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Modular Pico-Hydro Power Plant Mohari Village, Jumla, Nepal

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1. Summary

Nepal historically builds hydropower mini-grids to electrify remote communities, but they usually do not meet expectations. One common reason is that their kW capacity is so oversized for future growth that it is too expensive for the initially impoverished villages to maintain or the experience to manage. They run only during the night for lights only, and at only 5-10% of their capacity due to limited user demand. They are not designed to minimize O&M costs even if scaled appropriately, and there is no prepay or lifecycle cost analysis to ensure the systems are sustainable. A system is needed that the village can maintain and can be expanded as their energy needs grow.

This project constructed and operated a prototype modular pico-hydro system that can be scaled to a village's social, skill, and economic capacities. It is expandable in increments and is designed for reduced O&M costs. It includes a prepayment system to ensure revenue for O&M and future expansion. It employs several creative smart dump loads to direct excess power to useful purposes, e.g., generating hot water for showers, room heating, and heating a biogas digester. This increased the utilization factor to 100%, capturing greatly more value from the system. The system uses DC energy storage to support a much larger surge capacity to start motors for economic expansion. DC also enables easy integration of other forms of renewable energy such as PV and wind, although that was not included in this project phase. This system brings together available technologies which have not yet been applied and transferred to high altitude Himalayas, scaled appropriately.

The design through RIDS was done with help from industrial partners in Switzerland, Nepal, New Zealand and the USA, as well as in consultation with the Mohari village leadership. The design of the prepayment system was done by the same group with help from Itron and iPay, companies in the business of providing prepayment electric meters and cloud services.

Local Nepalis developed many skills during this project:

- Skills required to design and construct several sub-systems: 2-tier settling ponds and river diversion, thermally welded penstock, water distribution system to the turbines, water exhaust system, laying underground armored cable properly, and apprentice-level electrician work.
- One local from Mohari village received training as a general contractor on much of the system.
- Five villagers received additional training on wood working and general construction of the community center.
- Two villagers were trained as the system operator to perform basic maintenance on the system, and to be the vendor of tokens for the prepayment system.

Six turbines were functional at the initial system inauguration on 30th Nov. 2018, demonstrating that 6 kW was achievable. The system has been operational ever since which is a huge improvement over the previous defacto approach. By mid-March 2021 the system will have been operating for 20,000 hours virtually non-stop! The village residents are very pleased with the system.

We learned how to effectively operate the system. Maintenance costs were extremely low. Load shedding was never needed. Our use of prioritized dump loads in the local context resulted in some key learnings.

Although some initially expressed concerns about the 150 NRP/month (~1.5 USD/month) electricity and service charge including 3 kWh, the village occupants learned about the real costs of electricity and have accepted the idea that they must pay for this service.

Throughout 2020 two Pelton turbines, each generating 1.2kW, were running, generating a total of 21'100kWh. The 37 families (247 people), consumed total 3'100kWh for electricity, or 82kWh on average per household, per year. The electricity for the biogas generator, the consumption in the large community center, all the data monitoring, as well as the useful dump loads such as heating the rooms and the hot water shower in the community center and a large TV for education, amounted to a total of 18'000kWh in 2020. The village's average power consumption for electricity increased from 150W end of 2018 to 350W by the end of 2020, a doubling within 2 years. This steady growth in electricity demand shows increased awareness and understanding of the benefits electrify brings to their homes and that users are willing and can afford to pay for it.

Although a village shower system with hot water was built, the residents were not yet willing to pay 20 NRP for this service. Dignitaries who visited during the system's inaugural celebration were dancing with joy in the village shower room, so we are hopeful the residents' willingness to pay will eventually change. When the pandemic is over, we plan to bring a health expert to the village to educate them on the health benefits, and give free showers for 1 month so they can experience the joy of hot showers. A biogas generator was built as part of a different academic research project with the FHNW, but so far failed to

meet expectations because it was built too close to the creek, resulting in the constant inflow of cold water into the insulation. Thus, we could not keep the desired temperature to produce sufficient gas.

The development of other productive end uses such as a carpentry shop have not yet been pursued due to the pandemic. Illuminating a high-altitude greenhouse with LED lights for increase vegetable growth is another additional useful load application to be considered in the future, especially during the winter.

All 37 households so far connected to the mini-grid are very satisfied with the reliable and constant availability of power. They can't think of not having electricity anymore. In 2020 four new houses were built in Mohari village (the highest increase in houses per year since years). They will be connected to the mini-grid in 2021.

2. Abstract in local language

नेपालमा ऐतिहासिक काल देखि नै दुर्गम तथा शहरी क्षेत्रका लागि साना जल विद्युत उत्पादन गरिंदै आएको हो तर तिनीहरुले माग अनुसारका आवश्यकता भने पूरा गर्न सकेको देखिंदैन । यसको खास कारण चाहिं आवश्यकता भन्दा ठूलो क्षमताको विद्युतगृह बनाउनु र दुर्गम क्षेत्रका बासिन्दाले त्यसको मरम्मत सम्भारको व्यवस्था सम्म पनि गर्न नसक्नु हो । तिनीहरुमा विद्युतको धेरैजसो अन्य कुनै उपयोग नभएको र रातको बत्तीको लागि मात्र चलाउने र पूरा क्षमताको ५ देखि १० प्रतिशतमात्र प्रयोग हुनु हो । यस्ता जलविद्युतहरु वास्तविक खांचोको हिसावले डिजाइन गरिएका हुंदैनन र भएतापनि गाउंलेको त्यसको चालु खर्च र मरम्मत सम्भार खर्च पनि थेग्न सक्दैनन । त्यसैकारण धेरैजसो ग्रामीण जलविद्युत समयमा मरम्मत गर्न नसकेका कारण नै समाप्त हुन्छन । यसैले जलविद्युत निर्माण गर्दा आवश्यकता अनुसार पछि क्षमता बढाउन सकिने गरी पहिले हालको आवश्यकता पूरा गर्नकालागि निर्माण गरिनु पर्छ ।

