rocks


Pic. 18: Buriing the underground armoured copper cable to the power house


Pic. 19: Digging the canal for the undergound power and communication cables


Pic. 20: Digging the canal for the undergound power and communication cables


Pic. 21: Digging the path for the 200 mm diameter HDPE penstock pipes


Pic. 22: Digging the canal for the undergound powergraduate and communication cables


Pic. 23: Digging the 60cm deep canal for the undergound cables


Pic. 24: Digging the 400cm wide canal for the undergound cables


Pic. 25: The various HDPE penstock pipes based on the pressure/head


Pic. 26: Unrolling the underground cable from the turbine to the power house

Pic. 27: Unrolling the underground cable from the turbine to the power house

Pic. 28: Laying into the ground the cable from the turbine to the power house

Pic. 29: Unrolling the HDPE pipe for the communication cable

Pic. 30: Layed copper power cable and communication cable before buring them


Pic. 31: Buring the cables from the turbine to the power house


Pic. 32: Covering the power and communication cables with soil for protection


Pic. 33: Covering the power and communication cables with soil for protection


Pic. 34: Covering the power and communication cables with soil for protection


Pic. 35: Joining the 200mm HDPE penstock pipe with the heating plate (220° C)


Pic. 36: The metal heating plate is heated with the petrol generator up to220° C


Pic. 37: Joining the 200mm HDPE penstock pipe with the heating plate (220° C)


Pic. 38: Joining the 200mm HDPE penstock pipe with the heating plate (220° C)

Pic. 39: The HDPE pipes are held in place with chains to assure straighness

Pic. 40: The HDPE pipes are held in place with chains to assure straighness

Pic. 41: RIDS staff trained local people to wled the HDPE pipes together

Pic. 42: All local people are part in welding the HDPE pipes for the penstock

Pic. 43: Challening envirnmeht to weld the HDPE pipes for the penstock

Pic. 44: To wled on the 45° elbow HDPE has been particualr a challenge

Pic. 45: A close up of one of the 91 joints of the HDPE penstock pipes

Pic. 46: Welded 200mm diameter HDPE penstock ready for the pressure test


Pic. 47: Welding on a 45° HDPE elbow to assure the correct drop of the pipeline


Pic. 48: Welding on an HDPE flange to connect the expansion HDPE pipe


Pic. 49: Welding on the HDPE flange to connect to the flange set


Pic. 50: The 45° elbow of the steep drop is anchored and secured with cement

Pic. 51: The steep penstock drop is anchored and secured with cement

Pic. 52: The steep penstock drop is anchored and secured with cement

Pic. 53: Welded 200mm diameter HDPE penstock ready for the pressure test

Pic. 54: HDPE penstock over a stone bridge for a gradual slope

Pic. 55: HDPE penstock on a stone bridge for a gradual, contious slope

Pic. 56: The HDP penstock is layed on soil and stone bed for protection

Pic. 57: Joined HDPE penstock ready for the pressure test before being buried

Pic. 58: Welded HDPE penstock ready for the pressure test before being buried

Pic. 59: Joined HDPE penstock pipes before being buried

Pic. 60: The 455 m long HDPE penstock pipe line through fields

Pic. 61: Joined HDPE penstock pipes before being buried

Pic. 62: Joined HDPE penstock ready for pressure test before being covered

Pic. 63: Joined HDPE penstock ready for pressure test before being covered

Pic. 64: Joined HDPE penstock ready for pressure test before being covered

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Pic. 66: The last, steep sloped HDPE penstock pipe before the turbine house


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Pic. 71: Just before sunrise and another day of work in Mohari village


Pic. 72: Sunrise above the modular pico-hydro power penstock pipeline


Pic. 73: Sunrise over the modular pico-hydro power penstock pipeline


Pic. 74: Sunrise over the modular pico-hydro power penstock pipeline

Pic. 75: The sun over the modular pico-hydro power penstock pipeline

Pic. 76: The sun over the modular pico-hydro power penstock pipeline

Pic. 77: Diverting the river to be able to build the intake and sedimentation tank

Pic. 78: Diverting the river to be able to build the intake and sedimentation tank


Pic. 79: Diverting the river to be able to build the intake and sedimentation tank


