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Lifting All Boats: Productive Use of Renewable Energy for Sustainable Livelihoods in India

Compendium of Case Studies

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Abbreviations

AMC	Annual Maintenance Contract
APC	Agriculture Production Cluster
CSR	Corporate Social Responsibility
DRE	Decentralized Renewable Energy
FaaS	Farming-as-a-Service
FPC	Farmer Producer Company
FPO	Farmer Producer Organization
IFC	International Finance Corporation
IMC	Instant Milk Chiller
ISP	Irrigation Service Provider
LI	Lift Irrigation
MFI	Microfinance Institution
MIS	Management Information System
NABARD	National Bank for Agriculture and Rural Development
NGO	Non Governmental Organization
NTFP	Non-Timber Forest Produce
PM-KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan Yojana
PMFME	Pradhan Mantri Formalization of Micro Food Processing Enterprises
PMKSY	Pradhan Mantri Kisan Sampada Yojana
PURE	Productive Use of Renewable Energy
RBI	Reserve Bank of India
RMS	Remote Monitoring System
SHG	Self Help Group
SHM	State Horticulture Missions
SLF	Sustainable Livelihoods Framework
SMAs	Small and Medium Agribusinesses
SPI	Solar Pump Irrigation
UPSC	Universal Solar Pump Controller
VEC	Village Electrification Committee
VPC	Village Planning Committee
WUG	Water User Groups

Introduction

Direct energy is consumed at various stages of agricultural production, including land preparation, irrigation, harvesting, storage, processing and value addition, and commercialization of products. Energy is indispensable across the entire agricultural value chain, and the current system heavily relies on the use of fossil fuels to carry out its operations. Worldwide, 660 million individuals lack access to electricity, with 80 percent of them in within rural areas. Moreover, rural and remote regions often face a lack of reliable, affordable, and sustainable electricity, which limits agricultural expansion and increases operational costs and negative environmental impacts due to fossil-fuel dependence (Sustainable Energy For All 2024). Thus, universal access to cleaner electricity and other modern and reliable energy sources becomes crucial across the agricultural value chain for diversifying and expanding agriculture, improving yields, increasing incomes, reducing food losses, and building resilience in the agrifood system. The implementation of Productive Use of Renewable Energy (PURE) across the agrifood value chain has shown to enhance rural development by fostering livelihood activities, supporting microenterprises, promoting agriculture value-added endeavors, and extending productive hours (Barnes et al. 2023).

This compendium is a companion of the broader research report titled **"Lifting all boats: Productive use of renewable energy for sustainable livelihoods in India,"** which studies on-ground adoption of PURE interventions to understand factors contributing to the functioning and scalability of various PURE applications in the agrifood systems in India and the role they can play in enhancing rural livelihoods. The case studies in this compendium highlight on-the-ground experiences of anchor organizations (enterprises, individual farmers, farmer groups, non-governmental organizations (NGOs), and government agencies)[1] in deploying PURE applications. It covers information related to implementation models, technologies used, community engagement strategies, financing mechanisms, business models, and the observed impacts. The insights, drawn from fieldwork on the PURE interventions in agricultural livelihoods, are based on a detailed survey capturing both quantitative and qualitative aspects of each intervention, as presented in Appendix A of the report.

The compendium features 16 case studies from nine Indian states, each led by a different anchor organization. The documented cases showcase a diverse range of PURE applications—including solar irrigation pumps, solar cold storage units, solar dryers, and solar-powered agro-processing systems. These technologies have been deployed in different regional and
livelihood contexts.

Beyond documenting field interventions, the compendium also applies a Sustainable Livelihoods Framework (SLF) to analyze these cases, identifying the structural and relational factors that enable or hinder the sustained effectiveness and relevance of clean energy-powered agricultural livelihood activities, particularly in complex rural

settings involving smallholder farmers. For this compendium, the cases are grouped into three categories: irrigation, agro-processing, and multi-technology (cases involving multiple PURE applications). All cold-storage systems we studied were paired with other applications and are therefore included in the multi-technology category.

About the Sustainable Livelihoods Framework

Developed in the 1990s by Robert Chambers and Gordon Conway (Chambers and Conway 1992) and subsequently conceptualized by Ian Scoones in 1998 (Scoones 1998), the SLF remains a widely used tool in research and practice for understanding how people secure and sustain their livelihoods. It examines access to five key livelihood assets — natural, physical, financial, human, and social — and how households and communities use strategies like diversification, migration, or agricultural change to cope with and adapt to shocks, stresses, and seasonal shifts. The Framework also considers the institutional and organizational factors shaping livelihood outcomes and highlights how people adapt and recover in the face of vulnerabilities. Since its adoption by the UK's Department for International Development in the late 1990s, it has become a cornerstone of rural development analysis and has been reproduced in various academic and practitioner work. For the analysis in this compendium, we adopt the reformulated version of the SLF for the 21st century (Natarajan et al. 2022) as shown in Figure 1.

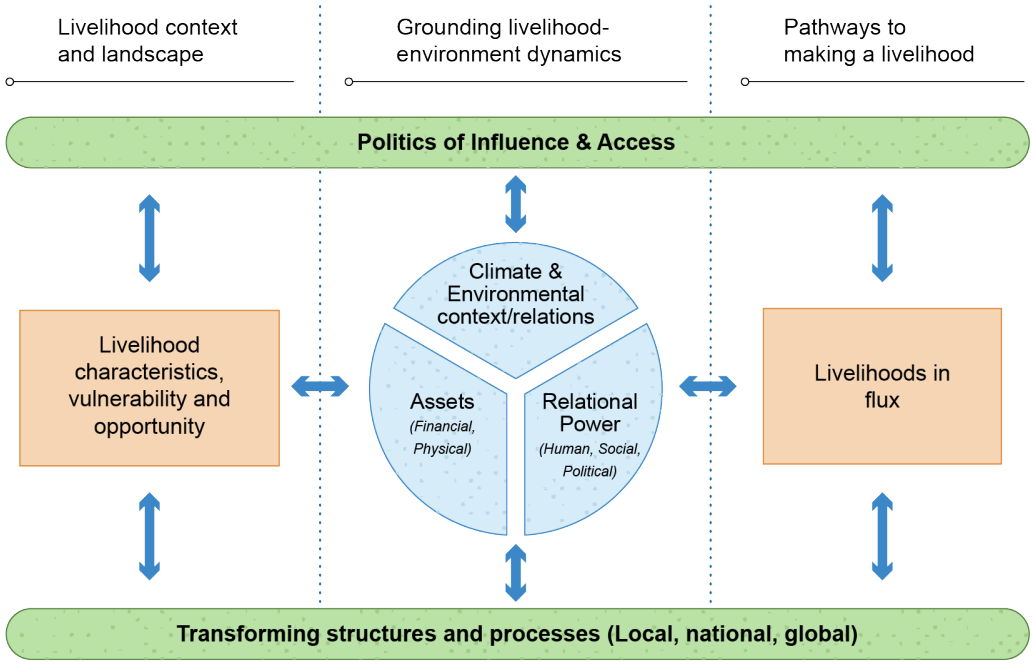


Figure 1: Sustainable Livelihoods Framework

Source: The new Sustainable Livelihoods Framework as proposed by Natarajan et al. (2022)

The Framework (in Figure 1) views vulnerabilities of rural livelihoods as dynamic and shaped by multiple, interconnected structural, and socio-economic factors. It also recognizes “opportunity” to consider positive livelihood transformation, not only risks.

The core of the SLF comprises three interlinked elements: a) climate and environmental context/relations, which recognizes how local environmental and climatic conditions (e.g., rainfall variability, resource availability) shape livelihoods; b) assets (financial, physical), that highlight material resources that people can access and use to support their livelihoods; and c) relational power (human, social, political), which foregrounds the socio-political economy in which livelihoods exist. The third element examines how the influence of gender, caste, class, and social networks determines who gets access to resources, opportunities, and decision-making. These elements interact, influencing both risks and opportunities for households and communities.

Finally, livelihoods are viewed as constantly in flux, adapting to both short-term changes and shocks such as fluctuations in crop prices, floods, or droughts, and long-term shifts like climate change, migration, or evolving farming practices. This study captures the current state of these changes rather than comparing before-and-after scenarios for energy interventions. Cross-cutting influences, which include the politics of influence and access in which power relations, norms, and institutions (both formal and informal) shape who benefits from interventions and policies. They also encompass transforming structures and processes, as local, national, and global policies, norms, and institutions determine how interventions are designed, implemented, and scaled, as well as how equitably their benefits are distributed.

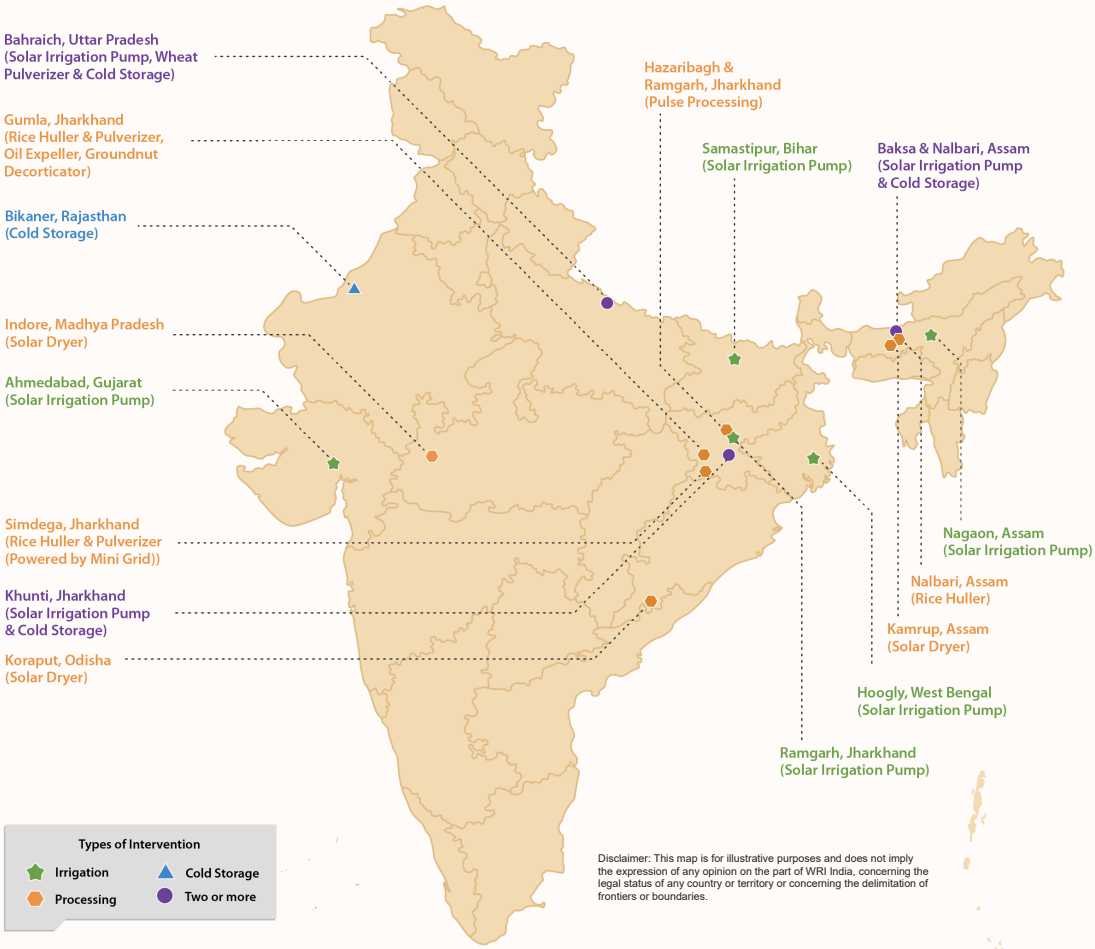
This version of the SLF emphasizes that rural livelihoods are shaped by a web of environmental, socio-economic, and power dynamics, and that interventions (such as PURE) must be understood in this wider context to address vulnerabilities and unlock transformation.

Limitations of the case studies

Based on insights from literature, technology scoping, and engagement with implementation partners, this compendium presents findings from 16 anchor institutions that have deployed single or multiple PURE technologies across different agro-climatic zones. Sites were selected based on specific criteria, with some excluded due to resource constraints, limiting the scope of the study.

The case studies reflect barriers, opportunities, and impacts of the interventions from the perspectives of anchor institutions rather than end users, which may introduce biases. However, our team traveled to each of these locations to collect data from members of 16 anchor institutions working in local regions, visited the installation sites, and conducted informal conversations and group discussions with the user groups, which helped us reflect on and sharpen our findings. While not exhaustive, the compendium aims to inform the broader adoption and scaling of PURE interventions within agriculture and allied value chains.

