# Solar Water Pumping for Productive Uses in Nepal

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**Abstract**

The market for solar pumps is rapidly increasing due to rapidly declining costs and technology improvements that are replacing traditional manual (hand) pumps, mechanical windmills, and diesel engines around the globe. They are also reducing the demands on local and national power grids. Solar pumping has become a significant and growing niche for the solar energy industry. Solar pumps are an important way for smallholder farmers to increase crop yields through irrigation; fish farmers can increase fish yields through reliable water and improved aeration; and livestock herders can increase income through a reliable water supply for their animal's welfare. This paper details solar water pumping advances and example economic impacts that are making a real difference in the daily lives of rural Nepali farmers and communities.

## 1. Modern Solar Water Pumping

Solar photovoltaic water pumping (PVWP) systems are simple, reliable, cost competitive, and low maintenance. There is typically an excellent match between seasonal solar resource and seasonal water needs, when it is sunnier and hotter, is precisely when there is more solar energy to pump water (Foster, 2009). Small and medium scale solar water pumping systems are more econmical to operate than diesel or even many electric grid powered pumps, and provides a good return on investment. Their positive impact is most significant in rural communities like those in Nepal where conventional grid electrical power does not exist. Modern PVWP systems are characterized by their reliability, durability, and low maintenance. These qualities translate into a long-term lower cost when compared with other alternatives like diesel, not to mention the environmental benefits (they do not pollute the air or water, and operate queitly). In addition, PVWPs are easily automated and do not require an operator. PVWPs also provide system modularity, which provides the owner with the ability to flexibly meet specific need at any given moment.

There have been significant advances with solar water pumping systems over the past decade. PVWP systems costs have dropped by ~2/3 since 2000. Photovoltaic module prices have decreased by over 90 percent since 2010. As a result, solar water pumping system costs have declined significantly, from a high of over US$25 per peak Watt 20 years ago, to under US$5 a Watt today. Market estimates are that PV module prices may decrease by another 50 percent in only the next 5 or so years. There have also been improvements with pump system controllers using maximum power point tracking. Solar water pumping is now competitive with retail electric grid pumping costs (Kunen, 2015).

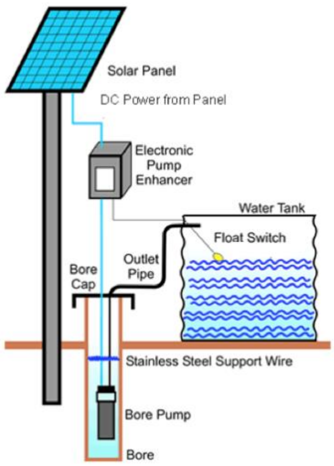


**Fig. 1: Typcal solar water pumping system layout for a borehole (well) in Nepal.**


doi:10.18086/swc.2017.30.02 Available at http://proceedings.ises.org

## 1.1. Centrifugal Solar Water Pumps

In Nepal, WI has been mostly deploying both DC and AC submersible and surface centrifugal water pumps. These pumps are readily available and affordable in the Nepalese Market. For a centrifugal pump, water enters at the center of the pump through a rotating impeller. The impeller spins the water, creating centrifugal force. The water gains both pressure and velocity as it flows through the impeller and is directed outward. A centrifugal pump can have multiple stages to increase its lift capacity. Each stage consists of one impeller with the output of the first stage feeding the input of the next. This is called a multi-stage centrifugal and may use up to about 20 stages to attain higher lifts. Each stage adds pressure, thus greater lift capacity. However, each stage also imposes friction, resulting in an efficiency loss of about 5 percent per stage.

Centrifugal pumps are especially efficient for higher flows > 40 lpm and for lifts of < 30 m. At lower flow rates and/or higher lifts, the efficiency is poor even under optimal conditions. To work efficiently, they need to run close to their full speed. Conventional power sources (grid or generator) provide stable power to maintain optimum rotational speed. Most solar pumps use variable power direct from a solar array; when power varies with the weather and the time of day, the speed of a pump will also vary (Foster, 2009). Centrifugal pumps are easily repairable locally in Nepal.