Pic. 80: Gabon wire boxes to streamline the river and secure the water intake


Pic. 81: The women crushing stones with a hammer for gravel for the cement


Pic. 82: Women washing the sand from mud to cement the sedimentation tank

Pic. 83: Securing the sedimentation tank and water intake with gabon wires

Pic. 84: Securing the sedimentation tank and water intake with gabon wires

Pic. 85: Building gabon wire protection to secure the sedimentation tank

Pic. 86: Ensuring that the river in the rainy season is not endangering the intake


Pic. 87: Women carrying stones for the gabon wire protection boxes


Pic. 88: Women crushing stones with a hammer for gravel for the cement


Pic. 89: Women crushing stones with a hammer for gravel for the cement


Pic. 90: Installing the sluice gate into the sedimentation tank in correct angles

Pic. 91: Gabon wire boxes protection for the sluice gate and sedimentation tank

Pic. 92: Gabon wire boxes protection for the sluice gate and sedimentation tank

Pic. 93: Gabon wire boxes protection for the sluice gate and sedimentation tank

Pic. 94: The sluice gate is the entry gate and protection to the sedimentation tank


Pic. 95: River, gabon wire protection boxes, sluice gate and sedimentation tank


Pic. 96: : River, gabon wire protection boxes, sluice gate and sedimentation tank


Pic. 97: :Sluice gate, sedimentation tank, penstock intake, overflow


Pic. 98: Sluice gate, sedimentation tank, penstock intake, washout, overflow


Pic. 99: Sluice gate, sedimentation tank, penstock intake, washout, overflow


Pic. 100: Flatting the ground for the power house building structure


Pic. 101: Flatting the ground for the power house building structure


Pic. 102: Installing the first ground level wooden door of the power house

Pic. 103: Building the ground walls of the power house

Pic. 104: Building the ground walls of the power house

Pic. 105: Women carrying all the stones needed for the power/turbine houses

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Pic. 108: Preparing the mud with water to be used as the “local cement”

Pic. 109: Buildng the power house ground walls with stones and mud mortar

Pic. 110: Carpenters, trainied by RIDS, manufacturing the doors and windows


Pic. 111: Buildng the power house ground walls with stones and mud mortar


Pic. 112: Buildng the power house ground walls with stones and mud mortar


Pic. 113: Buildng the walls of the power room of the power house ground walls


Pic. 114: Mansory work for the walls of the power room of the power house

Pic. 115: Building the ground walls of the power house stone walls

Pic. 116: Building the ground walls of the power house stone walls

Pic. 117: Power house first floor walls building structure

Pic. 118: Power house stone walls and wooden doors and windows


Pic. 119: Building the ground walls of the power house stone walls


Pic. 120: Mixing mud with water for “mortar” for building the ground walls


Pic. 121: Stone masonary work for buidling the stone walls


Pic. 122: Building the grond floor walls of the power room in the power house

Pic. 123: Milky Way over Mohari village during a clear night sky

Pic. 124: Milky Way in the Nepal Himalayas during a clear night sky

Pic. 125: Star Trails aroud Polaris near Mohari Village during a clear night sky in the Nepal Himalays