16 case studies of decentralized solar energy interventions across anchor institutions in 15 districts of 9 Indian states



Bahraich, Uttar Pradesh

- Year: 2022, 2020
- Implementer: Oorja
- Implementation Model: Mix of Top-Down & Bottom-Up
- Financing Model: Grant/Equity/ One-time Membership-based Collection from Farmer/Pay-Per-Use Revenue Model

Ahmedabad, Gujarat

- Year: 2018
- Implementer: UGVCL
- Implementation Model: Top-Down
- Financing Model: Govt. Scheme (Govt. subsidy + Farmer Contribution)

Hazaribagh & Ramgarh, Jharkhand

- Year: 2020
- Implementer: CES
- Implementation Model: Bottom-Up
- Financing Model: Grant + Community Contribution

Nalbari, Assam

- Year: 2022
- Implementer: TechnoVillage
- Implementation Model: Mix of Top-Down & Bottom-Up
- Financing Model: Grant

Gumla, Jharkhand

- Year: 2016
- Implementer: MCT
- Implementation Model: Mix of Top-Down & Bottom-Up
- Financing Model: Grant

Simdega, Jharkhand

- Year: 2021
- Implementer: TRI
- Implementation Model: Mix of Top-Down & Bottom-Up
- Financing Model: Grant + Community Contribution

Samastipur, Bihar

- Year: 2016
- Implementer: AKRSPI
- Implementation Model: Bottom-Up
- Financing Model: Grant + Community Contribution

Kamrup, Assam

- Year: 2022
- Implementer: SELCO Foundation
- Implementation Model: Bottom-Up
- Financing Model: Grant + Community Contribution

Bikaner, Rajasthan

- Year: 2021
- Implementer: Urmul
- Implementation Model: Bottom-Up
- Financing Model: Grant + Community Contribution

Khunti, Jharkhand

- Year: 2015, 2019
- Implementer: NBJK
- Implementation Model: Bottom-Up
- Financing Model: Grant + Community Contribution

Baksa & Nalbari, Assam

- Year: 2023, 2021
- Implementer: GVM
- Implementation Model: Bottom-Up
- Financing Model: Grant + Community Contribution

Hoogly, West Bengal

- Year: 2016
- Implementer: ONergy Solar
- Implementation Model: Mix of Top-Down & Bottom-Up
- Financing Model: Grant/Government Subsidies/Farmer contributions/ Bank Loans

Indore, Madhya Pradesh

- Year: 2019
- Implementer: Raheja
- Implementation Model: Mix of Top-Down & Bottom-Up
- Financing model: Farmer contribution/gov. scheme/bank loan

Koraput, Odisha

- Year: 2018
- Implementer: PRADAN
- Implementation Model: Bottom-Up
- Financing Model: Grant + Community Contribution

Nagaon, Assam

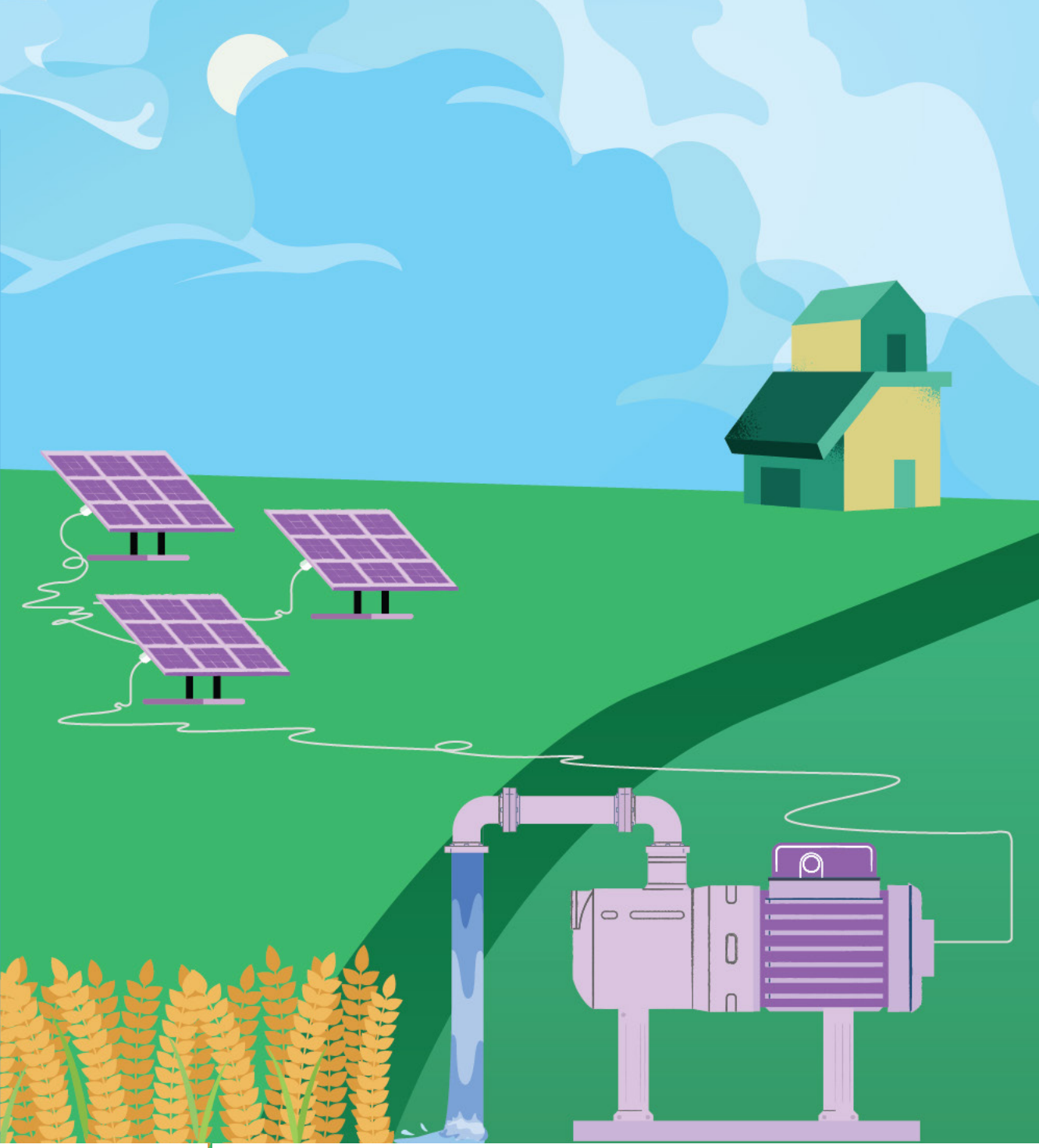
- Year: 2021
- Implementer: aQysta
- Implementation Model: Top-Down
- Financing Model: Self-funded + profit-sharing model

Ramgarh, Jharkhand

- Year: 2017
- Implementer: JSLPS
- Implementation Model: Top-Down
- Financing Model: Govt. Scheme (Govt. subsidy + Farmer Contribution)

Figure 2

Source: WRI India authors from technology/intervention scoping exercise



Irrigation Case Studies

Case Study 1 | Decentralized Renewable Energy enterprise-led irrigation in Nagaon, Assam

Livelihoods context

Nagaon district, located in central Assam within the Brahmaputra floodplain, offers fertile conditions ideal for agriculture. The region lies in the Eastern Himalayan division and boasts extensive cultivation of rice, jute, wheat, pulses, and oilseeds. However, increasingly erratic rainfall patterns and the growing intensity of floods have reduced the reliability of agriculture as a source of livelihood for the local community. This is exacerbated by the low proportion of areas under irrigation, at 30 percent, limiting the potential for improving crop productivity or expanding the scale of farming. During the winter or Rabi season, the water table drops to 61 meters, making groundwater extraction difficult. While a few farmers rely on diesel-run irrigation pumps, these are often inefficient and inaccessible for small and marginal landholder farmers due to high operational costs, especially as the water table reduces.

About the technology intervention

In 2021, a DRE enterprise installed 10 solar-powered micro pumps of 0.5 horsepower (HP) capacity each in Dhemaji Gaon village. These surface pumps were chosen for their ease of transportation and suitability for the local geography. Additionally, 2 electricity-powered pumps of 1.5 HP capacity were installed. Both types of pumps are used for collecting water in 1,000-liter Syntex tanks and supplying it to the farmlands. This system irrigates 33 bighas (approximately 20.46 acres) of land per day, drawing water primarily from nearby rivers. The pumps operate from September to April, avoiding the monsoon season. They are capable of lifting upto 1000 liters per hour and are used for crops such as watermelon, jute, and various horticultural crops.

Implementation model

The enterprise selected a group of 15 marginal farmers, including 5 women, for this intervention. The selection of the members was based on their land availability and willingness to participate in the intervention. Each site was required to have at least 20 bighas (approximately 6.67 acres) of contiguous land and access

to surface water such as rivers or streams. This selection process is crucial to the enterprise's model for maximizing the impact of the solar irrigation systems.

The enterprise also followed specific criteria for selecting installation sites and crops to be cultivated. They also enable backward and forward farm linkages for farmers by providing them with farm inputs.

The enterprise also has agreements with buyers that ensure farmers access to a reliable market with assured and fair (fixed) prices for their produce, and connects their produce to nearby markets in Nagaon and Guwahati. This approach ensures feasibility and sustainability while creating a platform to facilitate a significant impact from their interventions.

Financial model

The entire irrigation system (0.5 HP) costs ₹50,000 and was fully funded by the enterprise, with no external financial contributions from the farmers. This system compromised of the pump, solar panels (335W * 2), control units, and hose pipes. Other irrigation systems like drip kits or sprinklers were not used in Dhemajigaon. The pumps have been installed on farmland leased by the enterprise from a local farmer for ₹2,000 per month, paid biannually.

The enterprise facilitates the sale of their produce and bears the transportation cost, which was estimated to exceed ₹50,000 in 2023. Profits from the sale are shared with farmers, with input and transportation costs factored into the distribution. For the first three years of the intervention, profit sharing was fixed at 75% for the company and 25% for farmers. This ratio helped offset the initial input costs as outlined in the cost-benefit analysis (CBA) prepared for that location and its specific crops. In the fourth and fifth years, profits were shared equally between the company and the farmers.The enterprise's model is designed to ensure that farmers recover their input costs while still benefiting from improved irrigation, market access, and reduced logistical burden.



Crop cultivation in Dhemaji Gaon village, Nagaon district, Assam *Photo credit: Masfick Hazarika | WRI India*

Operations and maintenance

The enterprise owns and manages the operation and maintenance (O&M) of the solar pumps. Regular tracking of water output from the pumps ensures that the water from the river fills the storage tanks properly. Regular cleaning of solar panels ensures effective functioning. There were no significant technical issues or frequent breakdowns reported, and the system had not required substantial repairs till the time of our study. The enterprise also conducts monitoring and evaluation, and the data are shared with its monitoring and evaluation (M&E) team quarterly, complemented by site visits to assess the project's outcomes. Irrigation services are provided free of charge, and since the farmlands are clustered together, all farmers undertake irrigation daily. Under this model, the enterprise plans to work with farmers for at least 3 to 5 years, depending on income generation and the level of farmer participation.

The solar-powered pumps came with a one year warranty with an option to extend coverage through an Annual Maintenance Contract (AMC) after the first year. Once the enterprise exits the sites, the farmer groups are expected to assume ownership of the systems and take responsibility for O&M. This approach aims to ensure farmer ownership and continuity beyond the project period.

Impact

The intervention in Nagaon enables the replacement of diesel-run pumps with solar-powered alternatives, significantly reducing farmers' reliance on fossil fuels and lowering greenhouse gas emissions. The use of surface water from nearby rivers rather than groundwater is environmentally sustainable, especially in a region where the water table recedes considerably. Environmental stress during the rainy season is further reduced as the pumps operate only between September and April. However, as the model scales, continuous extraction from river sources must be carefully managed to avoid adverse consequences on water bodies.

In terms of positive changes for the participating farmers, the intervention has enabled them to diversify their cropping patterns, improve yields, and increase seasonal incomes.

Role of relational dimensions in shaping livelihood opportunities and outcomes

The model ensures participation of marginal farmers, a third of whom are women; however, the selection criteria—requiring significant land parcels adjacent

to other similar farmers—has the potential to systematically exclude farmers with limited and scattered land parcels. However, from the perspective of the enterprise, those criteria ensure maximum impact. At the same time, community participation in planning and decision-making in the implementation remains limited. For instance, crop selection is done by the enterprise, and farmers have little involvement in the O&M of the system. However, the company trained farmers in the O&M of the irrigation equipment through workshops. The workshops also focused on crop cultivation standards as per specific crop production manuals, pollination, and disease mitigation, with the option for farmers to receive a certification after completing the workshop. Though the enterprise plans to transfer the ownership and operation of the irrigation system to the farmer group after 4-5 years, this exit plan currently lacks enabling mechanisms and platforms. Local institutions such as farmer collectives or water user associations that have the resources to own and operate the systems in the absence of enterprise involvement are lacking and important to build.

In addition to enabling farmers to expand their agricultural capacity, the model ensures backward and forward linkages to the farmers and a share in the profit. Nonetheless, the system's financial sustainability is weak. The upfront cost of the irrigation system is currently borne entirely by the enterprise. Input costs and transportation expenses—estimated to exceed ₹50,000 annually—are also subsidized by the enterprise. Though this model demonstrates positive change in the pilot phase, it may not be viable to scale without continued external funding as it lacks pathways for cost recovery or community investment that could support long-term replication or scale.

Thus, while the enterprise-led solar irrigation model showcases technical feasibility and environmental benefits, it requires greater emphasis on economic viability and community capacity building to be truly sustainable. Future iterations of the model should consider involving farmers more directly in planning and operations, exploring innovative financing mechanisms such as partial cost-sharing and fostering local institutions that can manage the system independently. Such measures will ensure that the benefits of solar irrigation are not only immediate but also durable and scalable across similar geographies.

About the anchor organization

aQysta, an enterprise based in Guwahati, Assam with field offices in cluster areas such as Kampur, Nagaon, is committed to transforming agriculture through sustainable irrigation solutions. The organization's solar irrigation project was designed to support marginal farmers in the region in expanding their innovation and farming capabilities. Before starting the irrigation project, aQysta mapped the water resources and availability in the village to ensure efficient and sustainable usage of the newly installed irrigation systems.

Case Study 2

The role of water entrepreneurs and joint liability groups in expanding access to solar irrigation, Hoogly, West Bengal

Livelihoods context

Chanditola village, in Hooghly district of West Bengal, which lies within the Lower Gangetic Plains agro-climatic zone, has smallholder farmers who traditionally depended on diesel and electric pumps for irrigation. However, declining groundwater levels made irrigation increasingly difficult, while rising costs further strained their livelihoods. Farmers spent around ₹4,000 per bigha (0.62 acres) per season on diesel pumps, with rental charges as high as ₹200 per hour. In the case of electric pumps, costs reached nearly ₹20,000 per season for 8–10 shared connections.

A renewable energy enterprise partnered with an NGO to implement solar-powered irrigation pumps in Chanditola village, addressing water shortage and improving farmers' productivity through awareness creation and capacity building.

About the technology intervention

The enterprise installed 5 HP submersible solar pumps in Chanditola in 2018, each powered by 5 kW solar panels and equipped with a Solar Pump Controller for efficient operation. Supplied by vendors such as Kirloskar and Shakti, these submersible pumps irrigate 2.5 to 3 bighas (approximately 1–1.2 acres) daily, running for 6 to 8 hours without battery backup. Designed to draw water from borewells, the pumps are expected to support year-round cropping, including paddy crops in Kharif, pulse crops in Rabi, and horticultural crops and fruits in Zaid seasons. While lacking a Remote Monitoring System (RMS), the systems include a 5-year Annual Maintenance Contract (AMC) for reliability.