Any pump will have an optimum peak in its operating range, at which its energy efficiency is highest. Centrifugal pumps tend to have a narrow efficiency peak. A reduction in solar intensity reduces a centrifugal pump's performance disproportionately. This is because pressure is produced by centrifugal force, which is proportional to the square of the rotational speed. Thus, at half-speed, a centrifugal pump will produce only one-quarter pressure. Variation in water lift will also cause disproportionate drops in performance, if it falls outside the pump's range of efficiency. During late afternoon or early morning, or as cloud shadow appears, the pump may be spinning but the flow can stop completely.

A submersible pump is often simpler to install than a surface pump. It will not require intake piping or an intake valve. Nor will it require priming (being filled initially with water). It is less likely to be damaged from running dry due to pipe or valve leakage. Under ground and under water, it is protected from temperature extremes (e.g., freezing) and from human tampering.

**Fig. 2: Pedrollo (Italian) surface centrifugal AC solar pump used in Odaltal village of Surkhet District for rice irrigation.**

Horizontal submersible centrifugal pump installation (Fig. 3) is fine, but the lack of screen on the pump intake will cause the pump impellers to eventually clog from gravel and silt buildup that will require frequent cleaning of the pump stages. Pump intakes should be installed at least 1 meter from the bottom of well or river and with an intake screen to prevent large debris from entering. The community agreed to improve the pump setup.

Centrifugal pumps are useful for pumping large volumes of water and in situations of low head and are often the most efficient and economical. For example, in seeking a system to irrigate a large field requiring over 100 m3 per day, centrifugal pumps aer superior to positive displacement pumps.

**Fig. 3: Grundfos submersible centrifugal pump used in a river for Taule village.**

**Fig. 4: Flood irrigation via a surface centrifugal solar water pump managed by Phattu Tharu of Bansgadhi, Bardiya.**

The system above (Fig 4.) includes 8 TrinaSoar PV modules that are 315 Wp each (8 S X 1P configuration), directly powering a 1,800 W Italian Pedrollo AC surface centrifugal pump. The project irrigates rice and vegetables was implemented by the Hariyali Krishak Samuha farmer association in Bardiya in cooperation with the USAID Kisan project.

## 2. Accelerated Commercialization of Photovoltaic Water Pumping for Nepal

The USAID Accelerated Commercialization Solar Photovoltaic Water Pumping (AC-PVWP) project managed by Winrock Interational (WI) from 2015-17 is designed to expand the commercialization and adoption of PVWP systems for irrigation, livestock watering and community water supply in Nepal. The AC-PVWP project has worked closely with the USAID Knowledge-based Integrated Sustainable Agriculture and Nutrition (KISAN) Project in Nepal also managed by WI in supporting small scale farmers to transition from subsistence to commercial vegetable farming by helping implement new techniques and technologies such as solar water pumps, as well as the use of plastic houses and raised beds that replaced less effective traditional cultivation practices. Capacity building and market development activities have helped expanded commercialization and adoption of solar water pumping systems for irrigation, livestock watering, and community water supply. " Irrigation is a game changer for agricultural households in Nepal because they can grow during more seasons outside of the monsoon season and yields can be tremendously higher," states Phil Broughton, Chief of Party for the USAID

KISAN project (Warren, 2017).
The AC-PVWP project has been successful in establishing scalable and profitable business models. While higher upfront initial capital costs are always a barrier for the adoption of PVWP technology for rural communities and smallholder farmers in Nepal, the AC-PVWP project has worked closely with private suppliers, banks and financial institutions to develop business models such as credit financing, rent-to-own, water entrepreneurship, vendor financing to overcome this barrier and scale up installation of the technology. Furthermore, the project introduced new and affordable product with wide range of technology considering the need and affordability of the farmers for scaling up PVWP .market.

