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Key lessons from the grid-connected solar irrigation pilot project in Nepal

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This issue brief presents lessons from Nepal's first grid-connected Solar Irrigation Pump (SIP) pilot in Chhipaharmai Rural Municipality, Parsa. The initiative integrated eight off-grid SIPs into a 20 kWp community-scale system, providing year-round irrigation, reducing diesel use, and improving farm productivity. Farmers gained new income from water sales, while women benefited from reduced workloads, locally repairable pumps, and targeted training. Persistent gender norms and policy hurdles around net-metering and tariffs limited full benefits. Key lessons highlight the importance of community ownership, gender-inclusive design, capacity-building, and regulatory adaptation to scale grid-connected SIPs as a sustainable irrigation solution in Nepal.

Introduction

Terai plains in southern Nepal account for 56% of the country's arable land (Timilsina et al., 2019). Located in the eastern Gangetic plains, the region is rich in groundwater resources. However, only 22% of the available dynamic recharge is utilized for irrigation (Shrestha et al., 2018).

Farmers have traditionally relied on fossil fuel-based pumps to access groundwater for irrigation. These diesel pumps are expensive to operate and have a large carbon footprint (Foster et al., 2019). Solar irrigation pumps (SIPs), on the other hand, have emerged as a climate-smart solution to improve food and nutrition security (Shrestha & Uprety, 2021). The Alternative Energy Promotions Center (AEPC), the government agency responsible for implementing solar irrigation subsidy programs, targets off-grid areas that are at least 300 meters away from the nearest electricity grid. The off-grid nature of SIPs makes them ideal for areas that have high dependence on diesel pumps due to the absence of grid access (Mantri et al., 2020).

Despite their potential, these off-grid SIPs are typically not designed to meet peak irrigation demand in order to limit the upfront capital investment. A phone survey conducted by the International Water Management Institute (IWMI) in 2021 revealed that off-grid SIPs have a low utilization factor. Consequently, many farmers supplemented solar irrigation with diesel pumping during peak demand periods. As a result, while SIP adoption contributes to reducing greenhouse gas emissions, it does not fully eliminate them.

In addition to these challenges, Nepal's growing hydropower capacity has prompted the utility service provider, Nepal Electricity Authority (NEA), to expand its electric grid network to increase domestic consumption. In Madhesh Province, the provincial government and NEA's provincial office are collaborating to increase farm-level electrification. While such efforts promise improved access to affordable electricity for irrigation, they also present a potential trade-off: once farms are electrified, the farmers may abandon costly SIP systems, particularly when expensive components require replacement, thereby risking underutilization of the government's investment in solar irrigation.

Evolving opportunities for grid-connected solar irrigation

The ongoing expansion of Nepal's electricity grid in rural areas, particularly in the terai districts, has transformed the irrigation landscape. Regions that were previously off-grid and eligible for AEPC subsidies for SIPs now provide farmers with the opportunity to use both Electric Pumps (EPs) and SIPs. A system utilizing both grid and solar to pump irrigation water offers increased hours of pumping, and the same-sized system can irrigate more agricultural land, as shown in Figure 1. Such cases are becoming increasingly common in both individual and community-based projects.

Farmers who combine both SIP and EP are no longer dependent on diesel-based irrigation, which significantly reduces irrigation costs. Evidence from India demonstrates this advantage. Mantri et al. (2020) found that the levelized energy cost for grid-connected SIP is significantly lower than that of an off-grid SIP.

Building on this insight, integrating the existing off-grid SIPs into the national grid presents a two-fold opportunity. First, it can enhance the capacity utilization of these systems by enabling farmers to pump water during non-sunny hours. Second, grid integration allows surplus solar energy to be fed into the grid, creating a potential additional income stream for farmers through net metering arrangements, as already practiced in India.