Implementation model

The enterprise collaborates with farmers under the two models: the Local Water Entrepreneurs, model, where entrepreneurs install irrigation pumps by replacing diesel gensets, and the Joint Liability Group (JLG)[2], where 6 to 8 farmers collectively secure bank loans and guarantee repayments for each pump.

The model we observed in Chanditola village was that of a water entrepreneur, where the entrepreneur not only managed the installation and financing of the pump but also provided irrigation services to surrounding farmers on a pay-per-use basis, ensuring broader access while reducing individual risk and upfront costs.

ONergy solar supports awareness campaigns, capacity building, and bank linkages with institutions like Regional Rural Banks, Axis Bank, and the State Bank of India. It also coordinates with Krishi Vigyan Kendras (KVKs) and other organizations to raise awareness about solar irrigation, and climate-smart practices.

The enterprise provides training for operation and basic maintenance, though technical repairs are handled by vendors within 24 to 48 hours.

Financial model

The enterprise's 5 HP solar pump systems are financed through a blended model of government subsidies, farmer contributions, and bank loans. Each 5 HP solar pump, costing ₹3.92 lakh, is funded through farmers' upfront contribution of 10 to 20 percent, 60 to 70 percent government subsidies and 70 to 80 percent bank loans facilitated by partner banks. To address the collateral challenge, the enterprise promotes a JLG model where 4–10 farmers jointly secure loans, guaranteeing one another's repayments. Water entrepreneurs recover their investment by charging farmers approximately ₹1,500 per bigha per season, significantly lower than diesel-based pumping, which is around ₹4,000 per bigha. These lower costs have improved cash flows and enabled reinvestment in inputs.



5 kW ground-mounted solar panels in Chanditola village, Hooghly district, West Bengal. *Photo credit: Preeti Kumari | WRI India*

Operations and maintenance

The enterprise provides a 5-year AMC with each system and maintains a stock of spare parts in the local area to reduce downtime. Farmers bear the cost of replacing consumables such as the Solar Pump Controller, which remains a key operational challenge. Technical issues, such as controller failure or panel misalignment, are resolved within 24–48 hours. However, on cloudy or rainy days, pump performance drops, and farmers may temporarily resort to diesel or electric backups.

The enterprise provides training for operation and basic maintenance. Users are encouraged to monitor system usage and water consumption, although formal digital monitoring is not yet integrated .

Impact

In Chanditola and surrounding villages, solar irrigation has replaced costly and unreliable diesel and electric pumps. The intervention has enabled year-round cultivation, lowered irrigation costs, and allowed farmers to diversify into horticulture, pulses, and fruits. Irrigation costs have dropped from ₹4,000 to ₹1,500 per bigha, and collective ownership models have ensured benefits reach six to 10 farmers per pump. Irrigation costs have dropped from ₹4,000 to ₹1,500 per bigha, and collective ownership models have ensured benefits reach 6-10 farmers per pump. The enterprise has supported over 4,000 farmers in West Bengal, showcasing a model that can be replicated across similar contexts in India. The enterprise's collaborative financing model through the bank loan structure, water entrepreneurship model, and AMC-backed O&M support have proven essential for uptake. It has made solar pumps accessible to farmers with limited capital, significantly improving local incomes and productivity, and ensuring long-term sustainability of the system.



Rear side of the solar panels

Photo credit: Preeti Kumari | WRI India

Role of relational dimensions in shaping livelihood opportunities and outcomes

The enterprise's intervention in Chanditola village reflects a contextual DRE-based livelihood model that addresses financial and physical barriers to irrigation access for small and marginal farmers. The initiative creates local physical capital through tailored pump installations and maintenance support while boosting farmers' financial capital through reduced operational costs, access to government subsidies, FLDG, and bank partnerships. While community institutions are still nascent, the enterprise's work with JLGs, farmer groups, and local entrepreneurs builds social capital, collective efficacy, and trust in shared infrastructure. However, the availability of immediate cash for using the services or the type of farmers who can access the services remain unexplored.

Farmers' capacity and participation in cultivation have increased, but at the same time, their roles in technical management and O&M remain limited.

Implemented through farmer groups and strategic partnerships with KVKs, district agriculture offices, and banks, the enterprise's approach shows strong potential for scale.

About the anchor organization

ONergy Solar, founded in 2009, began as an off-grid solar lighting enterprise and gradually shifted focus to solar-powered irrigation in 2016. By 2018, it had fully transitioned to this commercial venture, backed by early support from GIZ. Operating across West Bengal, Odisha, Jharkhand, and Assam, the enterprise is now a key player in DRE, offering turnkey solar irrigation solutions to farmers. Its close partnership with ecosystem builders such as SwitchON Foundation and local FPOs has helped it bridge the energy-livelihood gap in underserved agricultural communities.

Case Study 3

Self Help Groups building a resilient agricultural system using solar irrigation, Samastipur, Bihar

Livelihoods context

Agriculture and animal husbandry form the backbone of livelihoods in Samastipur district, Bihar, which falls in the Middle Gangetic Plains agro-climatic zone. Farmers here typically grow paddy during the kharif season, vegetables during the rabi, and gourds in the summer. While groundwater is available at shallow depths (20–25 feet), lifting water for irrigation has been a persistent challenge. During rabi and summer, cultivation is heavily dependent on diesel pump sets. Access to irrigation remains uneven, with only a handful of medium to large farmers owning diesel pumps. Small and marginal farmers are largely dependent on pump operators and usually large landholders control water distribution. This dependence has restricted cultivation opportunities in the region.

To address these challenges, an NGO introduced shared diesel and electric pumps for farmer groups between 2012 and 2015 to strengthen agriculture and improve livelihoods. Yet, the rising cost of diesel and unreliable electricity supply soon made these solutions unsustainable which motivated the NGO to explore a solar-powered solution.

About the technology intervention

The NGO shifted to solar-powered irrigation in 2016 and deployed pumps of 5 HP capacity in a saturation model in Chakhaji village in Samastipur district. A total of seven solar pumps were installed, each with the capacity to irrigate about 25 acres of farmland and provide irrigation services to nearly 100 smallholder farmers.

Implementation model

Under this model, seven male Irrigation Service Providers (ISPs) were selected by the NGO to operate the pumps. The pumps were connected through underground pipelines with multiple outlets, ensuring efficient water distribution. This arrangement enabled access to irrigation for several farmers while reducing their dependence on diesel pumps and erratic electricity supply.

Financial model

The NGO deployed the irrigation pumps with support from multiple funding agencies. The pilot phase of this intervention began in 2016, supported by the International Water Management Institute (IWMI), and focused on the village of Chakhaji. This pilot also marked a shift from a fully grant-based model (by the NGO) to a blended financing approach. Each solar irrigation system comprised a borewell, an underground pipeline, and a pump house. This was valued at approximately ₹8 lakhs (2016) and was offered through a combination of a grant and an interest-free loan.

The loan, repayable in installments to the NGO, was structured with the intent of creating a revolving fund that could be reinvested into climate-smart agricultural initiatives by the NGO. While the NGO facilitated the installation of underground piping, farmers collectively contributed about ₹2 lakhs towards the construction of borewell and pump house. Additionally, the farmers made an upfront payment of ₹50,000 in the first year.

Owing to the high demand from farmers, the pilot intervention expanded to Chandauli village in Samastipur district by 2018 with 10 additional pumps. A reduction in pump costs to ₹5.8 lakhs allowed farmer contributions to rise to 70 percent. Each ISP operated the pump for 1,000 hours on an average annually and generated income by selling water to other farmers at ₹100–120 per hour, earning ₹1-1.5 lakh annually. The farmers in the villages also benefitted as the cost of irrigation reduced by 30 percent compared to diesel pumps. Solar pumps irrigated 3-4 kathas[3] (around 0.1 acre) per hour, significantly more than the 1-1.5 kathas possible with diesel pumps (also depending on soil and crops).

Cost Structure for Solar Pump Installations

S.No	Items	In 2016 (₹)	In 2018 (₹)
A	Solar Pump (5HP)	4,70,000	3,00,000
B	Borewell	1,30,000	1,30,000
C	Underground pipeline 1000 feet	1,30,000	80,000
D	Pump house	70,000	70,000
	Total	8,00,000	5,80,000
E	Farmer's contribution (upfront), interest-free loan for*	2,00,000	2,00,000
F	Farmer's contribution (B+D)	2,00,000	2,00,000
G	Farmer's investment/contribution (percent)	50	70

* In pilot in 2016, 5 years were given for repayment. In 2018, only 2 years were given for repayment for ISPs

Table no 1: The cost structure for solar pump installations, comparing expenses incured in 2016 and 2018



Solar-powered irrigation pump in Chakhaji village, Samastipur district, Bihar *Photo credit: Amit Kumar | WRI India*

Learnings from the pilot guided the NGO in designing its subsequent collaborations for financial sustainability and community engagement, including those with the HDFC Parivartan Programme, a Corporate Social Responsibility (CSR) initiative of HDFC Bank in 2016, Axis Bank Foundation in 2018, Gates Foundation in 2023, and JEEViKA (Bihar Rural Livelihoods Promotion Society) in Muzaffarpur district in 2023. The partnership with JEEViKA helped scale on-ground implementation to select blocks in Muzaffarpur district. These partnerships enabled the installation of over 100 solar pumps in Bochaha Block of Muzaffarpur district in Saturation mode.
The implementation model is women-centric and draws inspiration from the Chakhaji model where the upfront contributions are not based on loans. Beneficiaries arrange loans independently from sources like SHGs, or Rang de for components like the pipeline, the pumphouse, and the borewell. The NGO's support was limited to the solar pump component, which makes up approximately Rs 5.5 lakh of the total project cost.

Although solar irrigation pumps were successfully installed through this process, collecting loan repayments proved to be a challenge for the NGO because of the ISPs' hesitance towards new financial responsibilities and less business during the monsoon.

Operations and maintenance

As the intervention evolved, it incorporated learnings on technical maturity, vendor selection, and underground piping, prompting the integration of AMCs into the intervention. This allocation of 10 percent to retention vendors, procuring additional motors and Variable Frequency Drives at the local level, aims to ensure reliability and reduce downtime. The shift to the SHG model led to involving SHG members in operations – from approving installation requests to site selection, ensuring community buy-in and local governance. JEEViKA block officials also support in identifying farmers to ensure local acceptance and trust. Training programs were conducted for ISPs on O&M, troubleshooting, and additional technical assistance.

Impact

The intervention not only reduced farmers' reliance on costly diesel but also eased access for small and marginal farmers who previously depended on large landholders for irrigation.

The ISPs emerge as a pool of local entrepreneurs who enable increased access to irrigation and incomes of other farmers, while at the same time earning a livelihood for themselves. So far, 125 ISP model all with SHG women and in saturation mode have been established in Bochaha block.

Role of relational dimensions in shaping livelihood opportunities and outcomes

The solar irrigation pumps, while costly initially, offered multi-faceted opportunities for the rural community. The community's shift from diesel-powered irrigation systems not only represented an adoption of renewable resources but also aligned with the community's financial capital interests. This eliminated the recurring fuel costs and enhanced agricultural productivity through reliable electricity and irrigation access. It also enabled income generation through the sale of irrigation services for the ISPs. However, financial capital needed for the solar pump infrastructure can still be considered challenging for small farmers, especially since even those who invested found it difficult to repay the loans. The transition of the model to SHG-led has the potential to expand women's financial capacity as they can use the group as a safety net and share risks and benefits; however, we do not have data to make a case for that. SHG-led interventions involved and put women at the center by strengthening their livelihoods. At the same time, women owning, selling, operating, and managing irrigation were also seen as challenging social and gender norms in agriculture, where the gendered division of labor attributed mechanization as a male preserve. While interventions have contributed to diluting this perception, the gendered division of labor persists to some extent.

In terms of constraints on local natural resources, reliable and affordable technology to pump water through borewells may risk overuse and depletion of groundwater, a contextual consideration crucial in designing similar interventions.

Strategic partnerships, co-financing, and strong community mobilization have helped address barriers such as high upfront costs, unfamiliar loan structures, and technical apprehension to some extent. However, further iterations considering the differential impacts on the farmers need to be considered, while establishing a feasible and viable model. The program's iterative and learning-based approach has been critical to its continued success.

About the anchor organization

Aga Khan Rural Support Programme (India) is a non-government, non-denominational organization working to improve rural livelihoods. Active in 3,255 villages across Gujarat, Madhya Pradesh, Bihar, and Maharashtra, it has reached over 3.5 million people—primarily from marginalized communities such as tribals, Dalits, and minorities. Women make up over 60 percent of the beneficiaries and are central to its programs.

Case Study 4

State agency and NGO collaborate to implement solar irrigation pumps, Ramgarh, Jharkhand

Livelihoods context

Gola block in Ramgarh District of Jharkhand, which falls in the Eastern Plateau and Hill region, has rich agricultural potential and is predominantly inhabited by small and marginal landholders especially from the Other Backward Classes (OBCs). Gola is also well connected to nearby towns and even other states. However, irrigation remains a key challenge due to inconsistent electricity supply to run electric pumps and the high cost of diesel pumps, preventing farmers from unlocking significant benefits from agriculture. This makes agriculture less aspirational for the farmers, particularly the youth, who are increasingly shifting to non-agricultural labor. Recognizing these issues, a state government agency, along with an NGO as its technical partner, introduced solar irrigation pumps aimed at enhancing agricultural productivity and sustainability.

About the technology intervention

In Gola block, there are a total of 78 Solar Lift Irrigation (SLI) sites each with a standalone submersible irrigation pump with a capacity of 5 HP. These were installed in 2016-17 along the riverbanks, utilizing government-owned land and donations by Water User Group (WUG) members. Each 5 HP pump can irrigate 15-20 acres of land, with each SLI site benefiting around 15-20 farmers, offering significant potential to boost agricultural productivity. The system also includes delivery pipes designed to distribute water efficiently across uneven terrain. All the 78 pumps primarily source water from rivers, with some assistance from borewells and ponds.