यो परियोजना ग्रामीण क्षेत्रको हालको आवश्यकता पूरा गर्न र गाउंलेहरुको आर्थिक र सामाजिक विकाश हुदै गएको खण्डमा पछि चाहिएको मात्रामा यसको क्षमतामा बृद्धि गर्दै लैजान सकिने खालको यौटा नमूनाको रुपमा विकाश गरिएको हो । यो परियोजनामा कम से कम चालु तथा मरम्मत लागत पर्ने छ । यसको विस्तार, चालु खर्च र मरम्मत खर्च यसैको आम्दानीले धान्न सक्नेगरि योजना गरिएको छ । यसमा विभिन्न किसिमका वैज्ञानिक उपकरणहरु जडान गरिएका छन जसबाट गाउंलेले प्रयोग गरेर बांकि रहेको उत्पादित विद्युत सकेसम्म खेर नजाने उद्दश्यले नुहाउने पानी तताउने, वायोग्यास निकाल्ने तथा कोठा तातो राख्ने हिसावले बनाइएको छ । यसले गर्दा उत्पादित विद्युत शत प्रतिशत प्रयोगमा आइरहेको हुन्छ । यस परियोजनामा DC Battery हरु पनि जडान गरिएका छन जसले गर्दा अपर्झट ठूलो विद्युत भार आवश्यकता पर्दा ब्याट्रीबाट समेत पावर लिइनेगरि मिलाइएको छ । DC system मा पछि सोलर सिष्टम तथा हावाबाट समेत विजुली थप्न मिल्ने प्रावधान राखिएको छ तर हाललाइ त्यस्तो कुनै योजना छैन । यो परियोजनामा सवै किसिमका उपलब्ध प्रविधिहरु प्रयोगमा ल्याइएको छ जुन यस्तो उच्च हिमाली भागमा हाल सम्म अन्य कतै प्रयोग भएका छैनन होला ।

यो परियोजना स्वीजरल्यण्ड, न्युजिल्याण्ड, अमेरिकन प्राविधिक निकायहरुसंगको सहकार्यमा RIDS-Nepal ले जुम्लाको मोहरी गाउंको अगुवाइमा गरेको हो । विद्युत उपभोगको अग्रिम भुक्तानी गर्न सकिने प्रविधि चाहि Itron र iPay नामक संस्थाहरुले विकाश गरेका हुन ।

यस परियोजनाको दौरानमा स्थानीय वासिन्दाहरुले धेरै शीपहरुको ज्ञान हासिल गरेका छन ।

- ढुंगा, वालुवा थिग्राउने दुइ तहका पोखरीहरुको निर्माण, नदी वहावका मोडहरु मिलाउने, पि.भि.सि पाइपहरु तताएर जोडने, टर्वाइनहरुमा पानीको भागवण्डा गर्ने र आवश्यकता अनुसार खोल्ने वन्द गर्ने, अनावश्यक पानीलाइ बाहिर फाल्ने, underground armored cable व्यवस्थित तरिकाले जमीनमुनी विछ्याउने र साधारण तहको विद्युत-प्राविधिकको कामहरु सिकेका छन ।
- स्थानीय एक व्यक्तिले नै सवै कामहरु हेर्ने तथा स-साना प्राविधिक कामहरु समेत हेर्ने तालिम दिलाइएको छ ।
- मोहरीकै स्थानिय पांच जनाले काठको कामहरु गर्ने तालिम पनि प्राप्त गरेका छन ।
- दुइजना स्थानीयहरुलाइ system operator देखि system को साधारण मरम्मत गर्ने तथा भुक्तानीकोलागि टोकन बनाउने, वितरण गर्ने जस्ता कामहरुको तालिम पनि दिइएको छ ।

विद्युत उत्पादनको पहिलो दिन 30th Nov. 2018 मा ६ किलोवाट विजुली उत्पादनवाट उदघाटन गरिएको यस सिष्टममा धेरै सुधारहरु पनि भएका छन । २०२१ मार्च महिनाको आधा आधिसम्म २०,००० वीस हजार घण्टा नरोकिइ विद्युत उत्पादन भएको र हाल सम्म पनि यथावत उत्पादन भैरहेको छ । यसबाट ग्रामीण जनता साह्रै खुशी देखिएका छन ।

यस परियोजनाबाट हामीले यस्तो सिष्टमलाइ कमसे कम मरम्मत खर्चमा कसरी संचालन हुन सक्छ भन्ने कुराको जानकारी पायौं । लोड शेडिंग भन्ने कुराको नामै रहेन । बढी भएको विद्युतबाट नुहाउने पानी तताउने, वायोग्यास निकाल्ने तथा कोठा तातो राख्ने आदि जस्ता कुराहरु गाउका वासिन्दाको लागि धेरै उपयोगी सावित भएको छ ।

महिनाको रु १५० प्रतिघर, प्रति ३ किलोवाट विजुली सुरुका दिनहरुमा केही महंगो देखिएतापनि हाल गाउंवासिमा विद्युत सेवाको उपलब्धताको हिसावले हाल आएर सामान्य लागिसकेको छ र सुविधाको हिसावले मूल्य तिर्नुपर्छ भन्ने पनि थाहा पाएका छन ॥

इ.सं. २०२० सालभरि अर्थात १२ पूरा महिना २ जटा मात्र टर्वाइनहरु चलाइयो जसबाट बर्षभरिमा २११०० किलोवाट विजुली उत्पादन गरियो । ३७ परिवार (२४७ जनाको जनसंख्या) ले जम्मा ३१०० किलोवाट मात्र विजुली उपभोग गरे जुन प्रतिघर प्रतिवर्ष ८२ किलोवाट पर्न आउंछ । २०२०मा वायोग्यास उत्पादन, सामुदायिक सभा हल, कोठाहरु न्यानो वनाउन र सामुदायिक हलमा राखिएको ठूलो टिभी चलाउन बांकी १८००० किलोवाट विद्युत प्रयोग भयो । २०१८ को अन्यमा १५० वाट प्रतिदिन उपभोग भएथ्यो भने २०२० को अन्त्यमा आएर यो ३५० वाट प्रतिघर प्रतिदिन पुग्यो ।

यसरि २ वर्षको अन्तरालमा विद्युतको माग दोब्बर बढेको पाइन्छ । यसबाट के थाहा हुन्छ भने विद्युतको दैनिकीमा कस्तो उपयोगिता हुन्छ र त्यसका लागि उनीहरु मूल्य तिर्न पनि तयार रहेका छन ।

कोभिडको प्रकोपको कारण काठबाट उत्पादन हुने फर्निचर, झ्याल ढोका आदिको लागि कारखाना भने अझै खोल्न सकिएको छैन । बढी भएको विद्युत उत्पादनबाट ग्रीनहाउसका लागि प्रयोग हुने विषेश खालका LED बत्तीहरु प्रयोग गरि हिउंदमा बढी मात्रामा तरकारी उत्पादन गर्न सकिने सम्भावना भने अझै बांकी छ ।