The first phase of the AC-PVWP project in 2016 installed over 69 pilot PVWP systems with installed capacity of 53.15 kWP benefiting 392 farmer groups in 16 districts as follows: Jhapa, Morang, Siraha, Rautahat, Makwanpur, Chitwan, Kathmandu, Kapilvastu, Syangja, Dang, Banke, Surkhet, Dailekh, Bardiya, Kailali and Kanachapurt. An additional ~120 replicated systems will be deployed in the second phase by the end of 2017. The business models employed and the district wise installations as shown below:

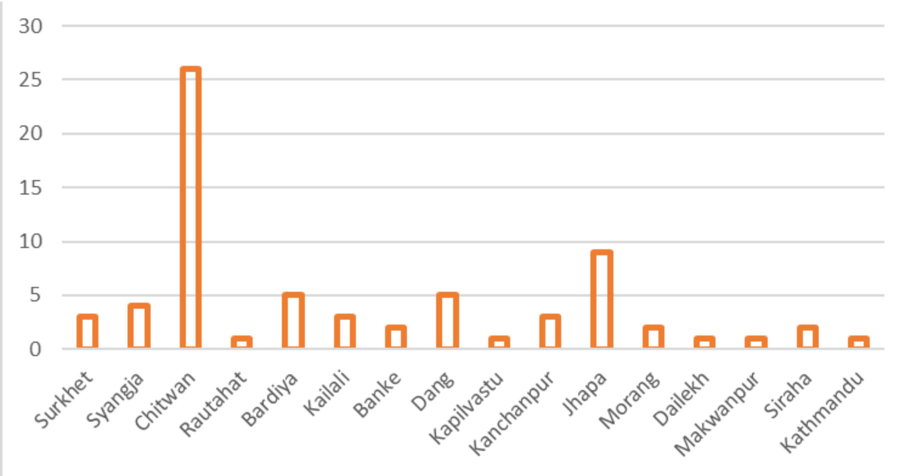


**Fig. 5: Number of first phase AC-PVWP system installations by District in Nepal**

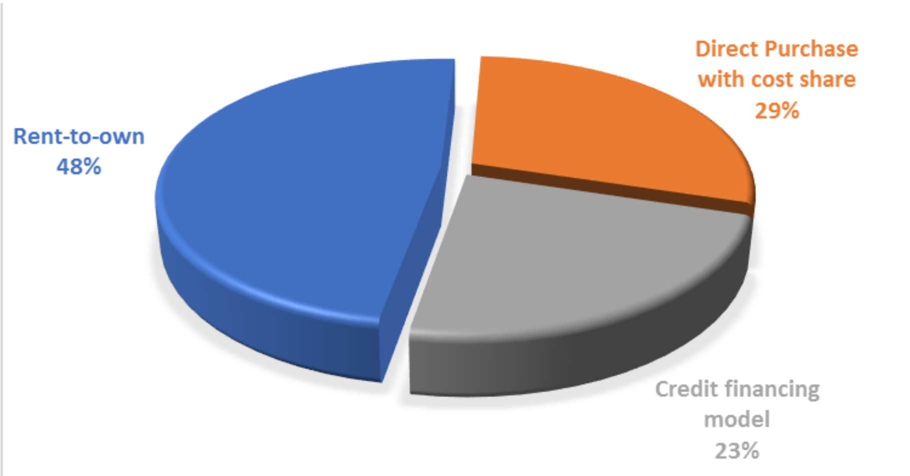


**Fig. 6: Finance models for AC-PVWP projects installed in Nepal**

## 3. Empowering Rural Women and Improving Livelihoods

*"I can now earn enough to invest on the education of my children and I feel empowered" - Ms. Dila Gurung*

Ms. Dila Gurung, 35 years old from the off-grid Taule village in Surkhet District, was in a difficult economic situation before acquiring a solar water pump which helped improve her livelihood. Even though she owned 5 Ropani (0.62 acres) of land, she was dependent on intermittent rainfed agriculture with no prospects for irrigation to increase productivity. WI approached the farmers about the potential to extend their ability to grow crops during the dry season through solar powered irrigation and that a solar-powered irrigation system would help transport 10,000 liters of water per day uphill from the nearby river to the fields where it was needed.