Implementation model

The technology was designed by the State Irrigation Execution Cell (SIEC), a part of the State Resource Cell within the state agency. The NGO played a crucial role in designing and implementing the project with the SIEC. The site selection process was conducted by the SIEC, and the criteria for selecting sites included

agricultural potential of the region, demand from the community, status of community mobilization, logistical feasibility, availability of natural streams, sufficient and consistent water supply, proximity to markets, and the presence of farmers engaged in intensive agriculture.

The intervention was implemented through WUGs. Each group, consisting of 30-40 members with equal participation of women and men, collectively owns and operates the pump. WUG members are trained extensively in operating and maintaining solar pumps, including basic troubleshooting, and efficient water management practices by the NGO and the state agency. Delivery pipes optimize water distribution across uneven terrain, addressing pump capacity limitations, especially in summer.

Financial model

The pumps were provided to the WUGs as grants by the state. Each WUG member contributes a nominal fee of ₹50–100 monthly, determined by the WUG, for maintenance of the irrigation system. These contributions are kept in WUG's bank account to foster a sense of responsibility and cooperation among the water users. Regular monitoring and support are ensured by the NGO and the state agency to ensure the intervention's sustainability.

Operations and maintenance

The operation and maintenance of the solar irrigation pumps in Gola block are managed through a community-driven model to ensure sustainability and local ownership. Each WUG, comprising 30-40 members, is responsible for the day-to-day operation and upkeep of the units. WUG members receive training from the state and the NGO on pump operation, basic troubleshooting, and water management. The cost for minor repairs comes from the monthly contributions made by the members. The NGO conducts regular monitoring, with its technicians addressing minor issues and vendors resolving major repairs within 7-15 days. However, WUG meetings are held regularly at few sites, while at most locations, they only occur during breakdowns in order to arrange for repairs.

Impact

With reliable irrigation, fallow lands in the region have become cultivable, increasing the cultivable land, and enabling year-round crop production. Traditionally, individual farmers used costly diesel-operated pumps or unreliable electric pumps, which have been replaced throughout the intervention area with 5 HP solar pumps, used collectively. Beneficiaries have reported that these pumps provide better water output, enhancing crop diversity and enabling them to cultivate vegetables like potatoes, brinjal, cauliflower, peas, and tomatoes in larger quantities. This has created stable income opportunities for farmers by tapping into local markets like Gola and Ramgarh, while having the potential to address the food and nutrition insecurity in farmer households. The shift from costly and price-volatile diesel to lower-maintenance, fuel-free solar pumps has reduced input costs. Some farmers have further boosted productivity by integrating drip irrigation, supported by government schemes.

Beyond improving farmers' incomes and promoting sustainable energy use, shared pump use and maintenance have fostered cooperation and built social cohesion among WUG members. During the time of the study, efforts were underway to link WUGs to farmer-producer organizations, encouraging collective efficacy. In Gola, 78 pumps are installed, and the anchor institutions have plans to add 7–8 more; the model is being replicated in five other blocks.



Photo credit: Amit Kumar | WRI India



Crop cultivation in Gola block, Ramgarh district, Jharkhand

Photo credit: Amit Kumar | WRI India

Role of relational dimensions in shaping livelihood opportunities and outcomes

The solar irrigation initiative in Gola block foregrounds the role of institutional partnerships and community ownership into integrating solar irrigation systems in local agrifood systems. The active involvement of communities in accessing, adopting, and managing solar technology, facilitated by the long-standing engagement of the NGO and the extensive outreach of the state agency, which implement social protection and livelihood enhancement programs, exhibits a robust implementation pathway. The intervention helped farmers in augmenting their livelihood assets by generating opportunities for income enhancement, building skills to run and operate the technology, and mobilizing farmers to create social capital to sustain the intervention.

In terms of the pump utilization, limitations in pump capacity were observed due to multiple simultaneous uses that restricted irrigation facilities, particularly in dry summer season. Farmers expect pumps with more power as water does not reach all plots, especially the faraway ones. Lands of farmers that are not contiguous face more issues as they have to depend on the water-pipe outlets in existing contiguous lands. This motivates us to consider local power dimensions that could be at play in water usage and distribution.

Led by a state agency, this implementation model finds itself in a stronger position to link with relevant government schemes for wider institutional support. Convergence with Agricultural Technology Management Agency (ATMA), Krishi Vigyan Kendras (KVKs), and agriculture departments is also helping more farmers access government schemes and maximize benefits. By leveraging state-level platforms and forging partnerships with other NGOs and government departments, the intervention demonstrates strong potential for scalability and long-term impact through convergence and institutional alignment. At the same time, it is important to address potential risks, such as over-reliance on institutional support, especially for monitoring of the pumps. This model needs to build strong community institutions to ensure the initiative's long-term viability and equitable benefits across diverse farmer groups.

About the anchor organization

This case study presents an initiative led by the **Jharkhand State Livelihood Promotion Society (JSLPS)** in collaboration with an NGO, Transform Rural India (TRI), to develop the Gola block of Ramgarh district as an agriculture production cluster through solar irrigation pumps as a lever. JSLPS is the nodal agency for the implementation of the National Rural Livelihoods Mission (NRLM) in the state, and it collaborates with various technical partners to encourage the implementation of innovative technologies and augment livelihoods in the rural areas.

Case Study 5 The role of state electricity utility in boosting farmers' income through solar irrigation systems, Gujarat

Livelihoods context

In the Daskroi block of Ahmedabad district, Gujarat, farmers traditionally relied on diesel pumps and erratic grid electricity for irrigation, facing high costs and unreliable water access that limited agricultural productivity. The region comes under the Gujarat Plain and Hill region agro-climatic zone.

The state electricity utility initiated a pilot project in 2018 under the Suryashakti Kisan Yojana (SKY) to deploy solar-powered submersible irrigation pumps. The initiative provided individual farmers with grid-connected solar submersible pump systems. This DRE intervention aimed to provide reliable daytime power, reduce farmers' diesel dependency in agriculture, and generate secondary income through surplus electricity sales to the grid. This case study highlights the state's electricity utility's efforts to enhance farmer livelihoods.

About the technology intervention

In September 2018, the state's electricity utility installed 12 grid-connected submersible solar pumps in Vehlal village of the Daskroi block. The submersible pumps are 400 ft deep with a pump capacity of 70 KW. One single pump has a sanctioned load of 50 HP but operational load is 35 HP. Each farmer has been provided with an AC pump of 35HP capacity, operating on 71 KW capacity solar panels. The pumps source water from the borewells and can irrigate approximately 25 acres of land per day and 1.5 acres in about 2 hours. The sites of the 12 farmers have been selected by the government in a three-party arrangement involving the farmers, the state electricity utility, and the installation agency (Zodiac Energy Limited), operating for 12 hours daily without battery backup. The sites of the 12 farmers have been selected by the government in a three-party arrangement involving the farmers, the state electricity utility company, and Zodiac Energy Limited. The grid-connected system ensures functionality during cloudy periods via grid power, though pumps do not operate at night. Grid connectivity of solar pumps also enables farmers to sell surplus electricity to the state grid.

The system is designed to withstand temperatures above 50°C, and given Gujarat's generally clear climate with minimal fog, the pumps can perform consistently. Line irrigation[4] is used to irrigate the field and allows water to be transferred efficiently between plots, reducing wastage and ensuring timely water delivery to crops. However, the absence of an RMS limits the ability to track usage, detect faults, and optimize performance in real time, potentially affecting long-term efficiency and maintenance.



Solar-powered, grid-connected submersible pump installation under Gujarat's SKY Scheme in Vehlal village, Daskroi block

Photo credit: Namrata Ginoya | WRI India

Implementation model

The state's electricity utility collaborates with farmers and Zodiac Energy Limited in a three-party arrangement to implement the intervention under the SKY Scheme. The state selected 12 farmers, all members of a cooperative society, based on their ownership of significant land parcels and financial capacity to contribute ₹1lakh upfront per pump. Farmers individually own and operate the pumps on individually owned farmland. The utility conducted awareness campaigns to promote solar irrigation benefits, like cost savings and grid revenue, overcoming initial skepticism. Farmers clean panels weekly to maintain efficiency.

Financial model

Each solar irrigation unit costs approximately ₹27 lakh. Farmers contributed ₹1 lakh (five percent of the total cost) as upfront capital, while 60 percent of the cost was subsidized by the central and state governments through SKY. The remaining 35 percent was covered through a low-interest loan provided by the state for a 7-year term. Farmers earn ₹1.5 lakh annually by selling surplus electricity to the grid, enabling them to recover their initial investment within the first year. The model's profitability, driven by grid sales and enhanced productivity.

Operations and maintenance

The O&M are managed by Zodiac Energy Limited and will be done for a period of seven years after which farmers are responsible for the costs. They are responsible for addressing issues like wire detachment (resolves within 1-2 days), with no major breakdowns reported since 2018. Farmers rely on the state's electricity utility or Zodiac for repairs due to limited technical training. Farmers clean panels weekly to ensure efficient electricity generation but cannot track water output or daily operations due to the absence of an RMS.

Impact

The solar irrigation initiative has enabled 12 farmers in Vehlal to irrigate 25 acres of farmland daily, thus doubling cultivable land under irrigation. These pumps are primarily used from June to November and have helped farmers grow wheat, castor, rice, and dill in increased quantities leading to an enhancement in income with reported annual earnings of ₹2 to 3 lakhs. The farmers take their products to sell by organizing transport that costs them ₹1,200 per trip to markets 15 km away. Although the initial investments or operational challenges may be significant, the higher returns offset initial costs. The intervention has reduced farmers' reliance on diesel-based irrigation, thus lowering the cost incurrent on buying diesel fuel. The initiative has also increased land values, with some families able to send their children abroad for education, reflecting notable economic upliftment.

Role of relational dimensions in shaping livelihood opportunities and outcomes

In Vehlal village, the pilot intervention has led to notable improvements in agricultural productivity and income. Farmers now grow diverse crops and report earning more than their initial investment in the first year itself. The time and labor involved in operating diesel pumps have also reduced significantly. Additionally, land values have increased due to the installations.

However, the model remains largely top-down, with farmers having limited awareness of the government departments, schemes, or private agencies promoting solar irrigation in the region. Furthermore, the intervention was designed without involving the community in planning or decision-making. The state selected the farmers—all members of cooperative societies, and the ones that had significant land. This excludes farmers who may have needed the intervention the most. Farmers are satisfied with the benefits from the solar-powered irrigation systems, but they have not considered the possibility of expanding the solarization to other stages of agriculture or other value chains. In terms of maintaining the system, farmers depend on the state utility or vendors and are not trained in monitoring or troubleshooting, posing risks to long-term sustainability.

While the current model is intended to enhance the financial and physical capital of individual farmers through building irrigation infrastructure and enhanced income through high-value crops, wider adoption among other farmers from the cooperative, converging with other government programs like drip irrigation, building user capacities, and strengthening local governance might create pathways for replication or broader and more sustainable livelihood transformation.

About the anchor organization

Uttar Gujarat Vij Company Limited (UGVCL) is a state-owned electricity distribution company under Gujarat Urja Vikas Nigam Ltd., responsible for power supply in the northern region of Gujarat. Committed to innovation and customer service, UGVCL plays a key role in rural electrification and renewable energy integration. Through schemes like Suryashakti Kisan Yojana (SKY), it is enabling farmers to adopt grid-connected solar-powered irrigation systems, promoting energy access, sustainability, and income generation.



Agro-processing Case Studies

Case Study 1

Self help group-led value addition through solar-powered drying and papad making in Kamrup, Assam

Livelihoods context

Located in the Eastern Himalayan agro-climatic zone in Assam's Kamrup district, farmers in Rangapara village primarily depend on subsistence agriculture, with limited opportunities for value addition. Women contribute extensively to cultivation, livestock rearing, and informal labor. Yet, their economic agency has historically remained limited. Women participate in small-scale papad making, but the activity yields minimal economic returns because it is time-intensive and because of the region's weak linkages with formal markets. Recognizing these constraints, a SHG in Rangapara, comprising 10 tribal women with low-income backgrounds, sought to transform their livelihoods through agro-processing infrastructure and services. A non-profit organization that works closely with communities in the region supported the SHG in addressing this challenge through solar-powered agro-processing machines.

About the technology intervention

In August 2022, a non-profit organization facilitated the installation of two solar-powered machines in Rangapara village: a solar dryer and a solar-powered papad1-making machine. The solar dryer, installed by a technology developer, is a tabletop multi-product dryer with a 30 kg capacity. It has four trays made with Ginegar greenhouse sheets and two exhaust fans. Powered by a 100 W solar panel, this active dryer enables efficient drying of agricultural and forest products. The papad-making machine is powered by 600 W solar panels, supported by a three kW inverter and two Amaron tubular batteries (12V, 200Ah) for backup. It is accompanied by a weighing scale and packaging sealer to support end-to-end production. Additionally, the SHG uses a two HP single-phase multi-product pulverizer, procured earlier with the support of another non-profit organization from Kamrup Machinery Stores. Though not solar-powered, it is essential for grinding turmeric, hilikha (haritaki), and black gram (urad dal), complementing the solar equipment and expanding their processing capacity.

Implementation model

Designed by a non-profit organization, the intervention aimed to meet the needs of the women in the SHG and is designed as a community-owned, solar-powered value addition approach in which SHGs manage operations including production, processing, and distribution while the intervention enhances women's economic empowerment by strengthening local agro-processing infrastructure. The SHG procures the products from other farmers in the village in addition to their own production. The installation of both the technologies is done on land voluntarily donated by one of the SHG office bearers. The solar dryer is mainly used from January until the paddy harvest period, especially for products like haritaki and turmeric. Haritaki, procured from the local market by farmers at ₹10 per kg, is dried in 2-3 days and then sold in powdered form for Ayurvedic use (e.g., Triphala). Turmeric, purchased at ₹30 per kg, is dried to produce turmeric powder, which is sold at ₹250 per kg after drying. For the papad-making machine, the SHG processes 10 kg of urad dal (worth ₹1200 + ₹300 transport) to make 100 papad packets, each sold at ₹40. These are supplied to the Assam State Rural Livelihoods Mission (ASRLM) and for weddings.