ग्रमीण नुहाउने तातोपानीको सिष्टम जडान गरिएको भएतापनि मोहरीका वासिन्दामा तातो पानीले नुहाउने बानी नभएकोले होला एक पटकमा २० रुपैयां तिरेर नुहाउन भने त्यत्ती रुचाएका छैनन । उदघाटनका समयमा आमन्त्रण गरिएका उच्च स्तरका व्यक्तिहरुले यसको राम्रो अनुभव गरेका थिए र वाथरुम भित्र खुशीले नाचेका पनि थिए जसको कारणबाट गाउंलेहरुको मनमा पनि यो रहर पलाउला र अन्त्यमा पैसा तिरेर नुहाउन सुरु गर्लान । कोभिड १९को संक्रमणको डर हल्का भएपछि एकजना स्वास्थ्य कार्यकर्ता बोलाएर तातो पानीले नुहाउनुको महत्व बुझाउनकासाथै एक महिनाको निशुल्क नुहाउने सुविधा प्रदान गर्ने लक्ष लिइएको छ । यसबाट उनीहरुले तातोपानीले नुहाउंदाको आनन्दको अनुभव गर्नेछन र बानी पनि पार्नेछन । यदि उनीहरुमा तातो पानीले नुहाउने बानी बस्न गयो भने ग्रामीण स्तरको धेरै कोठाहरु भएको स्नानगृह वनाउन पनि सकिनेछ । वायोग्यास बनाउनकालागि शैक्षिक अनुसन्धान परियोजना अन्तरगत FHNW द्धारा वनाइएको digester लाइ तातो पानीले घेरिएको भएतापनि कतै न कतैबाट चिसो पानी चुहिने गरेकाले चाहिने मात्रामा ग्यास भने निकाल्न सकिएको छैन ।

कोभिड १९ का कारणबाट विद्युतको अरु उत्पादनशील प्रयोगहरु जस्तै काठका फर्निचरहरु बनाउने, उच्च भूभागमा बनेका ग्रीनहाउसमा विषेशगरी हिउंदका समयमा विरुवा सुहाउंदो प्रकाशको प्रयोग गरी उत्पादन बढाउने जस्ता कामहरु गरि उत्पादित विद्युतलाइ उच्चतम लाभका लागि प्रयोग गर्न सकिएको छैन ।

गाउंका सवै ३७ घरहरु यस निर्वाध तथा अटूट विद्युत वितरणबाट निकै खुशी देखिएका छन । अव उनीहरुलाइ विजुली विना बांच्न गाह्रै होला भन्ने लाग्न थालेको छ । २०२० सालमा मोहरीमा अरु चार नयां घरहरु बनेका छन जुन गएका वर्षहरुमा भन्दा निक्कै बढी बनेको भन्नु पर्छ । यो शायद विद्युत प्रतिको आकर्षणले पनि हुन सक्छ । यी नयां घरहरुमा २०२१ सालमा विद्युत जडान गरिनेछ ।

3. Starting Point

RIDS had already addressed Mohari's self-identified needs for toilets, clean indoor air and less firewood consumption through smokeless metal stoves, clean and sufficient drinking water, high-altitude greenhouses, solar driers, 20W Solar PV Home Systems which have run since early 2010 using 1-3W LEDs and cell phone charging, scholarships for village students to learn a profession at the Karnali Technical School (KTS), and ten people each with carpentry and cloth stitching skills respectively with the aim of establishing viable businesses due to productivity gains from electricity.

The village had learned how to use limited electricity for 8 years. They wanted more lights, radio, battery charging e.g., for torches and laptops, public instructions in the community hall, and income generation activities, e.g., a powered carpentry shop.

Micro-hydro was already installed in other communities in the region using a single large generator, albeit with limited success due to high O&M costs, night time operation only, and lack of a revenue stream and properly trained operators. So, while the area knows about basic electrification principles the communities seek for a better, more sustainable and affordable approach.

4. Objectives

The primary objectives of the project were to:

1) Verify the approach's promise to provide sustainable and affordable renewable energy-based electricity for improved access to energy services for off-grid village communities, scalable from their first introduction to electricity through their reasonably expected economic and population growth.
2) Learn as much as possible about how this modular system approach can best be applied in the local context.
3) Disseminate this information and mini-grid technology so it can be replicated in Nepal and internationally.

5. Project Review

5.1 Project Implementation

The modular pico-hydro power plant project was implemented out under the following, subsequent key steps:

- **Water Intake**: To reduce the wear and tear on the turbines, two levels of sedimentation systems were used. 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. 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 to achieve an even slower flow rate for improved sedimentation, but sufficient to provide all the water needed by the turbines.
- **The Penstock**, 490m long, either buried or covered with mud and stones to protect it from the elements, 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 a 1'800W generator.
- **Turbine House:** The penstock is connected to a 200mm gate valve in the "turbine house" where six PowerSpout Pelton PLT-HP turbines from Ecoinnovation are mounted on a concrete exit channel. 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.
- **Buried Armored Transmission Lines**, 320m long, armored, underground buried, transmission cables were used to send the DC power from the turbine house to the power room in the village. The Pelton turbines operate at 300VDC, allowing the use of smaller diameter transmission lines.
- **Power Room:** The power electronics including the charge controllers, battery bank, and inverters (three XTM-4000 Xtender DC-AC converters) are housed in the power room in the village. Four ubiquitous N-200 truck batteries were used in the system as energy storage capacity. 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.
- **Charge Controllers:** The system is set up so the VS-70s charge controllers 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.
- **Village Power Distribution Lines:** 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. 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.
- **Pre-Payment System**: Itron's ACE9000 SSP DIN-R electric meters and Customer Interface Units have been installed as part of the pre-payment system. 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.
- **High Utilization Factor:** The 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. The Morningstar TS-60 diversion load controller 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 to heat different rooms in the community center. In order to improve the utilization factor of renewable energy systems, excess power is diverted to prioritized "smart dump" loads, such as water heating for showers or a heating a biogas digester for increased bio-gas production. The highest priority load that needed additional power based on its temperature takes the first or all the excess power generated. Second priority useful load is second and so on.
- **Central Computer:** A Linux-based, Schweitzer Engineering Labs, computer runs 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 the system, and its remote location makes replacement very difficult.