Her land is now green with high value commercial vegetables made possible with a PVWP system in collaboration with the Sitaram Agricultural Group. The financing for the PVWP was made accessible through the Small Farmer Saving and Credit Cooperative for commercial vegetable farming. Technical support was from WI from the USAID AC-PVWP project in collaboration with the Veri-Ganga municipality and USAID KISAN project.

The 1,260 Wp PVWP system installed at Taule-10 is primarily used for vegetable farming. The system includes 9 PV modules (140 Wp each) installed 9S X 1P. The mono-crystalline solar modules are manufactured by Ningbo Komaes Solar Technology Co. The system is community-based and owned by Sitaram Krishi Samuha benefiting 11 active farmers out of 16 members. The system pumps 10,000 liters per day of water at a total dynamic head (TDH) of 60 meters. The PVWP system was installed at a total cost of US$4,766 using a 1.26 kW SQF-3A10 manufactured by Grundfos. KISAN helped surmount that financial hurdle by arranging a cost-sharing agreement in which eight farmers took out a loan of $3,000 from a local farmers' cooperative, which would be paid back thanks to additional income from vegetable sales. In addition, Winrock, KISAN and the local Veri Ganga Municipal government contributed grants totaling $2,200. With labor supplied by the farmers and technical expertise from Winrock, the solar irrigation system was installed in May, 2015 (Warren, 2017).

**Fig. 7: Solar water pumping array (9s x 1p) rated at 1.26 kWp used for irrigation by the Taule village farmers.**

The difference consistent access to water has made in the amount of vegetables Gurung and his fellow farmers can grow has been dramatic. "After the solar pump the production has increased 70 or 80 percent," says Gurung. Household incomes have also risen between $300 and $2,750 annually, allowing the farmers to pay off the loan for the solar irrigation system (Warren, 2017).

The PVWP in Taule has completely changed Mrs. Gurung's lifestyle. She appreciates that the PVWP system has very low maintenance and running costs, quietly and reliably providing daily irrigation throughout the year. Her traditional subsistence farm was completely changed into a highly profitable enterprise based on using a PVWP systems for irrigation. She now harvests high value commercial vegetables and has seen a fivefold increase in her annual income from her former subsistence farming lifestyle. She grows cauliflower, cabbage, and red chilies and sells to the local markets. She is financially empowered and earned US$1,9145[1] last year from selling vegetables. She has better finances, improved self-esteem, and new technical skills attained from KISAN farmer trainings. "I feel socially, financially and technically empowered after commercial vegetable farming. I shared my journey of transition and boundless opportunities brought by the solar pump to Haree village to inspire women to switch to commercial vegetable farming." She looks forward to the returning of her husband from Qatar and she believes in their new potential to commercially grow vegetables together with no need for him to return to Qatar.

## 4. Case Study: Replacing Diesel Pumps for Solar Pumps for Fish Farming

*"We are easily paying off the installation of our solar pump from the savings of diesel fuel costs" - Ms. Bhundi*

[1] Exchange rate for 24 March, 2017: 1 US$=NPR 104.45

*Chaudhary*

Mrs. Bhundi Chaudhary, a 47 year old fish farmer from Maijui village of Chitwan district, whch is populated with indigenous Tharu residents whose main livelihood is fish farming. Mrs. Chaudhary decided to switch to solar water pumping system to fill her fish pond and aerate in order to eliminate the expense of her previous diesel powered water pump. Before installing solar water pumping system in her field, she used to fill the fish pond and irrigate her 13 Kattha ( 1.08 Acres) of land using an oversized 5 HP diesel water pump set. They used to operate diesel pump for 3 to 4 hours in every other day to meet their water requirements. They used to spend about US$ 81 per month for fuel to operate diesel pump.