Figure 1. Farmers utilize both SIP and Electric Pumps. Individual farmer in Chitwan (top) and community user in Nawalparasi (bottom). *(Photo: Shisher Shrestha/IWMI)*

The SoLAR Pilot in Chhipaharmai Parsa

To demonstrate the potential of grid-connected solar irrigation, IWMI evaluated data from 22 municipalities against technical, social, environmental, economic, and institutional criteria. Based on this evaluation, five candidate sites were prioritized for the demonstration pilot, as shown in Figure 2.

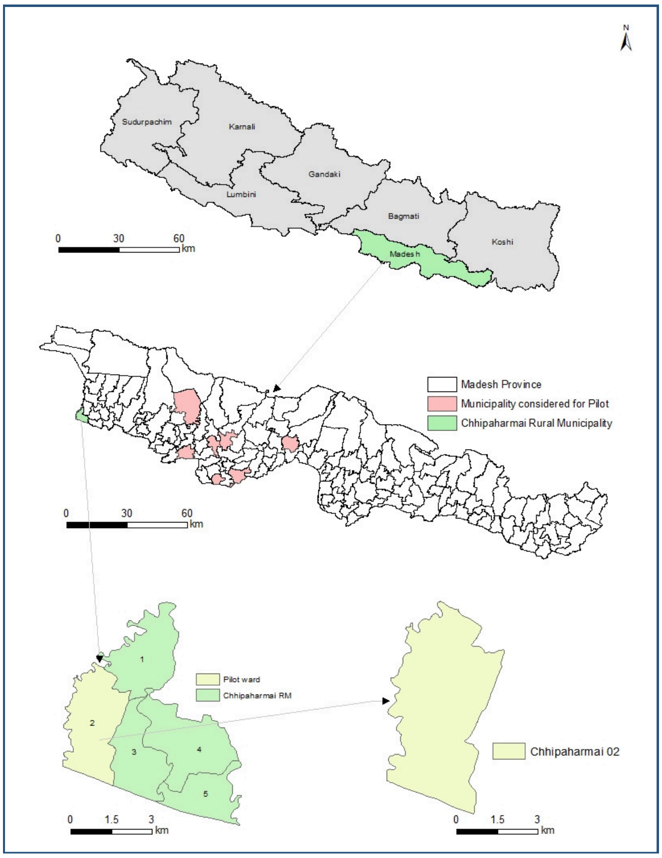

Figure 2. SoLAR project pilot site in Chhipaharmai Rural Municipality, Nepal.

The site at Chhipaharmai Rural Municipality in Parsa was ultimately selected for the pilot due to its favorable conditions, such as the high density of SIP installations within a radius of 1 km, proximity to NEA's grid, availability of public land for installing solar microgrids, and strong local government willingness to co-invest in the initiative. A detailed feasibility study was conducted at Chhipaharmai for technical assessment of the site for detailed design, cost estimation, and socio-economic profile of the village.

Institutional collaboration was formalized in December 2021 through a letter of intent (LOI) signed by AEPC, NEA, Chhipaharmai Rural Municipality, and IWMI. The installation began in 2022, and the project was commissioned in January 2023. The total investment was approximately USD 48,880, with cost-sharing between the SDC-funded SoLAR project through IWMI (51%), NEA (33%), and Chhipaharmai Rural Municipality (15%). Additionally, AEPC and the local government provided subsidies to the eight individual systems when they were initially installed in the year 2018-19. The solar panels from these individual systems were repurposed for the pilot. This initiative represents one of the first coordinated efforts in Nepal where a federal government agency (AEPC), local government (Chhipaharmai Rural Municipality), state utility (NEA), and research partner (IWMI) came together to undertake action research on grid-connected solar irrigation.