- **Failsafe System:** Two, customized solution levels of failsafe are employed in the turbine house to limit the voltage. The first is a custom PCB 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 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.
- **User Payment:** Each household pays 150 NRP (approximately 1.3 USD in December 2020) per month to connect to the electricity system, and this includes 3kWh per month. Because high efficiency LED lighting was installed throughout the village, 3kWh is usually sufficient for basic lighting and cell phone charging, but not enough for a TV. Additional energy costs 50 NRP (approximately 0.44 USD) per kWh if e.g., a family has a TV. Till December 2020 two families have "already" added a TV to their daily energy consumers, supporting their children in their education due to the closure of the schools due to COVID-19.

The following project partners have been involved in the modular pico-hydro power project, either by financial support, equipment sponsoring, hands-on work and voluntary work and participation:

- Mohari village community, as well as the local political/government departments of Patrasi Gaun-Palika, Jumla, Nepal
- REPIC, Switzerland (34% participation in financial support)
- RIDS-Switzerland/USA/Nepal (project design, overall implementing international and local NGO, voluntary participation etc.)
- PowerSpout Pelton PLT-HP turbines from Ecoinnovation, New Zealand
- Aurora Power and Design Boise, ID, USA, provided some of the miscellaneous turbine equipment needed in the project, as well as online and in person technical advice and hands-on support during the turbine installation phase.
- Itron (prepayment system, smart meters, and building cost of the large community center)
- Studer Innotec (inverters, charge controllers, battery management)
- IPay (prepayment token issuing software)
- Schweitzer Engineering Labs (ultra-high reliability computer for data monitoring and smart "dump load" management)
- Individual small financial contributions

The main, initially defined objectives of the project did not have to be modified during the 3-years building, installation and operation period.

5.2 Achievements of Objectives and Results

Objective 1 was largely met. We verified that we could create a system using this modular approach that was large enough to meet the needs of a mature village. Designing the turbines' output to be high voltage DC, in order to combine their output in a single, underground, buried transmission line to the charge controllers in the village's power house, to meet the village's AC loads directly through DC/AC inverters, while the rest of the power is used to charge the battery bank and the smart dump loads (e.g., room heaters and hot water), confirmed to be a good and context relevant approach. We had assumed that a single large penstock would be used in a minimal system, allowing incremental expansion by adding turbines and charge controllers (VS70's) with low risk. However, we learned that such a large-diameter HDPE pipe was difficult to bury and follow contours, and that multiple smaller diameter flexible penstocks would be a better solution. One advantage to this approach is that using a smaller capacity penstock would reduce the capital requirements of a minimal introductory system. The disadvantage is that incremental expansion would require the burial of an additional penstock, increasing the capital and labour needed for incremental expansion. Assuming smaller penstocks are used in the future, we have not yet learned about the issues present during incremental expansion. Similarly, the original system included all the necessary transmission line capacity for a mature com-munity, so we did not experiment with the issues that might occur when burying incremental transmission lines when turbines are added to an existing system.

The project proved that the modular approach is both feasible and sustainable. Local Nepalis have risen to the challenge of keeping the system operational, and maintenance costs have proven to be extremely low. The residents' NRP 150 monthly service fees have been able to pay the operator's salary and still accumulate approximately 1'200 USD over the first two years of operation.

This project was meant to be a proof of concept, not a means to evaluate the minimum viable capital costs needed to introduce electricity to a village. Even if it was, the cost would vary significantly from site to site due to the influences of terrain and distances, and the cost of the power electronic components are expected to fall over time. Although the project didn't verify the minimum capital needed for an introductory system, we still believe that a partnership between government, donor, and entrepreneurial sectors would be needed to create the initial system, and that incremental expansion could be done without significant help from government or donors.

Objective 2 was met.

The following main points have been learned of how this modular system approach can best be applied in the local context:

1. High gabion wire and stone walls 2m thick need to be placed in the river to protect the water intake infrastructure from boulders rolling down the river during the monsoon season, and to keep water from overflowing the walls and filling the settling pond with sand and rocks.
2. Although HDPE pipes are robust and can be thermally welded in the field, the bend radius of a 200mm diameter pipe is much too big for them to be routed around large boulders or to follow the contours of the terrain common in Nepal. Multiple smaller diameter HDPE pipes, available on large rolls, bend in a smaller radius and the number of time-consuming thermal welds would drop precipitously.
3. It took several months for the village residents to appreciate the need for a pay-as-you-go electricity system. They now accept a 150 NRP (~ 1.30 USD) per month base electricity fee as necessary to sustain the system.
4. We had mixed success regarding the smart dump loads. Although the electric heating of the community center and the hot water shower is much appreciated, no one from the village is charged for this energy, as visitors, researchers, students and tourist visiting the village and staying in the community center would pay for their stay and thus cover these costs. But du to COVID-19 since early 2020 no visitors could come. The hot shower dump load in the village was quite popular, but we have not yet convinced the residents to pay even 20 NRP for a warm/hot shower. This is primarily due to their poverty and lack of awareness about how poor hygiene can improve through periodically showering. So, continuing awareness and education needs to take place in Mohari village, as well as an economic expansion plan should accompany future replication projects.
5. The skills needed to perform the daily maintenance tasks and operation of the system were easily learned by a village resident. Less regular maintenance and enhancement tasks had to be performed by a more educated resident of the district center. Engineers in the USA were able to provide consultation on tasks the village or district resources could not handle. We expect this tiered approach to be necessary for successful replication.

For additional details on key learnings see the SWC2019 paper "Modular Pico-Hydro Power Plant Mini-Grid for Remote Himalayan Villages in Nepal" in Annex 2.

Objective 3 was partially met. More details in the following section.

5.3 Multiplication / Replication Preparation

Multiple papers were published on the project, and Zahnd and Stambaugh attended several renewable energy conferences to draw attention to the project. Schematics, custom PCB design information, embedded firmware, control software, and consultation are ready to be provided to anyone thinking of replicating the system.

Local political and government leaders attended the inauguration of the modular pico-hydro power plant. They received a detailed introduction and walk through the whole power system, in order to understand the new power generation approach and its benefits compared to the traditional approach. Their support is important to be able to reach out to the local industry, which is known to be very conservative in their approach to change the status quo, to get more interested and on board to con-sider the development and production of new power generation products and new income streams for rural village electrification. This is particularly important because Nepal's political system is now de-centralized ("gaunpalika" concept) with much more decision-making authority at the local level. Although this simplifies replication within the Jumla and neighbouring districts, it will create challenges to broader replication across Nepal because each district will have to be convinced separately.

Nepal government's Alternative Energy Promotion Center (AEPC), the department to develop policies for rural electrification, has adopted a strategy of extending Nepal's electricity grid to connect all communities. Given that strategy, AEPC's support of any pico/micro electrification system will be dependent on its ability to eventually connect to the grid. A system that can store energy and provide it during times of peak consumption would be highly attractive. The battery storage inherent in this modular pico-hydroelectricity approach should be very valuable to them.