Ms. Chaudhary learned about solar water pumping technology through a farmer's interaction program at Khareni, Chitwan organized by WI where she learned about a rent -to-own business financing program provided by Sun-Farmer Nepal. Leveraging the program, Ms. Chaudhary installed a 750 Wp solar pumping system that operates 0.8 HP submersible DC pump which pumps about 20,000 liters of water daily under this affordable financial model.

The PVWP was installed in December of 2015 at a total system installed cost of US$3,350, which included three years of vendor post-sales service. Since this was the first pilot in this region, and as incentive to buy down the technology risk for her as an early adopter, a subsidy of US$1,379 was provided jointly by WI and the Nepal Government Renewable Energy for Rural Livelihood project. As part of the subsidy agreement, she had to make her installation available as a demonstration for other area farmers. After providing equity of US$575 as up-front payment, NPR US$1,398 of the system and service cost was arranged under a rent-to -own business model through SunFarmer Nepal with a 3 years term. Under this scheme Ms. Chaudhary must pay monthly installment of US$39. Through productivity gains, she is paying back the installment from the savings of diesel fuel costs displaced. "Other farmers in the village were struggling to find diesel to run their diesel pump set during the Indian border blockade and were forced to buy diesel at higher price ranging up to NPR 350 (US$3.35) per liter. But, we were worry free as our solar water pump operated from the sun which was free from a blockade without incurring any cost and troubles" is Ms. Chaudhary's observation.

The 750 Wp Solar Water Pumping is used to draw water from an open-well to a canal to the pond. 3 panels each of 250 Wp are installed in configuration of 3 Sun-Worth PV models in series and 1 in parallel (3S X 1P). The pump is 600 W (48VDC submersible pump) from Solar Tech model SPM600C with a water output of 25,000 liters/day at 4.2-meter head for 6 kWh/m$^2$/day solar radiation. The system cost of the PVWP is NPR 350,000 (US$3,350.88). The system was installed under rent-to-model. In this model, the farmers provide a down payment upfront, and the remaining amount is financed by the company for a 3 years period. During the financed period, the PVWP vendor will be responsible for system operation and maintenance.

**Fig. 8: Mrs. Chaudhary with her 750 Wp PV water pumping system in the background in between her aquaculture ponds**

Besides the fish farm, Ms. Chaudhary also used water from solar pump to irrigate her land. She appreciates solar pump for several benefits such as minimal maintenance, effortless operation, minimal attention and continuous water supply compared to a diesel pump. The operation of diesel pump was not easy as it required physical strength to start and she had to look for help every time. She also had to remain standby to check the proper operation of diesel pump. Now, she is free as her solar pump is automated. The solar pump starts pumping water with the rising sun and stops as the sunset. She invests her saved time into productive works like vegetable farming, livestock rearing, and fencing her land. Her field is green with several types of vegetables. She is growing green peas, cauliflower and other seasonal vegetables. She made profit of US$718 by selling of fish and US$287 by selling green peas and vegetables last year.

According to Ms. Chaudhary, “Installation of the solar pump was my sole decision and it feels good to be appreciated by my husband and family.” She is now a model fish farmer in her village her self-confidence has been boosted from the interest and visits of other farmers to see her aquaculture operation and how they can also boost their productivity using a solar pump.