Financial model

The SHG's solar agro-processing initiative is supported through a blended financing model combining grant funding, community contribution, and subsidized credit. The non-profit organization funded 80 percent of the capital cost for the solar dryer and papad-making machine, while the SHG contributed the remaining 20 percent. To further scale operations, the SHG secured a low-interest loan of ₹100,000 from a public sector bank under the Pradhan Mantri Jan Dhan Yojana and Pradhan Mantri Van Dhan Yojna schemes. They received an interest subvention of ₹ 35,000, effectively reducing the borrowing cost to just 0.5 percent. This financial approach ensured low upfront risk for the community and allowed them to generate income by processing and selling value-added products like turmeric powder, Triphala, and papad to local and urban buyers.



Drying of haritaki in Rangapara village, Kamrup district, Assam

Photo credit: Masfick Hazarika | WRI India

Operations and maintenance

The SHG is responsible for the operation and maintenance of the system. The intervention supports women's economic empowerment by strengthening local agro-processing infrastructure.

Impact

The intervention has enabled SHG members to enhance their household incomes and better utilize their time and labor. The papad that was earlier manually dried under the sun now benefits from the solar dryer, which has reduced the time women spend on drying activities. They report that higher returns from dried products make them feel that their labor is more valued. The papad-making machine has also drastically cut down women's effort, from 8 hours to just 2 hours to produce 1 kg of papad, allowing the SHG to scale up production. The increased efficiency has also created livelihood opportunities for other local women, who earn ₹200-300 per day processing papads to meet bulk orders. Market access has expanded significantly, with products sold to the Assam State Rural Livelihoods Mission (ASRLM), while the SHG pursues Food Safety and Standards Authority of India (FSSAI) certification to reach beyond local stores. The machines also extend the shelf life of products and improve their quality, giving women more time to sell their products, which is not the case with raw produce or manual drying of products.



Interior of a house in Rangapara village where harataki is being prepared for drying. *Photo credit: Masfick Hazarika | WRI India*

Role of relational dimensions in shaping livelihood opportunities and outcomes

This case study illustrates how women's groups can take the lead in owning technologies and build their capacity to operate and integrate technologies into their local agriculture value chain. The SHG's proactive steps, such as purchasing a pulverizer with support from the NGO, accessing government schemes, seeking working capital, and linking with ASRLM, demonstrate how informed collectives can identify and tap into livelihood opportunities. A significant milestone for the SHG is applying for a FSSAI certification. This will enable them to expand their market reach, especially for their "Asomi" pickles, which have found success in the niche market through ASRLM.

However, challenges persist in sustaining these gains due to limited capacity in O&M, like cleaning rooftop solar panels and addressing technical issues that have arisen with a grid-powered grinder. A lack of knowledge about service contracts, warranties, and vendor relationships reveals gaps in institutional support and livelihood strategies, leaving SHG members reliant on a single contact from the NGO. Building an enabling ecosystem for these interventions to grow and expand is essential, particularly in technological interventions.

About the anchor organization

This case study presents DRE-powered agro-processing interventions led by **Bandhabi Milon SHG,** supported by the **SELCO Foundation** in the Kamrup district of Assam. Bandhabi Milon SHG is a women's empowerment organization that works with destitute communities to enable women's financial independence. The initiative was supported by the SELCO Foundation, which works closely with communities to identify livelihood challenges and address them using energy-efficient technologies and appropriately designed solar energy systems.

Case Study 2 | Two entrepreneurs' journey of building rural enterprise through rice processing in Chamta, Assam

Livelihoods context

Gangapur, a small village in the Chamta block of West Nalbari, Assam, which falls in the Lower Brahmaputra Valley (Eastern Himalayan division) agro-climatic zone, lacked post-harvest infrastructure for processing rice, making the local farmers dependent on distant markets or inefficient systems for rice hulling. This led to them incurring high costs and spending excessive travel time in processing. Recognizing this critical gap, a father-son duo emerged as local entrepreneurs and decided to initiate a local solar-powered rice processing facility with the support of an NGO.

About the technology intervention

In July 2022, the entrepreneurs, with technical support from Techno village (the energy enterprise) and financial assistance from the donor organization, installed a solar-powered rice huller-cum-grinder on their land. Branded as Bullet Raja, the system features a 3 HP motor with a rated power of 2.2 kWp solar PV setup comprising 10 panels along with a 10 kW inverter with a battery system, allowing operations even during non-sunny hours. The system typically runs for about 8 hours a day, including some operations at night, ensuring year-round service.

Implementation model

The donor organization subsidized 80 percent of the costs while the entrepreneurs made a sizable upfront contribution for the complete system. The entrepreneurs provide rice hulling and grinding services to farmers and fishery owners across 3 to 4 nearby villages. The end-users are largely marginal and smallholder farmers, who now have access to affordable and efficient rice processing which reduces broken grains and closer to home. The machine provides dehusking and polishing in a single pass, providing a better alternative to existing machinery in the area with greater customer satisfaction for self-consumption.



Solar-powered rice huller in Chamta block, Nalbari district, Assam *Photo credit: Lanvin Concessao | WRI India*

Financial model

The donor organization covered 80 percent of the capital costs, while the entrepreneurs contributed a significant upfront amount of INR ₹95,000 toward the complete system.The solar-powered rice hulling unit in Gangapur operates on a service-based revenue model. The entrepreneurs charge the farmers and local households based on the type of service provided: ₹20 per kg for parboiled rice, ₹10 per kg for normal rice, ₹30 per kg for masala grinding, and ₹40 for processing 30 kg of paddy. In addition to processing charges, they also generate income from selling rice husks produced during processing for selling as feed for fish and ducks. Together, these activities contribute to an average monthly income of ₹12,000 for the entrepreneurs.
The entrepreneurs made an upfront contribution of ₹95,000, while the donor organization covered most of the capital costs.

Operations and maintenance

Post-installation, the entrepreneurs have taken full ownership of the system, managing operations and maintenance independently, even resolving early technical issues like bearing problems such as resolving issues with the rotating components of the system to prevent breakdowns and ensure smooth, uninterrupted operation . Battery backup enables operations even during cloudy periods and at night. This locally anchored business model not only generates livelihood for the entrepreneurs but also offers affordable, value-added services to farmers in surrounding villages.

Impact

Farmers no longer need to travel long distances for processing, saving both time and transport expenses. The quality of processed rice is superior, boosting consumer demand. For the entrepreneurs, the initiative has created a sustainable income source while supporting the local economy. By diversifying into masala grinding and selling husk, they have expanded their revenue base. Looking ahead, they plan to add additional agro-processing equipment, such as an oil expeller, to further utilize their solar infrastructure.

Role of relational dimensions in shaping livelihood opportunities and outcomes

By using solar energy instead of diesel or unreliable grid power, the intervention draws on renewable sources to create reliable services in a remote local area. The skills, initiative, and problem-solving ability of entrepreneurs have been central to making the enterprise viable, improving their livelihoods, and at the same time improving farmers' access to processing that previously did not exist. Income has been generated both for the entrepreneurs and the wider community, as farmers benefit from reduced travel, lower costs, and better-quality rice. Trust and informal networks have been reinforced, as nearby villages now rely on the facility and view it as dependable.

The initiative presents an individually owned service-based model and offers limited insights into scaling or replicability. Implementation of the technology through farmer cooperatives or women's collectives also remains unexplored. Moreover, unless heavily subsidized by an anchor institution, it is difficult for individual entrepreneurs to procure, own, and operate such equipment. For the two entrepreneurs in this case, saturation of the local market may constrain future growth. Additionally, the gradual expansion of cheaper government grid electricity will create alternatives and competitiveness, potentially reducing its appeal for the farmers.

About the individual entrepreneurs

Ziaur Rehman and his son, **Jaherul Islam,** both enterprising individuals, have spearheaded the installation of a solar-powered rice huller cum grinder in the village of Gangapur, Chamta block, Nalbari, Assam.

Case Study 3

NGO integrates solar to strengthen local pulse value chain through self help groups in Ramgarh and Hazaribagh, Jharkhand.

Livelihoods context

Farmers in Rikwa village in Churchu block of Hazaribagh district primarily grow pulses. In this region, most farmers, own 0.5–2 hectares of land and produce about 700–800 kg of pulses annually. Roughly half is retained for household consumption, while the rest is sold to local traders at prices lower than APMC rates, as traders offer doorstep collection. Village-level production typically totals 15–20 MT per season, but due to limited logistics and value-addition facilities, farmers sell at minimal prices that barely cover input costs. However, the absence of efficient and accessible processing facilities has limited their ability to earn remunerative returns from their produce. To address this gap and enhance livelihood opportunities, a non-profit organization, facilitated by its parent energy advisory and service company, installed a solar-powered pulse processing unit in the village. This intervention, implemented under the Microgrid Initiative for Campus and Rural Opportunity (MICRO) program of the company, aims to support pulse farmers by reducing post-harvest losses, improving processing efficiency, and enabling better market access.

This case study highlights an NGO-led initiative in Hazaribagh and Ramgarh districts of Jharkhand's North Chotanagpur plateau, which promotes women-led micro-enterprises through agro-processing to strengthen local livelihoods and drive economic development.

About the technology intervention

The NGO established a pulse processing unit in January 2020 in Rikwa village of Hazaribagh. The unit is powered by a hybrid energy system comprising a 5 kW solar PV array with 10 kWh lithium-ion battery storage, complemented by a 7 kW grid connection. The system includes key processing components such as a destoner (3 HP), grader (0.5 HP), dryer (2 HP), pulse mill (5 HP), and pulverizer (5 HP). While the single-phase machines run on solar energy, the higher-capacity milling and pulverizing units operate on grid electricity due to their load requirements.

To optimize energy use, an inverter is configured to prioritize solar power, followed by battery backup, and lastly, the grid, ensuring cost efficiency and reliability. An RMS enables the company to track energy consumption and machine performance through a mobile app. The plant can process up to 20 tons of pulses per month, including pigeon peas

(toor), Bengal gram (chana), black gram (urad), and red lentils (masoor), operating 16–18 hours daily based on demand. The commercial grid connection incurs an average electricity cost of ₹5,500 per month, significantly lower than previous high electricity bills..

Implementation model

The implementation in Rikwa village involved forming a group of ten women called Sakhi Mandal, a local Producer Group (PG) supported by the non-profit organization. Five of the women were trained to operate a solar-powered pulse processing unit. To ensure smooth operations, the company provided extensive capacity-building support to the PG members. The women PG began running it as a micro-enterprise, sourcing pulses from nearby farms, processing them locally, and selling the final product in village markets.

Things were running smoothly, but over time, two challenges emerged. First, the processed pulses weren't meeting formal market quality standards, and the group struggled to find reliable buyers beyond the local area. Realizing this could limit their growth, the company stepped in with a solution and, in January 2022, installed a high-tech Sortex machine in Bhurkunda (a town 15 km from Ramgarh district and 50 km from Rikwa village), which has better electricity access, transport, and market linkages. The machine cost ₹16 lakh and was fully funded by the company. It uses digital imaging to sort and grade pulses for quality and consistency. By enhancing sorting efficiency and product quality, the machine aims to address market demand for high-quality pulses, thereby opening new avenues for revenue generation and market expansion.

Financial model

The pulse processing unit is owned and managed by the Women's PG, while the NGO currently owns the Sortex machine, with plans to transfer ownership to the PG in the future. The PG covers all operational costs, including monthly electricity bills averaging ₹6,000 (up to ₹9,000) for the Sortex unit. To fund operations and raw material procurement, five PG members received a joint loan of ₹5 lakh from a non-banking financial institution at an annual interest rate of 5.5 percent. The loan is held in the PG's account and repaid using profits from selling processed and sorted pulses. Due to limited local supply, the NGO supports the PG in sourcing pulses from Palamu and Latehar districts. Raw pulses, bought at ₹52–60/kg during April–May, are sold post-processing at around ₹110/kg under the registered brand Bhumi. The NGO's market study confirmed steady demand of 3 tons/month in Hazaribagh, 1 ton in Ramgarh, and 500–1000 kg in Ranchi, helping the PG access wider markets and improve profitability. In the last five months, PG has repaid ₹1.5 lakh/month (₹7.5 lakh total) from its profits. This shared account also covers wages for eight operators, electricity, rent, maintenance, and future upgrades. Additionally, processing byproducts, such as broken pulses and waste, is sold at ₹30/kg as animal feed, generating extra income and reducing overall losses.

Operations and maintenance

The overall management of the technology is done by collective members who were trained and skilled at operating the machines and managing the books and finances. The Sortex machine has a one-year guarantee, with service centers accessible in Ranchi, Jamshedpur, and Bihar. At Rikwa, electricity is supplied through a hybrid system, grid power for larger machines and solar for smaller ones, though battery failures have highlighted maintenance challenges. O&M costs, including electricity bills, rent, and service charges, are met through user fees and profits from pulse sales, with a share reserved for future repairs. Additionally, processing by-products—such as broken pulses and waste—are sold at ₹30/kg as animal feed, generating extra income and reducing overall losses.

Impact

The intervention brought economic returns for the PG members as they are now able to operate the machines year-round by procuring raw materials in bulk and selling their products within and beyond district boundaries. There was a consistent monthly supply of 3 tons of processed pulses in Hazaribagh and 1 ton in Ramgarh, and these were marketed under the registered brand name “Bhumi”. The non-profit organization facilitates the transport of 500–1000 kg of pulses to selected wholesalers and retailers in Ranchi, the capital city 95 km away. These market linkages have enabled the PG group to turn profitable by offering good-quality pulses and carving a niche in the regional quality pulse market. Additionally, the integration of a Sortex machine further strengthened the model by minimizing waste and enhancing the economic viability of operations. Solar-powered systems reduced the dependency on erratic grid supply, thus ensuring uninterrupted processing and lowering operational risks.