Zahnd and Stambaugh were not able to visit AEPC as planned in spring 2020 due to the pandemic lock-down of Nepal. Instead, one of our Nepali engineer staff visited the APEC executive director in March 2020, introducing the modular pico-hydro power concept and handed him over RIDS' recommended "Pico/Micro Hydroelectric Policy – Recommendations tor AEPC" for rural village electrification (see Annex 3). Permitting Nepal is open, Zahnd and Stambaugh plan to meet AEPC in 2021 (either in spring or autumn, dependant on Nepal's situation in 2021) to enforce what has been previously recommended as well as to emphasise that the replication of the modular pico-hydro power plant concept comprises of a standalone, islanding system for very remote village communities where the national grid will never reach, but as well will includes the ability to be integrated into the national grid when it is eventually connected to a served village community.

5.4 Impact / Sustainability

The system has been operational non-stop since it was turned on Nov 30, 2018. Few electrification systems in Nepal can claim those bragging rights. Even Kathmandu, until recently, had rolling blackouts, resolved only by purchasing coal power plants generated power from India in spite of having gigawatts of hydropower and solar potential in Nepal.

We experienced since the inauguration in November 2018, each two hard winter seasons (November – March), with lots of snow and monsoon seasons (June – September) with exceptionally lots of rain and high-water levels of the river tapped into for the water resource for the modular pico-hydro power plant. Throughout the last two years, the river protection purposely built to keep the built pond and cemented sedimentation tank have withheld the strong water force and boulders rolling down the stream. The underground buried penstock has shown to protect the water from freezing on its way from the sedimentation tank to the 490 meters away turbine house. Also, none of the 98, Ø200mm, HDPE pipes hot welded together (each 5 meters long) has leaked, despite the large temperature range throughout a year.

After the first 3-4 months hesitations to pay for electricity as mutually agreed, the village residents saw the benefits of having uninterrupted access to electricity 24/7 and thus soon after till today it has become normal that at the beginning of each month each family come to purchase their minimal monthly units for 150 NRP. All the residents are very happy about the project and can't think anymore of not having electricity any time they need it.

Ecological	**Unit**	**At the REPIC Project's Completion**
Installed renewable energy capacity	[kW]	6.6kW generation capacity with 6 Pelton Turbines tested. As of end of 2020, 2 Pelton Turbines 24/7 running, generation ~2.4kW non-stop. At any time, increased demand can be covered by running additional Pelton Turbines

Renewable energy produced	[kWh]/year	21,100kWh generated in 2020 with 2 Pelton Turbines generating each ~1.2kW non-stop (8 liters water per second, 40 m net head, resulting in ~75% system efficiency)
Amount of fossil fuel energy saved	[kWh]/year	Mohari village never used any fossil fuels to generate electricity. But a firewood consumption of approx. 5kg/household, or approximate 70 tons/year for the village was used to generate hot water for personal hygiene and dim indoor lighting (by burning wooden sticks inside the room) before they had electrified and, is now saved
Greenhouse gas reduction	[t CO_2-eq]/year	70 tons/year firewood saved for the Mohari village due to less firewood consumption as they have now uninterrupted access to electricity, reduces CO_2 greenhouse gas emission by about 137 tons CO_2-equivalent per year (as per formula on page 19 in "Gold Standard Technologies and Practices to Displace Decentralized Thermal Energy Consumption")
Newly collected and separated waste	[t]	NA
Newly recycled waste	[t]	All the 6 PowerSpout Pelton Turbines (from New Zealand) have been manufactured from ~60% recycled materials
Economic		
Energy costs (LCOE)	[ct/kWh]	50 NRP per kWh @ 115 NRP/USD = ~44 cents US/kWh
Triggered third-party funding/investments	[CHF]	68'800.- (as defined in the summary financial report, Annex 4)
Voluntary participation and sweat work	[CHF]	217'300.- (reflects the Voluntary participation/sweat-work valued in CHF monetary value, provided by the local Mohari village community and RIDS-Switzerland/USA/Nepal staff. Detailed contributions defined in the summary financial report, Annex 4)
Local private income generated	[CHF]	NA
Social		
Number of beneficiaries	[Number]	37 families with 247 people
Number of new jobs	[Number]	2 full-time jobs (modular pico-hydro power plant operators)
Number of trained personell	[Number]	8 people received vocational (semi-formal) training for new skills (pico-hydro plant operators, PC operation to issue monthly electricity token, accounting, electrical installations and house wiring) and >30 trained on the job for new and improved skills (such as stone masonry, carpentry, building structures with cement, HDPE penstock pipe-line welding etc.)

Other Indicators		
Indicator 1: Village power demand increase	watt [W]	More than doubling (from 150W to 350W) constant power demand increase over the course of 2 years uninterrupted electricity generation.
Indicator 2: Increased user families	[Unit]	4 new houses have been built in 2020 alone (totaling now 41 houses), showing a higher than average increase of homes compared to previous years, when mainly due to of migration for urbanized areas less new homes were built. These new houses will be connected to the mini-grid in 2021, once the families of the new homes have complied with the village community's set rule and regulations for the use of and

		payment for, electricity
Indicator 3: Increased power generation potential	Pelton Turbines [Unit]	The Mohari “modular pico-hydro power plant” has a total of 6 Pelton turbines installed, able to generate up to ~7kW. As per end of 2020 only 2 turbines are running as the village’s demand is still low. However, if the demand for electricity continues to grow as in the first two years, more turbines, up to 6, can be run to provide the increased demand in the years to come. Further, the pcio-hydro power system has been designed and built (water flow, cable capacity, power electronics, etc.) to enable the village to add 2 additional Pelton Turbines, totaling 8 (with ~9kW capacity), over the life-cycle (15-20 years) of the power plant. This can come to be in case a carpentry shop is built, new additional useful “dump loads” are installed and the village household power demand continuous to increase.

5.5 Political, Caste, Gender, and Economic Inclusivity

There are several aspects of inclusivity that have been addressed in this prototype system. Specifically, what groups are used during the construction of the system, what groups benefit from the system, and what groups can be employed to operate or construct replicated systems in the future.

Residents from all castes, politics, genders, and wealth contributed equally during the planning and construction of the system.