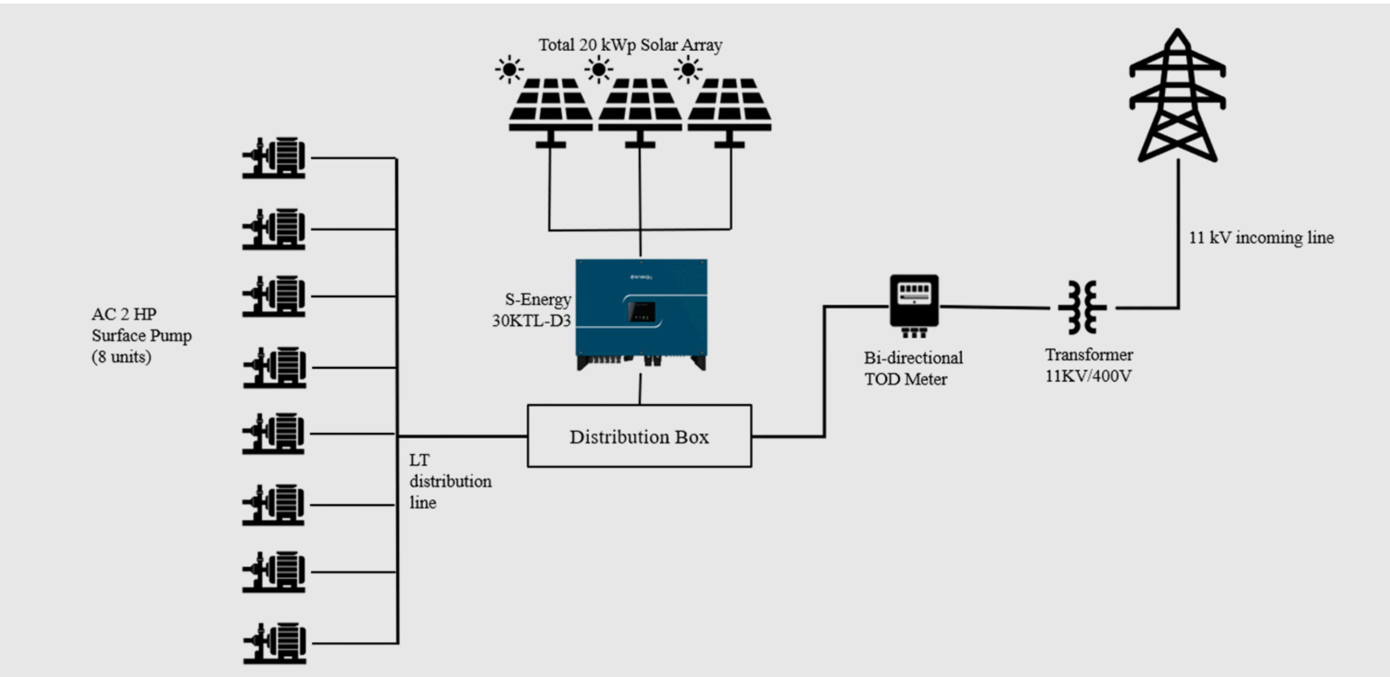

Figure 3. Schematic of the Grid-connected Solar Irrigation pilot implemented at Chhipaharmai Rural Municipality in Nepal.

The local government facilitated the formation of the Water User Group (WUG) to ensure community ownership. Farmers' WUG was onboarded for the planned pilot project after several rounds of sensitization meetings about the potential benefits of the project. The pilot project irrigates 29 acres of land belonging to 8 households from the WUG members, who are the direct beneficiaries. The system has the potential to irrigate an additional approximately 90 acres from neighboring farms, which are the indirect beneficiaries of 16 households. This project combined eight small individual SIP projects to build a community-scale 20 kWp solar plant integrated into the grid. The schematic of the grid-connected SIP pilot project is shown in Figure 3. These eight old SIPs, which had a two-year warranty period at the time of commissioning, were already out of warranty, and one of them was non-functional. Upon the WUG's request, a 2 HP AC surface pump was installed to provide higher discharge from these systems. The AC pumps came with a renewed warranty and could be repaired locally. If needed, farmers could replace them at a lower cost of approximately NPR 20,000 (~USD 143).