While the processing unit in Rikwa village runs primarily on solar energy, the Sortex machine is powered through a 3-phase conventional electricity connection. This hybrid energy approach combines the reliability of solar with the robustness of grid power, resulting in seamless operations, higher productivity, and greater resilience. Importantly, the usage of both the renewable and conventional sources of energy demonstrates a forward-looking commitment to both sustainability and enterprise growth.

Role of relational dimensions in shaping livelihood opportunities and outcomes

The model presented in this case presents an integration of agro-processing technology in the local pulse value chain through women farmers' collectives to improve livelihood outcomes. Solar energy emerges as a catalyst for value addition and processing unit, offering a reliable and cost-efficient alternative to conventional electricity.

As the management of the technology lies with collective members who are trained, this not only enables the development of human capital of the individuals and groups involved but also facilitates regular compensation for them based on their daily output or daily wages, whichever they choose. The intervention also supports linking final products with the market and creating and strengthening a local brand. The model involves strengthening the capacity of the producer group and transferring the assets to them within five years. Initiatives like "Rangde," play a significant role in creating a platform for women entrepreneurs from marginalised sections to access finance, thereby improving their opportunities to own and operate assets required to build sustainable livelihoods.Financing is considered an impediment to expanding rural livelihoods, including introducing innovation and mechanization. This model indicates that extensive and regular support of an implementation agency/ NGO is essential at every step. Such support creates a platform to onboard the financial and technical partners, and market players establishing an enabling ecosystem for farmers. It also facilitates the integration into the local context and enable farmers and collectives to adopt and own the technology. Linkages to state and national policies can be built into the model to bolster the intervention and create opportunities for scaling.

About the anchor organization

Customized Energy Solutions (CES) operates at the intersection of energy access and rural development, focusing on promoting livelihoods through DRE, particularly in the agricultural sector. By deploying clean energy solutions tailored to local needs, CES enables communities to improve productivity, reduce dependence on fossil fuels, and create sustainable income-generating opportunities. Beyond rural interventions, CES is deeply engaged in shaping the broader energy market. The organization is committed to fostering economic development by supporting the creation of transparent, efficient, and inclusive electricity and natural gas markets, both at the wholesale and retail levels. Through its work, CES contributes to building a resilient and equitable energy ecosystem that supports both growth and sustainability.

Case Study 4

NGO-led solar dryer intervention for livelihood enhancement through women's collectives, Koraput, Odisha

Livelihoods context

Koraput district in Odisha is home to tribal communities, predominantly the Paraja and Kondh tribes, where livelihoods are primarily based on subsistence agriculture and seasonal wage work. Despite growing crops like ginger, mustard, turmeric, and vegetables, local farmers struggle with poor market linkages and low price realization, exacerbating vulnerabilities like seasonal migration. An NGO has been working in the region since 2010 to strengthen rural livelihoods by building women-led institutions, supporting agro-processing initiatives, and facilitating farmers' participation in the Agriculture Production Cluster (APC). In 2018, recognizing the potential for value addition in agriculture, the NGO partnered with a technology provider placing 7 drying units (for 7 SHGs) in 3 villages, focused on ginger drying This Decentralized Renewable Energy (DRE) intervention aimed to enhance value addition, stabilize incomes, and reduce post-harvest losses. This case study highlights the efforts to empower women in the Eastern Ghats agro-climatic zone, fostering sustainable livelihoods through agro-processing.

About the technology intervention

The intervention, initiated in Nandpur in 2018, involves drying units comprising two 1.5 kW electric cutters, 10 fan-based dryers (FBDs), and 16 solar dryers per SHG comprising 10 to 12 members. The grid-powered cutters and FBDs process 50 kg batches of ginger, with solar dryers completing the drying process in 3 to 4 hours, protecting products from rain and storms. The units are modular and portable, allowing disassembly during off-seasons for land reuse for homestead farming. With a 5-year warranty, the units are maintained by the technical partner, which addresses technical issues within 2 days.



Drying of a batch of ginger in Koraput district, Odisha

Photo credit: Arundhita Bhanjdeo | WRI India



Solar-powered drying unit in Koraput district, Odisha *Photo credit: Arundhita Bhanjdeo | WRI India*

Implementation model

The NGO collaborated with the technology provider and implemented the intervention through SHGs and FPCs. It initially piloted 7 drying units across 3 villages in 2018, expanding to 50 units by 2023. FPC procures raw ginger from farmers. SHG members process it into dried ginger and earn ₹150 for a 50 kg batch. The SHG members have been trained by the technology provider, which buys back the dried product and pays directly to SHG bank accounts within 7 to 10 days. A Community Resource Person (CRP), appointed by the FPC, oversees operations, quality control, and troubleshooting. The buyback scheme ensures dried ginger is purchased at a ₹1/kg profit margin. The dried ginger is then transported to their Aurangabad facility. Women lead processing while men and children assist in manual tasks such as loading and unloading the ginger, washing. The land used for unit installation is contributed voluntarily by SHG members, and the machines are stored in an SHG member's house when not in use.

Financial model

Each drying unit costs ₹5.5 lakh, funded by a UN Women project in the pilot phase and later, by a government program. SHG members, who are FPC members, contribute no direct upfront costs, as units are FPO assets, with land provided rent-free by members. They process up to 4 batches in a day, earning ₹600, yielding ₹20,000 to ₹25,000 annually over 3 to 4 months. The FPC's ₹1 per kg profit margin from technical partner buyback supports operations, with O&M costs of ₹5,000 to ₹10,000 annually covered by FPC revenue.

Operations and maintenance

SHG members are trained in daily operations, while the CRP monitors drying processes and coordinates with the technician assigned by the technology provider in the district for repairs. Machines are maintained locally, and technical issues are resolved within 2 days. The 5-year warranty covers maintenance, with post-warranty costs borne by the FPC. Separate electricity connections were facilitated by the NGO to prevent occasional overload issues by grid-powered cutters and FBDs. Insurance covers theft or natural calamities, posing risks. Solar dryers also help reduce electricity bills and safeguard produce during inclement weather. The NGO's oversight ensures operational competence, but robust M&E systems are needed to optimize performance and address quality-related losses.

Impact

The intervention benefits 50 SHGs—nearly 600 women across Nandapur—enabling ₹20,000-₹25,000 annual earnings per woman through ginger processing. This creates local and remunerative opportunities for women to earn and reduces out-migration. Farmers selling raw ginger to the FPO receive higher incomes due to stable prices, with post-harvest losses reduced by up to a third. Solar dryers were reported to cut electricity costs, and though the cutters and FBDs rely on grid power, the NGO and SHGs plan to operate on solar in the future to further reduce the operational cost. SHGs have built skills in women to operate the machines and strengthened their collective efficacy to run the processing systems and generate livelihoods for themselves. Market linkages via the technology provider ensure sales, but dependence on a single buyer limits flexibility.

Role of relational dimensions in shaping livelihood opportunities and outcomes

Farmers in the region already grew ginger and other crops, but they struggled with post-harvest losses and low, fluctuating prices. The intervention helped them make better use of their land and crops by adding value through solar drying. Women farmers learned new skills in cutting, drying, and quality control, and exposure visits built their confidence by showing them how peers had succeeded elsewhere. The roles of SHGs and the FPC have been equally important, as these collectives created trust, helped women share labor, and allowed them to

negotiate with buyers collectively. Some members even provided land for installing the units without charge, showing how social networks were leveraged for the effort. Financially, group arrangements meant earnings were managed more transparently, and households augmented their earnings. The NGO and technology provider linked the community to finances, training, technology, and markets, though reliance on a single buyer also created risks. Low utilizationhigh cost of system, and single-buyer reliance questions the sustainability of the intervention and prevent unlocking its full potential.

Additionally, there are chances of elite capture by SHG leaders who have more access and information and farmers who have more land as they are able to grow larger quantities of ginger as compared to those with less land. Overall, the intervention makes a case for leveraging social capital of the NGO, forward linkage and post-installation support by the technology provider, and strong collectives, not just the technology itself. Sustenance and scaling of the intervention would require tapping into several local, sub-national, and national opportunities and addressing barriers.

About the anchor organization

PRADAN, established in 1983, is a non-profit organization working to empower rural communities, particularly women, across India's poorest regions, PRADAN partners with local institutions, such as SHGs and FPOs, to enhance livelihoods through agriculture, natural resource management, and enterprise development. It focuses on building self-reliant community institutions and enabling access to markets, finance, and public services. With a strong presence in tribal and marginalized geographies, PRADAN promotes inclusive, sustainable rural development.

Case Study 5

Enterprise-driven drying of horticultural crops through self help groups in Khargone, Madhya Pradesh

Livelihoods context

Khargone district in Madhya Pradesh, part of the Nimar Valley within the western plateau and hill region, has an agriculture-based economy, has an agriculture-based economy dominated by cotton production along with food grains, pulses, oilseeds, and sugarcane. Improved irrigation and adoption of modern farming practices have boosted crop productivity and resilience in the region. However, in the Rao village of Khargone district, small and marginal farmers face significant post-harvest losses due to inadequate storage facilities and fluctuating market prices for perishable crops, such as fruits, vegetables, and spices. To address this challenge, a social enterprise that manufactures and exports solar dryers and solar-dried agricultural products has introduced solar-powered drying technology. The intervention aimed to offer farmers an opportunity to preserve surplus horticultural produce, reduce losses, and generate year-round income through value-added products.

About the technology intervention

The enterprise installed polyhouse and tabletop tank solar dryers in Rao village in 2019, with multiple capacities ranging from 5 kg, 20 kg, 40 kg, 50 kg, 80 kg, 100 kg, 500 kg, and 1000 kg. The dryers are powered by 18 W solar panels for 20 kg dryers (with one fan), 40 W panels with 100 kg dryers, and 120 W panels for 500 kg dryers (with 5 fans). Drying is carried out at 50–60°C for 7-8 hours a day, and several crops are dried in these dryers, including black grapes, tomatoes, mangoes, ginger, turmeric, cardamom, and rose petals.

Drying times vary across products; for instance, flowers take 2 to 3 hours to dry, whereas fruits and vegetables require 2 to 3 days to dry in the dryers. The solar drying units, manufactured by the DRE enterprise, include polycarbonate sheets for heat retention and durability. They are also equipped with lightning arrestors, which make the units resilient to damage caused by lightning, preventing costly repairs and downtime. An RMS is installed to track performance and provide feedback for more efficient use. Since the unit runs during the daytime, battery backup is not required.

Implementation model

The enterprise implemented the intervention through FPOs and SHGs. To overcome initial resistance due to low awareness, the enterprise conducted workshops with farmers to demonstrate the benefits of solar drying and how it would help them receive higher prices for their crops and address issues of crop spoilage.

Solar dryers are individually owned by farmers and are placed on their lands, selected by the FPOs.

The intervention targets farmers whose crops are priced at ₹10/kg or less and of moderate quality, ensuring affordability and relevance for smallholders. So, farmers with poor-quality crops are not considered owing to the lower chance of value addition of such crops, and those with high-quality crops are assumed to receive remunerative prices in the market. Women farmers are primarily responsible for drying operations, but they are not involved in the maintenance of these systems. The enterprise provides free online training on dryer use, sorting, and packaging, along with protective gear like hair masks and gloves. The FPO helps organize these trainings with farmers, women's groups, and through online meeting platforms. Additionally, once the dried produce exceeds 100 kg, the enterprise procures it, covers transportation costs, and sells it in larger markets, including industry, food chains, and ready-to-use product segments.

Financial model

The cost of one solar dryer ranges from ₹50,000 to ₹1.15 lakh, depending on its size and capacity. Individual farmers have to pay the dryer price upfront. The dryers are financed through a combination of a 35 percent subsidy under the Pradhan Mantri Fasal Bima Yojana (PMFBY), bank loans and upfront payments of the remaining amount by farmers. Three farmers use a 100 kg dryer and they earn around ₹35,000 per month from their dried crops. Revenue generated varies between crops and can range from ₹125 per kg to ₹1,500 per kg. For instance, rose petals are sold at ₹500 per kg, Aparajita (Blue Pea) at ₹700 per kg, and cardamom at ₹2,000 per kg, considerably higher than the prices of raw products. In addition, the food/ products that were earlier wasted are now converted to revenue. This technology provides value addition to the product or raw material, while maintaining the nutrient value and fragrance of the product.

Operations and maintenance

Maintenance, including tray cleaning and panel upkeep, is managed by the members of the FPO/SHGs, with the enterprise overseeing the process. In case of any issues with the dryers, the company replaces the spare parts such as the fan or the polycarbonate sheets that cover the tray. The cost of any replacement is borne by the farmers' group. The monitoring and evaluation are conducted by the enterprise, which collects baseline data on various parameters, including crop cycle, farmer landholdings, productivity, selling price of crops, price fluctuations across seasons, crop storage and spoilage, existing processing practices and gaps, and labor-related challenges, especially for small farmers.

Impact

The solar drying initiative has reduced post-harvest losses, increased shelf life, and created stable income opportunities for smallholder farmers. It demonstrates that decentralized post-harvest technologies can convert perishable surplus into high-value commodities. Employment for women in sorting and grading activities has also emerged as a co-benefit. Despite early challenges in farmer awareness and risk from cloudy days, the model received farmers' buy-in, especially for farmers with limited market access.

The enterprise is exploring partnerships with the State Bank of India to offer affordable loans for scaling. The model's profitability, driven by high-value dried products and year-round operation, supports loan repayment within 2–3 years, enhancing financial sustainability. Dryers are expected to enhance the shelf life of the products by 6 months to 1 year.



Solar-powered dryer in Khargone district, Madhya Pradesh. *Photo credit: Namrata Ginoya | WRI India*

Role of relational dimensions in shaping livelihood opportunities and outcomes

The intervention trains women farmers in dryer operation, sorting, and packaging, while partnerships with FPOs and SHGs help facilitate market linkages. Challenges remain around consistent demand, timely procurement of products for drying, and equitable benefit sharing among the farmers group. While the dryers have strengthened local processing infrastructure, their fragility and dependence on weather conditions present significant challenges. The 35 percent PMFBY subsidy and bank loans support affordability, but high upfront costs exclude small and marginal farmers who cannot access bank loans or have limited financial resources to invest in a dryer.