Residents from all castes, politics, genders, and even economic status have access to the electricity produced. The community expressed concern over the 150 NRP (1.5 USD) per month service fee because some residents could not afford this, predominantly low caste widows. The more affluent people in the village volunteered to pay their service fees to ensure that everyone can enjoy its benefits, even those who cannot afford it. The only people without electricity in the community were out of town and could not help during its construction. They could ‘buy-in’ to the system by paying 500 NRP (5 USD) per day they could not work, giving everyone quite an incentive to contribute during its construction. Furthermore, RIDS-Nepal’s efforts to educate women and children in the village have been enhanced by the electricity accessible to everyone.

People with a reasonable base level of education are needed to work in any business operating or replicating this modular pico-hydroelectric system. This is needed to ensure they can be economically educated in the specific skills required to run these businesses. For example, they need very basic computer skills, and the ability to read and write. These skills are currently more available in district centers than in remote communities. Fortunately, this is where these businesses would exist. Existing regional education centers around Nepal, such as the Karnali Technical School in Jumla, continue to teach these skills and more to all castes, politics, and genders in the remote regions, ensuring an inclusive supply of sufficiently educated people to support replication. RIDS has been involved since 1999 in providing scholarships to mainly low caste young females and males from Mohari village and other villages in the area, to study at the Karnali Technical School in Jumla, to have a government certified apprenticeship and/or profession which enables them to have far better chances to get a well paid job, either with one of the government departments or local NGO.

6. Outlook / Further Actions

6.1 Multiplication / Replication

With our RIDS staff being permanently working and living in the area, the prototype modular pico-hydro power plant can continue to be closely monitored over the next 3+ years. That enables to learn more about the long-term performance, local user acceptability, user ownership and sustainability of a system scaled for first time use of electricity.

With this system being the first prototype modular pico-hydro power plant, the initial costs were obviously high. Thus, special emphasis will be given over the next 3 years to bring down the initial capital costs for such a modular system and learn what needs to be done in the initial installation to reduce the cost and effort of incrementally expanding the system capacity.

Continue to look into more and broader economic development activities in the village, and productive end uses such as greenhouse heating and lighting, or powering the tools and machines needed in a carpentry workshop.

Continue to meet and work with AEPC to include the modular pico-hydro power plant concept into their nation-wide applicable policies.

Search for funding for a second modular pico-hydro power plant system in partnership with a remote village community to apply what we have learned so far, to get more data and experience for this new approach to rural electrification. The next project should start with a minimal system and expand it incrementally, with the potential to be connected to the national or district grid to demonstrate how this system can support AEPC's long term strategy.

Meet with local industries to discuss the potential to develop and manufacture locally a contextualized and applicable turbine and its needed periphery systems, so that in the long-term the knowledge and capacity to manufacture the modular pico-hydro power plant system can be done in Nepal.

6.1.1 Business Model

A lease-to-own model doesn't make sense for a system that cannot be easily removed in case of stopped payments. A more traditional model where an entrepreneur pays for the system and receives a return on his investment would be more appropriate.

Rough estimates show that a system scaled to satisfy the needs of a small community's first introduction to electricity would cost on the order of 4M NRP (~40,000 USD). Table 1 shows the financial analysis of this community prior to economic expansion.

Energy Production / month	2kW * 24 * 30	1'440 kWh
Revenue for 40 homes and businesses	150 NRP base rate for 3 kWh	6'000 NRP
Operator salary	3'000 NRP	-3'000 NRP
Routine Maintenance	2'000 NRP	-2'000 NRP
Net Income / month		1'000 NRP
Breakeven	4M NRP / 1'000 NRP	3 centuries
MIRR	Over 20 years, 8% finance rate, 3% reinvestment rate	-12%

Table 1 - Financial Analysis of a Community Able to Purchase only 150 NRP/month

Clearly there would be no purely entrepreneurial interest in supporting a community with no plans for economic development.

Fehler! Verweisquelle konnte nicht gefunden werden. shows the financial analysis for various communities and business models.

Business Model	MIRR
Subsistence community, household growth 3%/yr, yearly consumption growth 3 kWh/month. System expanded by 2 turbines when necessary. No government or donor capital contribution	8%
Same as above, but with 50% capital contribution from government or donors toward the initial installation with 2 turbines.	12%

Table 2 – Financial Analysis for Various Communities & Systems

6.2 *Impact / Sustainability*

Environmental impact/sustainability: With tapping into the local stream of water, taking far less than 1 % (max. 24 liter/sec.) of the minimum annual flow of the river upstream and feeding all the water again back into the river downstream, there is no adverse impact on the environment nor the living organisms in the water whatsoever.

Socio-economic impact/sustainability: After 2 years of uninterrupted access to electricity for 37 households in Mohari village, the local residents can't imagine living without electricity anymore at an instant flick of a switch. There are now more community-based teaching video evenings in the community center, as well as children can do their homework any time in the morning and evening before and after sunrise and sunset respectively. Woman can do their indoor work at all hours, and more efficiently, e.g., use their tailoring skills in the evening with light. That leads to longer working hours and more products to be produced and potentially sold for additional income generation.

CO_2 impact/sustainability: With tapping into the local stream, a renewable energy resource is utilized, producing no CO_2 emission and reducing the consumption of forest resources. As in chapter 5.4. table "Ecological", "Greenhouse gas reduction" mentioned, due to access to interrupted electricity, approximately 70 tons firewood per year, which was previously used to generate dim indoor lighting and hot water in each household (consuming approx. 5kg/household per day), can now be saved by the Mohari village. That reduces the CO_2 greenhouse gas emission of the village by approximately 137 tons CO_2-equivalent per year, calculated as per the Gold Standard Technologies and Practices to Displace Decentralized Thermal Energy Consumption (page 19).

Resource efficiency impact/sustainability: The overall generation efficiency is around 70-75% based on energy delivered to the power house (kW) vs energy input (flow times vertical drop), which is high for such a small hydro-power plant. In comparison nearby micro-hydro power plants, generating between 10 kW and 50 kW, have been measured to be between 35% to 50% maximum. This impressive system efficiency is due to a combination of molded blades in the high efficiency Pelton turbines, direct drive to one of the most efficient permanent magnet generators available, and the use of high efficiency power electronic equipment.