## 5. Case Study: Replacing Diesel Pumps for Solar Pumps for Fish Farming

*“We no longer have to rely on rain to cultivate land. The barren land is now green with commercial vegetable farming” - Ms. Ganga Garanja*

Ms. Ganga Garanja, 44 is a single mother of Pingale village of Pokharikada in Surkhet District who was a subsistence farmer who grew limited cereal crops to feed her family throughout the year. She owns 6 Ropani (0.75 acres) of mountain side land that was barren as irrigation was not feasible and she had to depend on inadequate rainfed agriculture compelling her to take out a loan just to feed her family. She along with her 2 daughters and a son were stuck in grinding poverty. Likewise, 29 other village households in Pingale were faced with a similar situation.

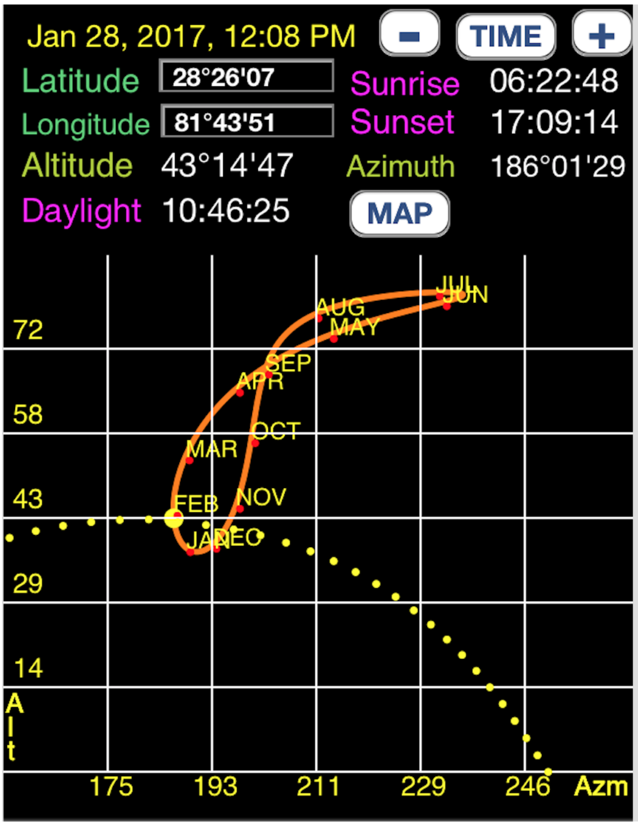


**Fig. 9: Solar analemma near solar noon for Pokharikada (Solar Track App)**

Despite owning land, the people of the village had to work as day laborers to survive. However, the money earned as day laborers was never sufficient to provide a good education and sufficient food for their children. Villagers intially tried to organize into a group named Milijuli Tarkari Utpadan Samuha to initiate commercial vegetable farming in 2009, but it was of no help as the group had no means for irrigation and depended on rain-fed agriculture.

**Figure 10: Solar power array using German made Komaes140 Wp PV modules (9s x 1p) for t Pokharikada using a Grundfos submersible centrifugal solar water pump.**

After 6 years in 2015, in collaboration with the AC-PVWP and KISAN projects, the Pingale village group installed a PVWP system for crop irrigation. The PVWP system helps farmers to irrigate throughout the year from a natural spring utilzing a spring catchment reservoir pumping to a higher altitude storage tank from where the water is distributed for irrigation. The villagers paid NPR. US$ 3,407 for the installation of the system. WI provided a pilot subsidy of US$1,436 through the AC-PVWP project and KISAN project provided US$192 to create a regional demonstration for other farmers in the district. Similarly, RISMFP and Pokharikanda VDC also provided grants of US$ 2,528 and US$ 1,292 for the installation of the system. .The system is managed and owned Milijuli Tarkari Utpadan Krishak Samuha farmer group.

**Fig. 11: Pokharikada main water storage tank for solar water pumping from a spring for irrigation.**

The PVWP helped the villagers make the transition from subsistence to commercial vegetable farming. The results for villagers has been life-changing from subsistence to commercial farming which has increased Ms. Granaja's income by 3-fold and enabled her to cultivate tomatoes and boost the quantity and quality of her crops. Now Ms. Granaja makes an annual profit of more than US$ 478.69 from tomatoes and US$ 287 from selling other seasonal vegetable and US$ 191 from livestock.