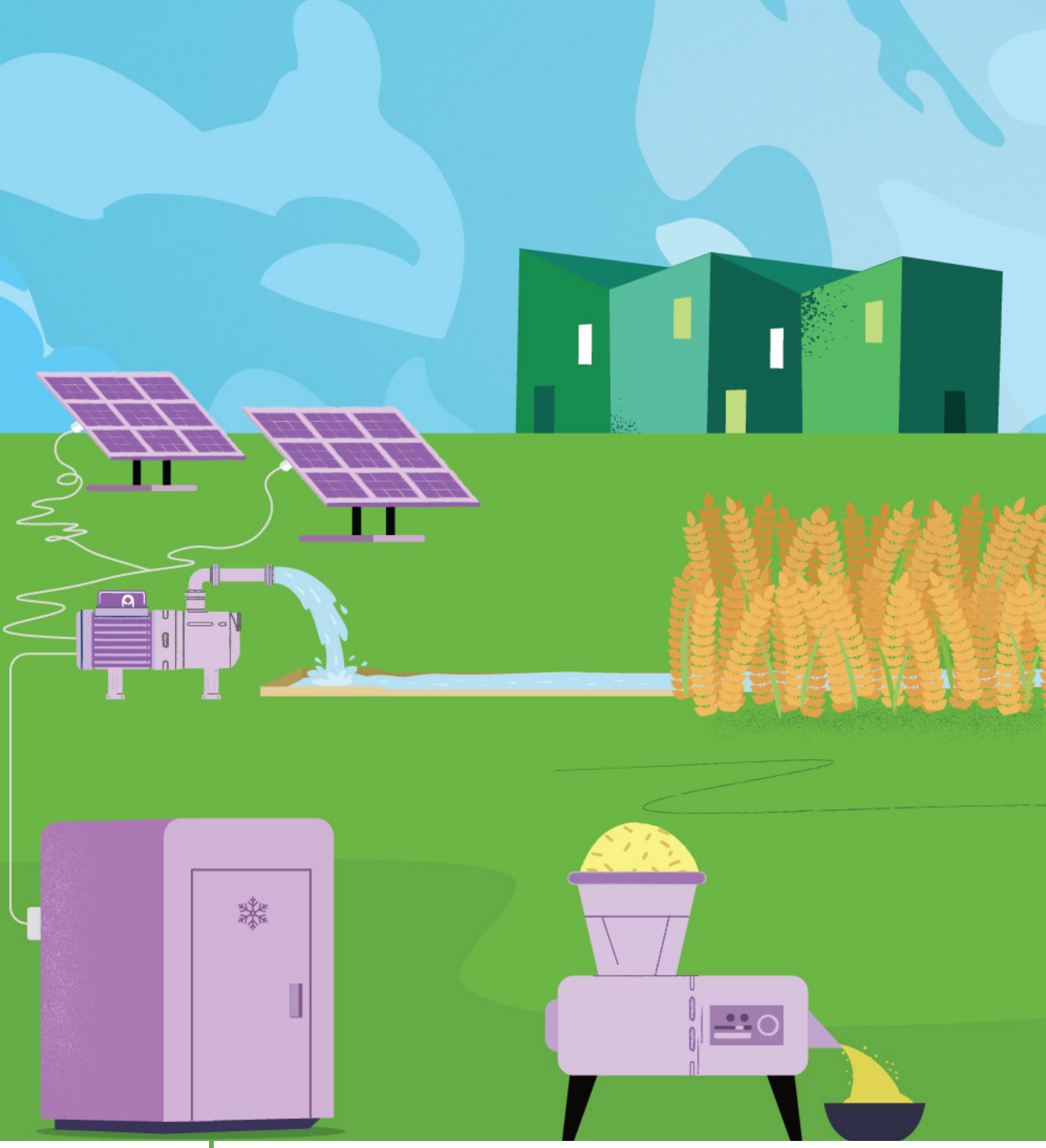
The intervention mitigates shocks like crop spoilage and seasonal income fluctuations by enabling year-round drying, supported by the enterprise's market linkages. However, the enterprise's selection criteria exclude farmers whose crops are affected by climate shocks or pest attacks, as only the produce of selected quality is procured. Additionally, once the dried produce exceeds 100 kg, the enterprise procures it, covers transportation costs, and sells it in larger markets, including industry, food chains, and ready-to-use product segments. This ensures cost efficiency; however, this practice raises concerns over what happens to smaller quantities or significantly larger surpluses, where aggregation and timely procurement become uncertain.

The dryers, though user-friendly, falter on cloudy days, risking moisture damage to the produce, and their fragile polycarbonate sheets quiver under strong winds, demanding costly replacements borne by farmers. The SHG/FPO platform appears underutilized, and it is unclear how it contributes to the intervention or represents the voices of other farmers. Additionally, concerns remain around bank loans, whether these are taken in the name of husbands due to land title requirements or routed through SHGs instead. Additionally, the SHGs' women's exclusion from M&E hinders them from participating fully in the intervention despite their operational roles.

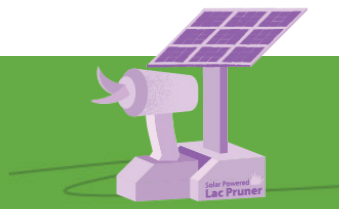
By addressing the gaps of collective ownership, enhancing women's roles in O&M, making the technology more robust, and introducing inclusive financing tools, the initiative could achieve more equitable and sustainable livelihood outcomes.

About the anchor organization

Raheja Solar Food Processing Private Limited (RSFPL), founded in 2018 by Varun Raheja and Babita Raheja, empowers small farmers in India by providing affordable solar dryers to reduce post-harvest losses and enhance income through value-added dried products. Operating from Indore, Madhya Pradesh, RSFPL offers models such as Sahaj, Samagra, and Agraj for drying fruits, vegetables, spices, and flowers, with capacities from 5 kg to 1,000 kg. The enterprise supports farmers with training and market linkages, connecting them to B2B buyers, and has deployed over 1,000 dryers across 23 Indian states



Multi-technology Case Studies



Case Study 1

NGO-led irrigation and cold storage intervention with farmer collectives in Baksa and Nalbari, Assam

Livelihoods context

The northeastern region of India presents unique challenges to agriculture, stemming from its complex hydrology and diverse smallholder communities. This case study details two distinct, solar-powered livelihood interventions implemented by an NGO in Baksa and Nalbari districts of Assam, highlighting how technical reliability and institutional support are as critical as the technology itself.

Both Baksa and Nalbari districts are located within the fertile Brahmaputra Valley and are part of the larger Eastern Himalayan Region agro-climatic zone. Baksa district lies in the northwestern part of Assam, forming part of the Bodoland Territorial Region, spans fertile plains, forested foothills, and dense woodland areas which is inhabited by tribal communities, namely Boro, Rabha, Sarania Kachari, and Madah. The district's farming system was crippled by erratic water supply with the Balti River, a tributary to Brahmaputra, creating floods during the monsoon and drying up completely during winter, and summers; forcing reliance on costly diesel pumps for irrigation. Nalbarihome to a diverse mix of Assamese Hindus, Muslims, Bodos, Bengalis, and Nepalis, presented distinct challenges for smallholder farmers- the issue of post-harvest loss. In the Borbhag block of Nalbari, small and marginal farmers growing vegetables and potatoes lacked reliable cold storage, leading to distress sales.

To address these challenges, the NGO, in partnership with the National Bank for Agriculture and Rural Development (NABARD), introduced solar-powered irrigation systems in two villages: Khatarbari and Kalseni villages of Nagrizuli block of Baksa and in partnership with technology partner, a solar cold-storage unit in Naherbari village of Borbhag block of Nalbari to strengthen local farming systems and their incomes.

About the technology intervention

Solar Powered Irrigation:
At Baksa, five 1 HP surface solar pumps (installed by one technology provider) and four ½ HP portable solar pumps (installed by another provider) were deployed. Together, these pumps allow year-round irrigation, catering to small plots of 0.5 acres and above, eliminating the recurring fuel expenses that farmers earlier faced with diesel-based pumps drawing water from canals.

Solar Cold Storage:
At Borbhag block of Nalbari district, a 10 MT solar-powered cold storage, was installed by another technology provider in January 2021, through the the NGO with the support of technology provider. The unit maintains a temperature of 2°C to preserve potato seeds and other horticultural produce. Though a multi-commodity storage facility, it is used to preserve potato seeds from March to November.

Due to frequent power outages in the region, the unit was designed to run on a hybrid energy model—solar power during the day and grid electricity at night. The unit initially included battery backup but was later discontinued due to poor charging performance. The system has an RMS, data from which is accessible to the technology provider and the NGO.

Implementation model

At Baksa, the intervention was implemented under NABARD's Tribal Development Fund (TDF) It focused on tribal communities, with priority given to farmers owning up to 0.5 acres of land. Village selection was based on a need assessment conducted by the NGO and submitted to NABARD, and pump installation sites were finalized through consultations with local farmers and Krishi Vigyan Kendras (KVKs).

To ensure the smooth implementation and management of the irrigation systems, the NGO facilitated the formation of a Village Planning Committee (VPC) comprising 70 farmers, nearly one-third of whom are women. The lands on which the solar pumps are installed are owned by individual farmers who are members of the VPC, but the ownership of the pumps lies with the VPC, and not the individual farmers. For using the pumps, these VPC farmers have to pay a rent, which is collected by a VPC member assigned by the group. The VPC develops schedules for each of the 70 farmers to use the pumps, depending on their demand.

At Nalbari, the cold storage unit is implemented through and owned by a Farmer Producer Company (FPC) constituting 500 farmers as members, and was mobilized by the NGO to strengthen the backward and forward linkages for the small and marginal farmers of the region. The cold storage unit is installed on a land voluntarily provided by an FPC member at a nominal rent amount paid by the FPC. The unit sits in a strategic location in Naherbari village, jointly identified by the farmers and the NGO, making it easily accessible to most farmers of the FPC, reducing transportation costs. The nearby market in Nalbari district is 8 km away, and middlemen often pick up farmers' crops from the village through the FPC, minimizing transportation costs and efforts for the farmers.

Financial model

The solar-powered irrigation systems at Baksa were funded through a co-financing model in which NABARD covered 80 percent of the system cost under its Tribal Development Programme, while the remaining 20 percent was supported by the NGO. The capital cost of the cold storage at Nalbari unit was Rs 14,00,000, fully funded as a grant by two technology partners. There was no financial contribution from the farmers. One FPC member voluntarily provided the land at the farm gate for installation of the cold storage unit, for a minimal rent. The model thus relied entirely on grant-based capital expenditure, with the intention that recurring operational expenses would be managed through a user-fee model.

Operations and maintenance

The VPC and the NGO have faced challenges in maintaining pump efficiency. There have been delays in technical servicing by vendors, and recurring issues, such as reduced water flow, have constrained full utilization of the pumps.

Though the cold storage unit had a multi-commodity horticultural product storage capacity, it was primarily used for storing potato seeds between March and November in 2021. The need for storing potato seeds emerged from the FPC members, who had to travel to other districts to purchase and store potato seeds. This is one of the limitations for the revenue stream and adds seasonal variability to the business model. Additionally, repeated technical issues such as prolonged cooling failures and delayed repair services have undermined farmer confidence, affecting utilization levels, thus impacting long-term viability.

One major setback reported was the loss of potato seeds worth ₹4-5 lakhs when the unit broke down, causing significant community losses and becoming a source for demotivation. This was later compensated by the vendor under the Annual Maintenance Contract. However, it revealed systemic gaps in technical reliability, service quality, and responsiveness—all critical to the success of such livelihood-linked infrastructure.

The FPC also handles operations and maintenance (O&M), covering costs by charging rental fees to users of the facility. These fees are for creating a self-sustaining O&M model. The cost of the unit was Rs 1,400,000 and was provided as a grant from two organizations: SELCO Foundation and Sustain Plus Energy Foundation.

Impact

In **Baksa,** the installation of nine solar irrigation pumps enabled over 70 smallholder farmers, many from tribal communities, to access year-round irrigation without recurring diesel costs. Collective management through Village Planning Committees (VPCs) fostered equitable access, women's participation, and pooling of resources for operations and maintenance. Farmers reported reduced input costs and greater cropping flexibility, though recurring technical issues and delayed servicing limited full utilization of the systems.

In Nalbari, a 10 MT solar cold storage unit has had limited success in creating new opportunities for small and marginal farmers for storing potatoes. Since its installation, the unit has faced technical issues with cooling and unreliable power. Furthermore, since it takes several days to make repairs, there have been many instance where produce worth lakhs have spoiled. While the FPC model provided collective ownership and market linkages, frequent breakdowns, lack of farmer investment in the asset, limited know-how of the technology, inadequate local capacity building, and restricted access to monitoring data have eroded farmer confidence and jeopardised long-term viability. The seasonal nature of potato storage also limits revenue recovery for operations and maintenance.

Role of relational dimensions in shaping livelihood opportunities and outcomes

The interventions underscore that building resilient livelihood systems depends critically on the relationships among farmers, FPCs, the NGO, and the technology providers. In Baksa, the VPCs became central to ensuring access to solar irrigation for all farmers, with farmers voluntarily providing land for pump installations and participating in collective decision-making on scheduling and fee collection. This shared responsibility fostered community trust and accountability, enabling even small and marginal farmers to benefit from year-round irrigation.

In Nalbari, the cold storage unit was implemented through an FPC, and the land was also contributed voluntarily by a member. While this reflects strong community willingness to support common infrastructure, the absence of direct farmer investment in the asset has created ownership gaps that affect the creation of livelihood assets for the community and thus long-term sustainability. Repeated technical failures and delayed servicing have further strained trust between farmers, the FPC, the NGO, and technology providers. Although the FPC has been proactive in managing operations and ensuring access, the lack of transparency—such as farmers not being able to access the remote monitoring system data—has limited their control and agency over the intervention. Technical challenges escalate O&M costs as well as capital loss and seasonal use, resulting in underutilization. As these costs rise, user fees alone can no longer cover them, putting the sustainability of the intervention at risk.