7. Lessons Learned / Conclusions

The project's main lessons learned and findings can be summarized as following:

1) The monitoring system experienced several issues.
   a) A 100 USD device connecting the inverters and charge controllers to the control/monitoring computer failed, so US based engineers could not see how the system was running.
   b) We used a pay-as-you-go cell modem to connect the monitoring system to the global internet. Since the SIM card could be removed from the modem and installed in a phone, we had a difficult time keeping it charged with money. Some means of physically securing the card, or password protecting it are needed.
2) Turbines produced by Ecoinnovation are ideal for developing areas due to low cost, low weight, durability, high efficiency, and easy repair and maintenance in the field using inexpensive and readily available components, Support from Ecoinnovation is outstanding.
3) Use good quality grease purchased directly from an SKF agent. Counterfeit grease is common and of very poor quality.
4) Studer Innotec's Extender system of inverters and charge controllers just plain works, and can be readily expanded in parallel for higher capacity or to make a 3-phase system. Setup is simple. A translation of the user's manual into Nepali would be very beneficial.
5) Operation of turbines at 300VDC is too high. Turbines can create 3x higher voltage than normal if they are not loaded, easily destroying many components in the system. Several layers of protection were used to reliably maintain a load at all times, and this created unnecessary complexity.
6) Our decision to reduce transmission line weight and transmission losses by running at 300 VDC should not be repeated in replicated systems. First, an unloaded turbine could damage the system, so multiple levels of redundant protection were used to ensure the turbines were always loaded. This created additional complexity and cost. Second, 3-phase rectifiers were damaged in 3 of the 6 turbines over 2 years. Fortunately, these are inexpensive components that are readily available. In order to apply what we learned and mitigate the situation, we purchased replacement 200 VDC

stators that we will replaced when Zahnd and Stambaugh return in 2021 (COVID pandemic permitting). 200VDC is commonly used on similar systems in the developed world, so we are confident these fixes will solve the issue. Running at 200VDC will result in some minimal additional losses, but that is quite tolerable considering that reliability and long-term sustainability of the modular pico-hydro power system will only increase.

A concise and detailed summary of the modular pico-hydro power plant, its configuration, operation, usage of power etc., is described in the SWC2019 conference paper "Modular Pico-Hydro Power Plant Mini-Grid for Remote Himalayan Villages in Nepal" (Annex 2).

8. References

8.1 Academic refereed conference papers and workshops:

- **SWC 2019 (Solar World Congress 2019), Santiago, Chile, 04.11. – 07.11.2019**
  Conference paper: *Modular Pico-Hydro Power Plant Mini-Grid for Remote Himalayan Villages in Nepal.* **doi:10.18086/swc.2019.08.10 /** *http://proceedings.ises.org/paper/swc2019/swc2019-0040-Zahnd.pdf*
- **SWC 2019 (Solar World Congress 2019), Santiago, Chile, 04.11. – 07.11.2019**
  Conference paper: *Synergistic Benefits of a Holistic Community Development Project Concept Approach.* **doi:10.18086/swc.2019.52.04** / *http://proceedings.ises.org/paper/swc2019/swc2019-0251-Zahnd.pdf*
- **SWC 2019 (Solar World Congress 2019), Santiago, Chile, 04.11. – 07.11.2019**
  Conference paper: *Participatory Videos to Teach the Use of Renewable Energy Systems. A Case Study from Rural Nepal.* **doi:10.18086/swc.2019.52.03** / *http://proceedings.ises.org/paper/swc2019/swc2019-0250-Zahnd.pdf*
- **EuroSun 2018, HSR, Rapperswil, Switzerland, 10.09. – 13.09.2018**
  Forum/Workshop on: *Breaking the Vicious Circle of Poverty / https://www.youtube.com/watch?v=7fn_x4tel-o / https://www.colorado.edu/center/mortenson/sites/default/files/attached-files/lecture_2_-_breaking_the_cycle_of_poverty_-_3rd_april_2017.pdf*
- **SWC 2017 (Solar World Congress 2017), Abu Dhabi, 29.10. – 2.11.2017**
  Conference paper: *Improving the Utilization Factor of Islanded Renewable Energy Systems.* **doi:10.18086/swc.2017.16.04** / *http://proceedings.ises.org/paper/swc2017/swc2017-0096-Stambaugh.pdf*
- **SWC 2017 (Solar World Congress 2017), Abu Dhabi, 29.10. – 2.11.2017**
  Conference paper: *Sustainability As A Characteristic Of Renewable Energy Systems In Remote Himalayan Villages.* **doi:10.18086/swc.2017.24.03** / *http://proceedings.ises.org/paper/swc2017/swc2017-0152-Sturdivant.pdf*
- **World Renewable Energy Congress XVI - *5*-9 February 2017, Murdoch University, Western Australia**
  Modular Pico-Hydro Power System for Remote Himalayan Villages / https://link.springer.com/chapter/10.1007/978-3-319-69844-1_45

8.2 Teaching and Lecturing Videos in English and Nepali language for local operators, illiterate users, mainly women), international students, NGOs and small-scall hydro power plant developer and operators, via the RIDS-Nepal YouTube Channel:

https://www.youtube.com/playlist?list=PLM5tNUriiE49lBkt4TVQScwvnfKpSCBUs

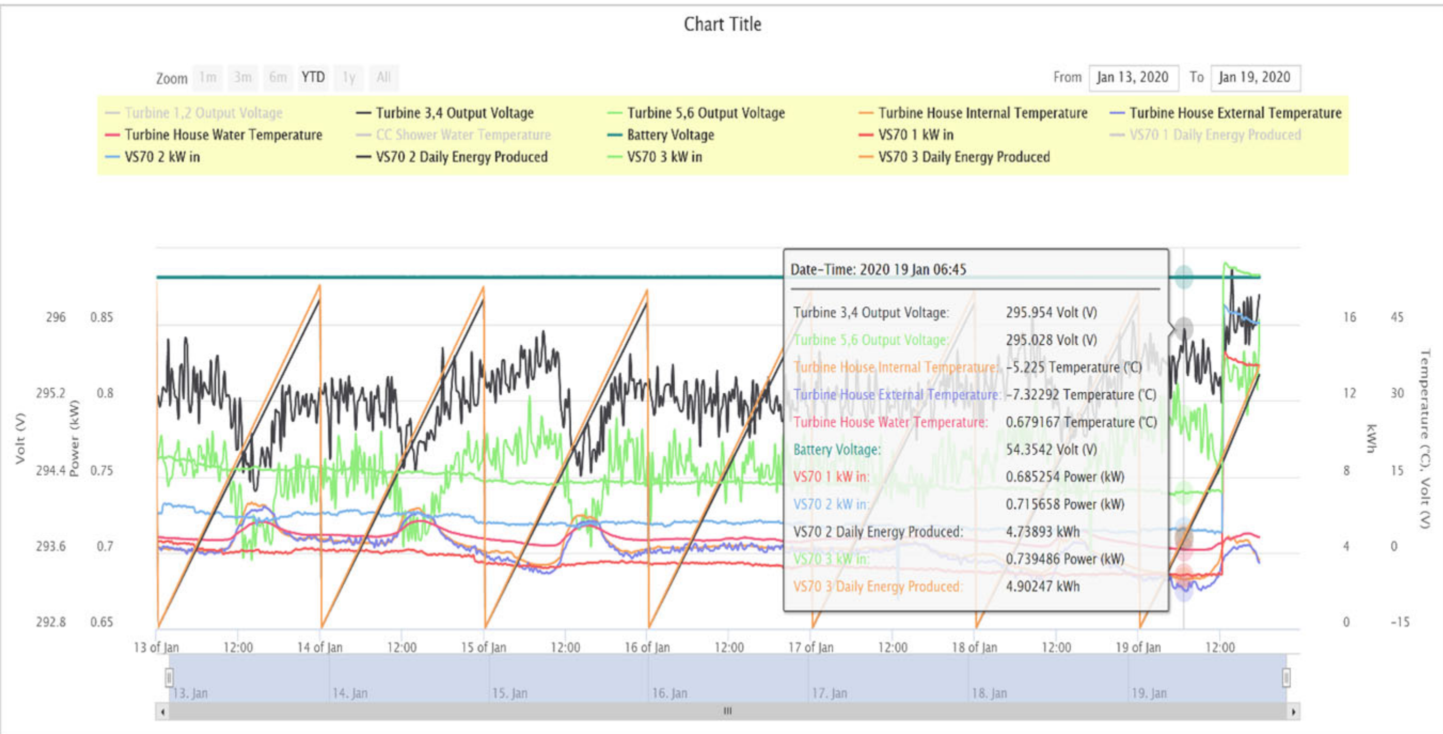
- **01 English – Modular Pico-Hydro Power Plant Prototype Project in Mohari Village Jumla Nepal** *(**40 min.** with detailed, overall concept of the modular pico-hydro power plant for students and international NGOs and operators): https://www.youtube.com/watch?v=yPnd4GCGywY&list=PLM5tNUriiE49lBkt4TVQScwvnfKpSCBUs&index=1&t=4s*
- **02 English – Modular Pico-Hydro Power Plant Prototype Project in Mohari Village Jumla Nepal** *(**20 min.** for overall concept of the modular pico-hydro power plant, interested people groups and international NGOs): https://www.youtube.com/watch?v=yyg-D9ETMOc&list=PLM5tNUriiE49lBkt4TVQScwvnfKpSCBUs&index=2*
- **03 English – Modular Pico-Hydro Power Plant Prototype Project in Mohari Village Jumla Nepal *(8 min.*** *for short overall concept of the modular pico-hydro power plant, interested people*

groups and international donor organizations and INGOs):
https://www.youtube.com/watch?v=BED08P_7HlU&list=PLM5tNUriiE49lBkt4TVQScwvnfKpSCBUs&index=3

- **01 Nepali – Modular Pico-Hydro Power Plant Prototype Project in Mohari Village Jumla Nepal** *(**40 min.** with detailed, overall concept of the modular pico-hydro power plant for Nepali students and Nepali NGOs, manufacturers and operators):*
  https://www.youtube.com/watch?v=eyWvTrmM3ZI&list=PLM5tNUriiE49lBkt4TVQScwvnfKpSCBUs&index=4
- **02 Nepali – Modular Pico-Hydro Power Plant Prototype Project in Mohari Village Jumla Nepal** *(**20 min.** for overall concept of the modular pico-hydro power plant, interested Nepali people groups and Nepali NGOs, manufacturers and operators):*
  https://www.youtube.com/watch?v=fLINtsrU4LE&list=PLM5tNUriiE49lBkt4TVQScwvnfKpSCBUs&index=5
- **03 Nepali – Modular Pico-Hydro Power Plant Prototype Project in Mohari Village Jumla Nepal** *(**8 min.** for short overall concept of the modular pico-hydro power plant, interested Nepali people groups and local Nepali donor organizations and NGOs):*
  https://www.youtube.com/watch?v=RiuBizO9Qqs&list=PLM5tNUriiE49lBkt4TVQScwvnfKpSCBUs&index=6

9. Annex

Part of the project was the development of an online “Modular Pico-Hydro Power Plant Performance Monitoring System”, in order to monitor the major parameters of the modular pico-hydro power plant (http://www.mohari.rids-usa.org/index.php). This allows us to understand how the system works and to learn what can and needs to be improved. Further, it allows to improve and optimize the operation and maintenance by the locally trained operators for greatest constancy and sustainability of the system. The following graph show 11 of the 39 parameters which are measured and recorded of the Mohari modular pico-hydro power plant with at the time 3 running turbines over the days from the 13th to the 20th January 2020.



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, Dilichaur, 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
टेक बहादुर बुढथापा
प्रमुख प्रशासकीय अधिकृत

Chairperson
गाउँपालिका अध्यक्ष

Phone :9758901232 Email: patarasirmjumla@gmail.com Web page: www.patarasimun.gov.np

The local district municipality of Patrasi, where the village of Mohari is located, issued RIDS-Nepal (in the name of Dr. Alex Zahnd, though all the work and projects done have been implemented by RIDS-Nepal and the local end users), a letter of appreciation for the long-term ongoing development work, which includes the Mohari village modular pico-hydro power plant.

The letter of appreciation was handed over by the Patrasi government and political leaders to RIDS-Nepal on the inauguration day of the Mohari village modular pico-hydro power plant

Annex 1: REPIC FINAL Project Picture SUMMARY Report 2018-2020_January 2021

Annex 2: REPIC 5th Pico Picture Report_December 2020

Annex 3: Modular Pico-Hydro Power Plant Mini-Grid for Remote Himalayan Villages in Nepal

Annex 4: Modular Pico/Micro Policy Recommendations to AEPC - December 2020

Annex 5: REPIC - Mohari Pico Hydro Project Final Financial Report January 2021

Annex 6: REPIC 4th Pico Picture Report_January 2020

Annex 7: REPIC 3rd Pico Picture Report_June 2019

Annex 8: REPIC 2nd Pico Picture Report_December 2018

Annex 9: PowerSpout_Michael_Lawley_Pico_Mohari_Report_December_2018

Annex 10: REPIC 1st Pico Picture Report_June 2018

Annex 11: REPIC Mohari Village Location and Project Pictures September 2017