The technical skills provided by the KISAN project on commercial vegetable farming regarding the better seeds, vitamins, tillage, plant spacing, varieties and scheduling irrigation has been very effective. Mrs. Granaia concludes that "The technical assistance from Winrock International has helped us to have received the solar water pump that requires less attention, effortless operation, and minimal maintenance." The villagers now have a better financial status because of solar powered irrigation for commercial vegetable farming.

## 6. Commercial Rice Irrigation

A solar water pumping system was installed with WI assistance in the village of Odaltal of Surkhet District by Ghampower Pvt. Ltd. in November, 2016. The farmer group installed the distribution pipes and water storage tank in mid-2017. The system is managed by Jagaran Krishak Samuha, who is part of a 30 farmer cooperative group, whose chairperson is Ms. Tej Kumari Sunar.

The system consists of a 2,340 Wp array TrinaSolar modules from China ( 9S X 1 P configuration), each solar panel is 260 Wp. A 2,300 W Italian Pedrollo 2 HP AC surface pump is used to deliver water to the water storage tank from the spring reservoir. The total PVWP system cost was US$5,170, which excludes civil works such as the spring reservoir, storage tank, and distribution pipes. The irrigation system only became operational in mi-2017 and economic impacts for rice irrigation season have not yet been determined.

**Figure 12: WI technicians measuring solar irradiance for the PVWP installed in Odaltal village of Surkhet District.**

### *6.1. Rice and Vegetable Irrigation*

A large solar water pump system was installed in November 2016 in Piparkoti, Valkachuha in Kailali District using a Trina Solar 3,120 kWp solar power array used for irrigation of rice and vegetables. The farmer group that uses this system was formed by USAID-KISAN project and has 20 members. The solar power system is owned and managed by Sirjana  Krishak Samuha from the farmer group. The PV system is somewhat unique for solar water pumpoing in that it charges a battery bank to operate the solar pump and a crop grinder processing unit.

The battery bank is comprised of eight 150 Ah 12 V Asian batteries (made in Nepal) that are wired in a 4S X 2P configuration for a total capacity of 300 Ah at 48 V. (14,400 kWh). The battery bank is used to power a Chinese made 4 kW VOP Solar Hybrid Inverter model InfiSolar V 4000-48 operating at 220 V and 50 Hz. The PV power system operates an AC powered 1.5 HP Pedrollo AC surface centrifugal pump for irrigation. The total system cost of the PVWP was US$7,430 which includes the balance of system (batteries, inverter, etc.), as well as the crop grinder; it excludes civil works and power house costs.

**Fig. 13: Piparkoti village inverter and controls for large scale rice irrigation**

## 7. Lessons Learned

Solar water pumping technology ensures sustainable and effective access to water for irrigation, livestock watering and drinking water supply for smallholder farmers in Nepal. Easy access to water encourages smallholding farmers to carry out or increase their economic activity graduating them from subsistence farming to commercial farming. However, the key barriers for generating large scale commercial sales of solar water pumping systems are related to financial and market access issues, rather than technology which is reliable and mature. PVWP water pumping systems have dropped dramatically in price over the past decade, but still require a somewhat higher initial capital investment than diesel pumps. Experience in Nepal has shown that with access to financing, the challenges can be overcome by taking advantage of relative cost savings, increased reliability for both electricity and irrigation systems, increasing access to technology and technological assistance, and reduced greenhouse gas emissions, when compared with diesel pumps. Efforts to commercialize PVWP technology for irrigation are ongoing, by embedding the technologies in value chain projects which support farmers to increase income by growing off-season vegetables and fruits, fish, and livestock. Barriers include lack of awareness about the technology, high upfront costs, and absence of technical repair services can be overcome through demonstration projects, linkage with finance institutions, and partnerships with technology providers.

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