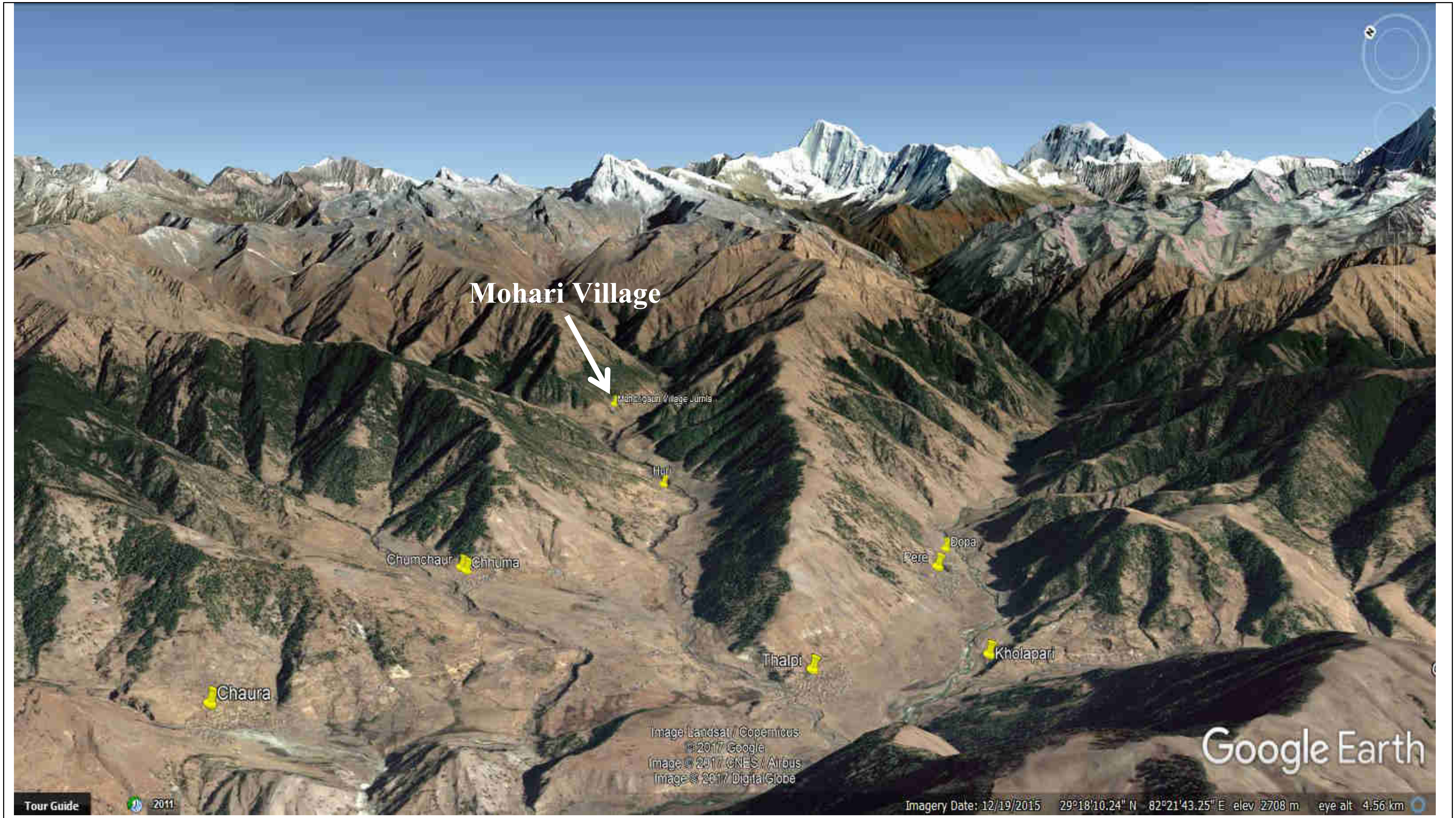
ANNEX 11

Mohari Village Google Earth Location and Project Pictures September 2017

RIDS-Nepal has had a deep rooted relationship with Mohari's Village Development Committee since 1997, with a gap during some years of the Nepali civil war (2003-2009), introducing and implementing the "Family of 4" and later the "Family of 4 PLUS" holistic community development (HCD) projects with the local families. Improvements included pit latrines, smokeless metal stoves, solar PV home systems capable of driving low power LED bulbs, clean drinking water, slow-sand water filters, high altitude greenhouses, solar food driers, solar cookers. Further, two young men have been granted a scholarship for a 2½ years apprenticeship training education at the KTS in Jumla, as well as 10 women and men have been trained in the stitching of cloths with stitching machines and 10 men have been trained as carpenters, as part of the skill training program for the creation of new economic income streams.

Mohari Village, in the North-East of the Jumla district, North-West Nepal. Coordinates: North Latitude: 29° 20' 06" / East Longitude: 82° 22'27 / Altitude: 3'150 m.a.s.l. In particular after the civil war the community development projects in partnership with RIDS-Nepal has enabled that now each home in Mohari has a Pit Latrine, a Smokeless Metal Stove, a Slow-Sand Water Filter, Basic Indoor lighting through a 20W Solar PV Home System, a High-Altitude Greenhouse, a Solar Drier and access to clean and sufficient drinking water through various tap stands in the village, from their own, village owned water source. Additionally, so far 10 women and men have been trained in how to stitch cloths and 10 have been trained to be carpenters, in anticipation that the increased access to electricity through the proposed modular pic-hydro power plant will create new business opportunities and thus increased chances to create additional income for the families in Mohari village.