Early insights from the pilot

IWMI collected data from May 2023 to December 2024 on the impacts of energy and water access in cropping systems and production, and livelihoods amongst eight grid-connected SIP farmers, and the water buyers from the neighboring farms. Baseline and end-line surveys were conducted in 2022 and 2024, respectively, to evaluate the project.

Grid-connected SIP ensured adequate irrigation year-round and reduced GHG emissions

Surplus solar energy was injected into the grid and accounted for in the WUG's energy balance in the NEA's bi-directional energy meter. This surplus energy was ready for use when more pumping hours were required by the WUG during the peak irrigation season.

As seen in Figure 4, solar energy generation alone was insufficient to meet total irrigation demand during June and July. Following the grid integration, the farmers involved in the pilot project are particularly pleased with the increased pumping hours available, which eliminated the need to rely on costly and polluting diesel pumps during peak irrigation periods. Overall, the grid-integrated SIPs ensured year-round irrigation and contributed to improved agricultural productivity for the farmers.

Additional income for farmers through the sales of water

Under the current net-metering arrangement, NEA does not provide direct payment for surplus energy injected into the grid. However, the energy contributed is recorded in the WUG's account and can offset up to 90% of total electricity consumption. Leveraging the increased pumping hours and accumulated surplus energy, pilot farmers began selling irrigation water to neighboring farms, generating additional income.

Before the pilot, farmers typically rented diesel pumps for an hourly rate of NPR 300-400 (~USD 2-3). With access to grid-connected SIPs, they have access to much cheaper water for irrigation, where they need to pay only NPR 50-100 per hour (~USD 0.3-0.7). This arrangement has not only created a new revenue stream for the pilot farmers but has also offered more affordable irrigation options for nearby farms, substantially reducing reliance on diesel pumps and reshaping the local irrigation market.

Improved farm productivity due to secured irrigation

The data collected on the impacts of energy and water access on cropping systems and livelihoods indicate significant improvements in farm productivity among the pilot farmers. With reliable irrigation from the grid-connected SIPs, farmers have expanded from a traditional two-crop cycle to cultivating a third crop. Most pilot farmers are now able to grow spring paddy, which has substantially increased farm income. Additionally, with reliable and affordable water, these farmers can irrigate their fields consistently, leading to improved crop yields and diversified cropping patterns, while reducing dependence on rainwater as well as costly diesel pumps. Non-pilot farmers who purchase water from pilot farmers have also experienced increased productivity and reduced irrigation costs. Nevertheless, purchasing water for spring paddy remains relatively expensive for these neighboring farmers, who have expressed interest in participating in the grid-integrated SIP system.

Reduction in women's workload

Both pilot and non-pilot women farmers (who buy water from pilot farmers) reported a significant reduction in their workload. Previously, these women or their husbands spent long hours in the field, waiting for their turn to irrigate using canals. The grid-connected SIPs have alleviated this burden, offering more affordable and timely irrigation, allowing them to allocate time for other productive activities.

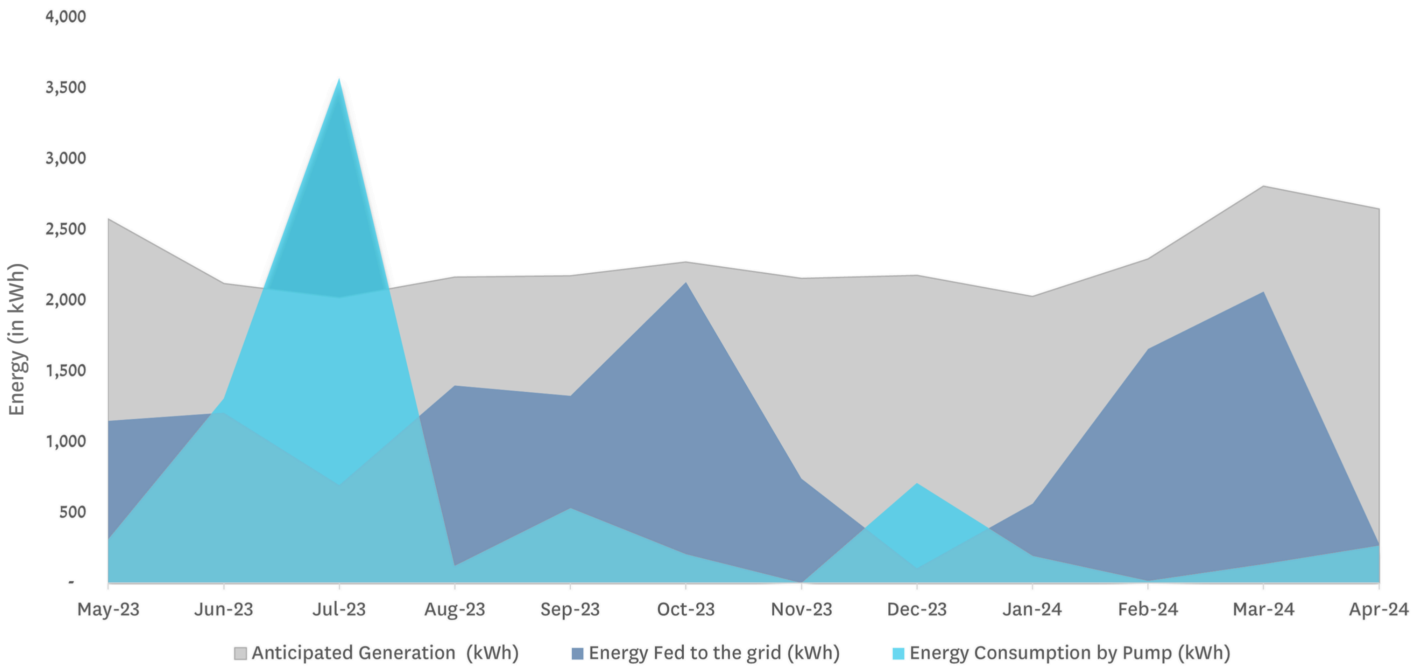

Figure 4. Analysis of energy fed to the grid and energy consumed by the pumps.

Locally repairable pumps that are female farmer-friendly and address theft concerns

Off-grid SIPs were regarded as a more female-friendly technology than diesel pumps because they did not require manual labor to transport or start. However, due to the risk of theft in the area, farmers frequently uninstalled the pump controller of SIP when the pump was not in use. Female farmers were not taught how to re-install these pump controllers, so they relied on male members of their families for irrigation.

As part of the pilot, a secure pump house was constructed to protect the pumps from theft, and female farmers were trained to operate the new pumps. In addition, the pilot introduced AC pumps, which are widely available and easily repaired locally. To date, two out of eight farmers have repaired their pumps locally at their own expense, demonstrating the practicality of these upgraded systems for smallholder farmers.

Multiple sensitization workshops to strengthen WUG capacity and optimize the pilot

To build ownership of the project, IWMI engaged with the community through dedicated field staff to improve the governance of the WUG and enhance their capacity to optimize the use of the pilot project. In 2022, an exposure visit to the Indian state of Gujarat, where a similar project has been implemented, was organized. This visit provided an opportunity for farmers and local government officials to engage with their counterparts in Gujarat who are part of a similar pilot, helping them to understand the innovative pilot before the implementation process began.

After the project's commissioning, a needs assessment was conducted in 2023 to evaluate the capacity-building requirements of the WUG to help them optimize the pilot system. The needs assessment revealed the demand for customized training on agricultural productivity and the development of training materials in the local language (Bhojpuri). To address the social norms at the site, gender-segregated capacity-building workshops were carried out. The training workshops were complemented by a number of pre- and post-training engagements.