Mohari Village as seen in Google Earth. Coordinates: North Latitude: 29° 20’ 06” / East Longitude: 82° 22’27 / Altitude: 3’150 m.a.s.l.



Mohari Village 42 Families (246 people) with some of its neighboring village where RIDS-Nepal has been partnering with since the late 90's as seen in Google Earth

The “Family of 4” Holistic Community Development Projects implemented with the Mohari Families since early 2010

PIC (Project Implementation Committee): In each village with whom RIDS-Nepal is partnering for a Holistic Community Development (HCD) such as the “Family of 4” and the “Family of 4 PLUS”, as PIC group, consisting of 9 local people (with at least 2 women), chosen by the whole community, working in close relationship with the RIDS-Nepal field staff, discussing, planning and implementing each of the HCD projects. The PIC is among other tasks, as well responsible to mobilize the local people to provide the agreed upon voluntary sweat work and local materials and equipment to implement a project.

Fig. 1: PIC group of Mohari village in a weekly project meeting with the RIDS-Nepal field staff. In the background the RIDS-Nepal Mohari village project office ca be seen where the RIDS-Nepal field staff stay during the implementation of all the projects.

Fig. 2: PIC meeting in Mohari village in one of their monthly meeting with the RIDS-Nepal Jumla field staff.

1) Pit Latrines: The Pi Latrine is always the FIRST of the "Family of 4" HCD program. Each family has to have a pit latrine in order to apply for a heavily subsided smokeless metal stove.

Fig 3: Pit Latrine in Mohari Village, one per family

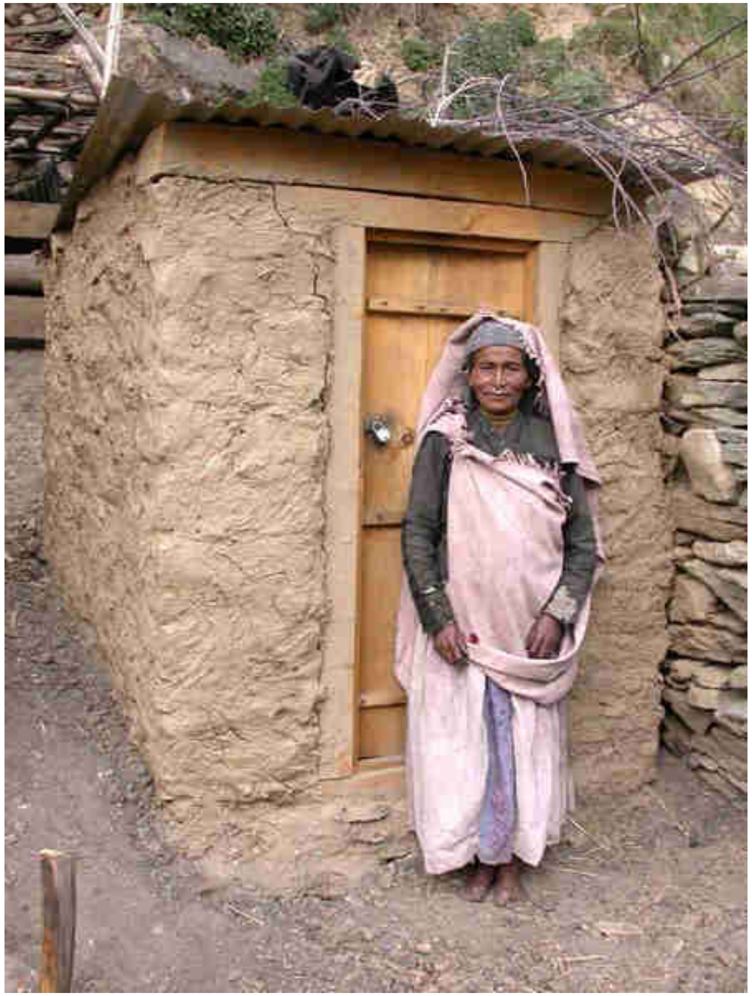


Fig 4: Pit Latrine in Mohari Village, which each family built under RIDS' instructions

2) Smokeless Metal Stove: The Smokeless Metal Stove (SMS) is always the second project implemented under the “Family of 4” HCD concept. Families are able, once they have built their own pit latrine under the instruction and guidance of RIDS-Nepal to purchase by RIDS highly subsidized smokeless metal stove. That means that since 2011 all 42 families in Mohari village have each one SMS in their home to cook their daily food, heat their room and have hot water for personal hygiene and tea brewing.

Fig 5: The Smokeless Metal Stove, developed by RIDS-Nepal, has become the first metal stove subsidized with some financial support by the Nepal government since 2008. This model of a smokeless meta stove is now manufactured by over 45 private companies throughout the nation of Nepal under the government’s supervision, to disseminate this stove to a wider remote, mountain community. RIDS-Nepal continues to manufacture and install this stove in all its partnering village communities in Jumla and Humla, two of the poorest and most underdeveloped districts of Nepal. Here one of the 42 families in Mohari village with an installed RIDS-Nepal smokeless metal stove.

Fig 6: Smokeless Metal Stove in one of the Mohari village’s families installed. The first, RIDS-Nepal developed, smokeless metal stoves have been installed in Mohari village in 2002 and all of them are still functional and in daily use.

3) Basic Indoor Lighting. Basic indoor lighting, generated by tapping into one of the local renewable energy resources and converted to electricity is one part of the basic needs of the “Family of 4”, identified by the local users themselves. All 42 families in Mohari village have a SHS since 2010.

Fig. 7: Basic Indoor Lighting in one of the Mohari Village’s families through their 20 Watt Solar PV home system and 3 white LED lamps.
Now with 7½ years of practical experience of having had three, 1-3 watt white LED lamps, powered by each families’ own 20 watt solar PV home system, the Mohari village families have learned how valuable even small amounts of light ad access to energy services are for the long-term development of their families and village. Therefore they are ready for the next step, to build and run a larger electricity generation system, the mini-grid, modular, 6kW pico-hydro power plant.

Fig. 8: Installation of a 20 watt Solar PV home system on the mud roof of one of the Mohari families homes, with two of the three 1 watt white LED lamps in their main room.

4) Clean and Sufficient Drinking Water from Tap Stands in the Village: Access to clean and sufficient drinking water form tap stands in the village is another basic need addressed as part of the "Family of 4" HCD concept.

Fig. 9: In close collaboration with RIDS-Nepal the Mohari Village community built its village drinking water system. Water is tapped from their own water source above the village and piped in underground buried HDPE pipes to the various drinking water tap stands distributed in the village according to where they decided they should be.

Fig. 10: To have clean and sufficient drinking water from tap stands in the village is a central part of holistic community development. It marks a milestone in improving living conditions health and hygienic conditions of all people in a village, especially of the most vulnerable ones , the children.

The “Family of 4 PLUS” Holistic Community Development Projects implemented with the Mohari Families since early 2010

While the “Family of 4 PLUS” Holistic Community Development program consists of 11 different possible projects and programs which RIDS-Nepal can support and implement with the local end users, it is the end users who define what needs they want to address with RIDS-Nepal as their project partner. Here we show just 4 of the 11 different possible and at various times and in various villages, implemented projects and programs.

1) **High-Altitude Greenhouse:** With the building of a high-altitude greenhouse the for each family in Mohari village, they can now grow vegetables for 10 month per year, rather than only 3-4 month previously. The RIDS-Nepal Jumla staff instruct and teach the local farmers how to build and plant the respected crops in their new greenhouse

Fig. 11: RIDS-Nepal staff instruct and teach the local farmers and families from Mohari village how a high-altitude greenhouse is built, crops are planted an cared for throughout the year.

Fig. 12: New completed High-Altitude Greenhouses in Mohari to grow vegetables not just for 3-4 months a year, but now for up to 10 months a year. One can only imagine in what health and living standard improvement that results over the years, especially for the more marginalised people, the women and children.