The assessment also highlighted the importance of creating a female subcommittee to provide women farmers with a platform for discussion and engagement on SIP operations and agricultural practices. Consequently, a subcommittee of five female farmers was formed to facilitate inclusive participation and informal exchanges among women. These experiences highlighted the need for integrated sensitization activities and customized training, especially for technology-heavy pilot projects (Rauniyar & Shrestha, 2024).

Policy hurdles for net-metering for Solar Irrigation projects

The existing net-metering directives in Nepal were originally designed for institutional rooftop solar installations and did not explicitly account for solar irrigation projects. A key challenge from the disparity between the subsidized electricity tariff for agricultural users and the cost at which NEA purchases energy through net metering. Farmers pay NPR 2.3/unit (~USD 0.016/unit) via agriculture meters, while NEA's purchased rate through net metering is NPR 5.94/unit (~USD 0.043/unit). This significant difference (selling at NPR 2.3/unit vs. buying at NPR 5.94/unit) made net metering financially unviable for NEA.

A grid connected pilot site in Nepal. *(Photo: Nabin Baral for IWMI)*

Despite these challenges, IWMI facilitated the signing of net-metering agreements between the Farmers' WUG and NEA (Pokhariya DCS) in February 2024, after overcoming bureaucratic and policy hurdles to pave the way for future net-metered grid-connected SIP projects in the country. However, even after signing the net-metering agreement, the local NEA office has not yet been able to issue a net-metered bill to the WUG, highlighting ongoing implementation barriers.

Key Lessons from the Pilot

- Higher-level government officials should actively participate to facilitate any uncertainty on policy guidelines for experimental action research projects.
- Involve Local governments from the inception and design phase, as they play a crucial role in project implementation.
- Adequate investment is needed to help WUGs comprehend the benefit of such a project; the exposure visits for farmers and LG officials to Gujarat, India, were organized to help them understand the benefits of grid-connected SIP.
- Additional efforts to involve women farmers are needed to ensure equitable gender participation; for example, forming a women-only subcommittee and defining a role for women farmers resulted in an improved gender balance in interactions with the WUG. However, continued efforts are needed to improve the gender dynamics of the projects due to challenging social norms in the region.
- Technical interventions depend on community dynamics for success. For example, even if the technical interventions are effective, if there are social conflicts within the community, the project may be considered a failure. Therefore, such technological interventions need to be incorporated with capacity-building
- Women's participation in technical training is important to gain autonomy to irrigate their farms, especially when male household members are absent.
- Community's voices must be incorporated into the design phase of the project. For example, the community suggested installing AC surface pumps so that they can be repaired locally and have higher water discharge than DC submersible pumps.
- It is critical for NEA to adapt its communication methods and capacitate its local offices to lay out procedures for net metering at their local level offices for a smooth application process.

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Project

The Solar Irrigation for Agricultural Resilience in South Asia (SoLAR-SA) project aims to sustainably manage the water-energy and climate interlinkages in South Asia through the promotion of SIPs. The main goal of the project is to contribute to climate-resilient, gender-equitable, and socially inclusive agrarian livelihoods in Bangladesh, India, Nepal and Pakistan by supporting government efforts to promote solar irrigation. This project responds to government commitments to transition to clean energy pathways in agriculture. All countries in this project have Nationally Determined Contribution (NDC) commitments to reduce greenhouse gas (GHG) emissions and SIPs can play a significant role in reducing emissions in agriculture. www.solar.iwmi.org

About SDC

The SoLAR -SA project is supported by the Swiss Agency for Development and Cooperation (SDC). SDC is the agency for international cooperation of the Federal Department of Foreign Affairs (FDFA). Swiss Agency for Development and Cooperation, which is an integral part of the Federal Council's foreign policy, aims to contribute to a world without poverty and in peace, for sustainable development. SDC, through its Global Programme Climate Change and Environment (GPCCE), helps find solutions to global challenges linked to climate change. It engages in global political dialogue and manages specific projects in the fields of energy, climate change adaptation, sustainable development of mountainous regions and prevention of natural hazards that are likely to influence regional and international policy.

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