2) **Solar Drier:** With significant more vegetables grown throughout the year with their high-altitude greenhouses people can now dry some of their vegetables with the RIDS-Nepal developed solar driers, to store them for times during the year when they have less or no vegetables available.

Fig. 13: RIDS-Nepal's Large, for more commercial use, solar drier in use. It can dry products (vegetables, herbs, meat etc.) in an indirect way, so that there is no discoloration, which makes it easier to sell the dried products.

Fig. 14: The local families in Mohari village are instructed how to use the family sized solar drier to dry their vegetables grown in their high-altitude greenhouse, the herbs or even meat from their own animals. This smaller, family sized solar drier is part of the greenhouse project in order to dry vegetables in times of overproduction to store them under safe conditions for the harsh four winter months.

3) **Slow Sand Water Filter:** With the Mohari village drinking water system built and running, people have now access to clean and sufficient drinking water throughout the year. However, while most of the year, except may be during the monsoon season, the water from the different tap stands in the village is clean, often the water is again contaminated while carrying the water canisters home and even more in the way the families store the collected drinking water in their home. Mize, dogs chicken etc. have easy access to the drinking water and thus the danger to be contaminated is very high. But if the collected water is poured into the slow sand water filter (SSWF) as seen in Figure 16, the water is running a through 900mm long sand filter bed and stored (up to 9 liters) safely inside the SSWF. Once needed, people can access the clean water through a tap at the SSWF. In this way, the RIDS-Nepal developed and manufactured slow sand water filter enables people to keep healthy.

Fig. 15: RIDS-Nepal staff instructing a lady from Mohari, how to install the slow sand water filter inside her home and how to fill it with the sand she collected from the nearby river.

Fig.16: A restaurant owner from another village is filling the slow sand water filter in the morning to be ready when traveler pass by his restaurant and stop for a snack or something to eat. As additional service he can now provide with the SSWF clean drinking water and thus makes sure that the travelers stopping at his restaurant, remain health.

4) **Karnali Technical School (KTS) Apprenticeship Scholarship:** In order to make sure that the young people, women and men, from the villages RIDS-Nepal partners with in holistic community development projects, have the needed skills and professional education, one of the 11 “Family of 4 PLUS” HCD programs is the provision of a Karnali Technical School (KTS) scholarship for a 2 ½ years apprenticeship education in one of the four fields of technical sub-overseer, mid-wife, nurse and agriculture (farming or veterinary). In this way RIDS-Nepal tries to enable the next generation of men and women to have not only a good, hands-on professional education, but the needed skills to work either with RIDS-Nepal and their village in one of the projects, or to apply for a job with any NGO, INGO or government department. This enables these young people to earn a living, enabling them to build a family. That allows them to more likely stay in their villages and participate actively in the development of their own community, rather than migrate to the cities or even to India or further abroad.

Fig. 17: Presently RIDS-Nepal supports 12 KTS scholarship students from Jumla and Humla with one scholarship student (right) from Mohari village in his sub-overseer education course.

Fig. 18: The RIDS-Nepal Mohari village KTS scholarship student learns the basics of how to work with a PC as well as some basic drawing skills with AUTO-CAD, an important course for his sub-overseer apprenticeship course.

Proposed “Modular Pico-Hydro Power Plant” in Mohari Village – Base Line Survey 2016

Fig. 19: Mohari village community and RIDS-Nepal Jumla staff conducting the survey for the modular pico-hydro power plant for the Mohari village. Here the people are measuring the length of the pen stock pipe, which will be buried underground, from the water intake tank to the turbine house. The person to the very right is the RIDS-Nepal sponsored Karnali Technical School sub-overseer student who puts to work some of his newly learned knowledge. He will be a potential future pico-hydro power plant operator once he finished his studies and the Mohari modular pic-hydro power plant is built and running.

Fig. 20: Mohari village community and RIDS-Nepal Jumla staff conducting the base line survey for modular pico-hydro power plant for the Mohari village. Here they are measuring the head height from the river water intake tank to the turbine house, applying along the whole pen stock pipe the water tube method which results in the total gross head. A technology which RIDS-Nepal taught the local Mohari village user group.