Both experiences underscore that building resilient livelihood systems depends not only on financing and technology but also on strengthening relationships among farmers, FPCs, NGOs, and technology providers. Ensuring timely vendor accountability, localized servicing, and greater farmer involvement in ownership and monitoring are critical to restoring confidence, improving outcomes, and sustaining collective models over the long term.

About the anchor organization

Gramya Vikash Mancha (GVM) is a non-profit working in rural Assam to empower marginalized communities, especially women, to lead social change and live with dignity. It promotes self-employment, social justice, and inclusion across Nalbari, Kamrup, Barpeta, and Baksa districts of Assam as well as the state of Tripura.

Case Study 2

Powering rural livelihood and value chain enterprises through mini-grids: NGO-led model in Gumla, Jharkhand

Livelihoods context

Ghaghra, Gumla, and Raidih blocks of the Gumla district in Jharkhand are inhabited primarily by indigenous population groups, predominantly by Oraon, Munda and Kharia tribes. The region located in the south-west of the state, the eastern plateau and hill region zone, is characterized by undulating terrain, rainfed agriculture, and fragmented landholdings. Agriculture remains the mainstay of Gumla's economy, dominated by rainfed paddy, maize, pulses, oilseeds, and vegetables, but productivity is low due to poor irrigation and limited market access. Electricity supply is erratic, with grid connections often unreliable and costly, especially for three-phase uses needed in machines and equipment. Due to the combination of weak agriculture infrastructure, crop storage challenges and other systemic constraints, low farm incomes and out-migration for work is prevalent. In this context, decentralized renewable energy (DRE) mini-grids provide an opportunity to energize enterprises, strengthen value chains, and support more resilient rural livelihoods.

This case study describes the intervention led by an NGO in the three blocks to improve reliable electricity sources and enhancing agricultural outcomes through mini-grids and value chain development. Based on needs assessment surveys with the communities, market surveys, and in-house research, the NGO identified promising value chains like paddy, mustard groundnut, and karanj for value addition in these blocks. Assessments for electricity availability and requirements were also conducted to understand the scope of innovation and mechanization.

About the technology intervention

By 2022, the NGO, in collaboration with a clean energy enterprise had installed solar mini-grids across 44 villages in the Gumla district of Jharkhand, with an average capacity of 25 kW (ranging up to 35 kW). These grids provide both single-phase and three-phase connections, serving domestic consumption and powering productive enterprises. A modular grid system based on solar power has been established, with diesel generator as a backup and peak management solution.

The NGO has also installed mustard oil expellers, groundnut decorticators, a karanj decorticator, solar-powered rice hullers, and pulverizers. Machines operate primarily during the day, reducing reliance on battery storage.

Implementation model

The NGO followed a value chain approach rather than standalone micro-enterprises, ensuring continuity from cultivation to processing and marketing. Before installations, needs assessments and discussions with entrepreneurs SHGs, village organizations, and cluster level federations were conducted to understand their requirements for training, finance, and market support. Farmers are equipped with business skills such as bookkeeping and profit calculation, and linked to buyers through established networks.

Collaborations with livelihood-focused NGO and the Jharkhand State Livelihoods Promotion Society (JSLPS) strengthened the model by providing quality seeds, capacity building, and farmer engagement. Village organizations, Self-Help Groups (SHGs), and Farmer Producer Organizations (FPOs) have been central to running enterprises, with the NGO providing handholding support in technology, compliance, and financial linkages.

Financial model

In March 2022, an oil expeller was installed and handed over to an SHG in one of the villages. The mustard oil enterprise, run by an SHG of 12 tribal women, availed a loan of ₹1,25,000 from HDFC Microfinance and collectively reinvested ₹38,000 of profits into loan repayment within the first six months. Similarly, the groundnut decorticator machine was financed through partial grant support from a donor organization, with capital contributions from the FPO, which took a loan.



Solar-powered mini grid in Gumla district, Jharkhand *Photo credit: Dheeraj Gupta | WRI India*

Operations and maintenance

Mini grids are managed with in-house repair teams, ensuring most faults are resolved within a day. Prepaid meters are used for billing, recharged by consumers through local grid operators. Load scheduling is practiced, balancing domestic and productive use, though challenges such as tripping due to overload and limited storage in older systems remain. Theft and damage from natural calamities are managed at the village level.

Entrepreneurs receive training in equipment use, business management, and compliance requirements such as food safety certification, which typically takes a month to secure. While mobile hulling and pulverizing units are emerging competitors, community-based enterprises powered by solar mini-grids offer lower costs and higher quality, sustaining local demand.

Impact

The NGO's interventions have strengthened local value chains and improved farmer incomes. In mustard cultivation, 900 acres in Ghaghra and 700 acres in Gumla and Raidih blocks were brought under cultivation. An SHG now operates a mustard oil expeller, procuring mustard at ₹58–62/kg, extracting one liter of oil from three kilograms of mustard, and selling oil at ₹20 per liter. By-products like mustard-cake are sold at ₹25–30/kg, adding to incomes.

Similarly, the groundnut and karanj decorticator enabled the FPO in Gumla to sell shelled groundnuts locally. Earlier, farmers incurred high costs in transporting groundnuts to Ranchi (about 100 kms away) for de-shelling. The FPO had sold about 2 quintals of groundnuts locally or to wholesalers during the time of the study and plans were underway to increase production and sales. Groundnuts, sourced locally with prices ranging between ₹50 to 60 per kilogram, undergo meticulous quality checks by the FPO before processing. Rice hullers and pulverizers have provided individual entrepreneurs with the ability to cater to local needs. These enterprises are cost-competitive against diesel and grid-powered alternatives, charging ₹1 per kg for hulling and ₹5 per kg for pulverizing, compared to ₹1.5 and ₹7, respectively.

Beyond income generation, access to reliable electricity and collective entrepreneurial opportunities has fostered ownership and confidence among SHGs and FPOs and has created peer leaders in the village.

However, higher tariffs than government supply, poor road connectivity, and market competition constrain growth. Productive load expansion is cost-intensive, and prepaid systems can be burdensome for households with low liquidity. Nevertheless, the model demonstrates that integrating renewable energy with value chain development has the potential to generate sustainable livelihoods.



Solar-powered mini grid in Gumla district, Jharkhand *Photo credit: Dheeraj Gupta | WRI India*

Role of relational dimensions in shaping livelihood opportunities and outcomes

The initiative builds local skills in enterprise management, compliance, and operations, while also strengthening collective institutions like SHGs and FPOs that support decision-making and access to finance. Through mini-grids and agricultural machines, communities gained dependable infrastructure, and by replacing diesel with solar power, they reduced environmental stress.

Linking cultivation with processing and marketing provides multiple income streams and reduces risks from seasonal shocks. The emphasis on community ownership has encouraged responsibility and resilience, though high tariffs, weak infrastructure, and limited storage for horticultural produce remains a challenges. The mini-grids remain formally owned by the NGO, which reduces the sense of full ownership at the community level. The case points to the need for stronger transition strategies and long-term planning to ensure sustainability.

About the anchor organization

Mlinda Charitable Trust (MCT) operates with a vision of leveraging diversity, equity, inclusion, and sustainability as drivers for economic development in rural areas. MCT's model revolves around community empowerment, with an emphasis on transitioning from direct management with handholding support to community-led enterprises. This case study explores MCT's interventions, primarily focusing on the value chain development approach spanning from cultivation to market access.

Case Study 3

NGO drives DRE and mini-grid installation to improve livelihoods of communities in Ranchi and Simdega, Jharkhand

Livelihoods context

Ranchi and Simdega districts in Jharkhand represent two important agricultural clusters with distinct challenges and are located within the Eastern Plateau and Hill Region agro-climatic zone. Bero block of Ranchi, is considered the vegetable hub of the state, cultivating crops such as peas, beans, cauliflower, chilies, cabbage, potatoes, and tomatoes. However, farmers struggle with irrigation due to irregular electricity and reliance on costly diesel pumps. Market access is another concern, as it lacks a government-regulated mandi with farmers selling produce to private vendors at low prices.

Simdega is one of the state's remote districts where electrification and basic infrastructure remain limited. Agriculture remains rainfed and dependent on traditional, high-cost diesel and kerosene pumps, while several habitations are yet to be electrified.

In such rural regions, an NGO has been working since 2015 to create meaningful livelihood opportunities for marginalized communities. Through tailored decentralized renewable energy (DRE) technologies, the NGO is helping rural populations transition toward self-sufficiency. This case study explores two interventions led by the NGO: solar-powered irrigation in Hulsi village in Bero block of Ranchi district and mini-grid solution powering households in Tangertoli, a remote hamlet in Kersai block of Simdega district.

About the technology intervention

In the Potpoto river of Hulsi village of Bedo, a 5 HP solar pump draws water year-round, supplemented by the Bori Bandh (sand dam) method during dry spells. Installed in March 2022, the pump is equipped with a 5-kW solar panel and a Universal Solar Pump Controller. The pump delivers water to a storage pond during excess, irrigating 3-4 acres daily and up to 20 acres total. The system includes an RMS for performance tracking and a lightning arrestor for durability, operating 6–8 hours daily without battery backup.

In Tangertoli, Simdega, the NGO established a 21-kW solar mini grid in July 2022. This provides electricity to 67 households and some productive-use applications. The NGO, with the support of a technical partner, has designed the mini grid to power household lighting, 10 irrigation pumps (each 0.5 HP), one rice huller, and one huller with pulverizer (3 HP capacity). Each irrigation pump can irrigate approximately 0.4 acres of land, the rice huller processes up to 1.5 quintals of paddy, and the pulverizer's usage is driven by demand.

Implementation model

The NGO collaborates with local communities to implement these interventions. It conducted awareness campaigns to overcome initial skepticism about solar technology, emphasizing reduced costs and time savings. In Hulsi, a water-user group of 13 volunteering farmers (men and women), having land in the vicinity of the sand dam, collectively manages the solar pump, with the NGO providing technical training for O&M. Farmers sell their produce at Bero market, located 10 km away, through private vendors who often offer low prices.

In Tangertoli (Simdega), a Village Electrification Committee (VEC) of eight members, including an operator trained by the technical partner, oversees the mini-grid. The VEC, consists of both men and women and is constituted with the approval of the Gram Sabha. The VEC schedules machine-use timings (e.g., irrigation pumps to be used between 8 AM–10 AM and huller between 10 AM–2 PM). These timings are flexible to prevent tripping due to farmers using the machines at the same time. VEC collects payments monthly, which are saved in a bank account created for VEC. The rice huller has reduced reliance on diesel-powered mobile hullers, though their use persists due to their mobility, as they are tractor-mounted and offer significantly higher processing capacity.

Financial model

The solar pump in Hulsi, costing approximately ₹7-8 lakh, was fully funded by a grant through the NGO. The water-users' group charges ₹20 per month per member for maintenance, with plans to introduce a ₹20 per hour irrigation fee to sustain O&M. Increased cultivation area enhanced farmer incomes by 30-40 percent, with farmers earning ₹12,000 to ₹15,000 monthly from vegetable sales (e.g., tomatoes, chillies).

In Tangertoli, the mini-grid's installation cost (estimated ₹10-12 lakh) was also grant-funded. Each household pays ₹100 per month fixed charges plus ₹10 per unit of electricity consumed. The VEC has saved ₹2 lakh from the rent collection since August 2022, in their bank account for O&M and potential grid expansion.



Solar-powered irrigation pump in Tangartoli, Simdega district, Jharkhand *Photo credit: Dheeraj Gupta | WRI India*

Operations and maintenance

Both systems are operated and maintained by the user groups or local resource persons. In Hulsi, the water user group handles operations, while the NGO supports repair and troubleshooting till the time of the study. In Tangertoli, a trained village operator oversees the mini-grid, records meter readings, and handles minor faults such as replacing meters. There have been a few technical breakdowns and operational challenges with both systems. Opening multiple valves at once reduces water flow.

In Tangertoli, the grid occasionally trips when multiple processing units operate simultaneously. Also, power generation is reduced during cloudy seasons.

Impact

The solar pump in Hulsi now supports irrigation for up to 20 acres of land and enables year-round vegetable cultivation. Farmers report a doubling of area under cultivation and improved productivity. The presence of consistent irrigation allows farmers to plan multiple crop cycles and shift to more lucrative vegetable farming. In Tangertoli, electricity has reached its inhabitants for the very first time. The villagers no longer need to travel 15–20 km for rice or wheat processing. The rice huller has reduced reliance on diesel-powered mobile hullers, though their use persists as they are tractor-mounted thus mobile, and offer significantly higher processing capacity. The mini-grid powers machines locally, reducing effort and costs. Households use solar energy for both domestic and agricultural needs. There are plans to further expand services to include an oil expeller and photocopy center

Role of relational dimensions in shaping livelihood opportunities and outcomes

The NGO's interventions in Hulsi (Ranchi) and Tangertoli (Simdega) in Jharkhand demonstrate how DRE can serve as a powerful enabler of rural livelihood transformation when combined with building and strengthening local institutions, community ownership and local capacity-building. The NGO's exploration of partnerships with Jharkhand State Livelihoods Promotion Society (JSLPS) aims to secure additional funding for scaling, ensuring long-term sustainability. In both cases, the NGO has played a critical role in mobilizing the community, forming inclusive user groups, and ensuring transparent and participatory governance structures such as water user groups and VECs which has the mandate from larger community institution, the Gram Sabha. These institutions not only manage infrastructure but also build trust, ownership, and long-term sustainability.

Households contribute financially through

user fees and shared maintenance funds which reflects both economic value creation and growing local self-reliance. The nature of usage and access of these technological interventions and questions such as who benefits more, who takes the decisions and other power dimensions further needs to be studied. Initial technical challenges like pump inefficiencies and mini grid tripping emerged, communities were trained to troubleshoot and adapt usage patterns to seasonal needs. Both interventions integrate women, who participate in farming and agro-processing, though their role in technical O&M remains limited.

About the anchor organization

Transform Rural India (TRI), is a non-profit organization committed to enabling inclusive and sustainable development in India's most under-served rural geographies. TRI works across health, education, livelihoods, governance, and gender inclusion by partnering with communities, public systems, and markets. Operating in over 20,000 villages across 42 districts in 8 states, it aligns closely with government programs like NRLM and Aspirational Districts.



Solar panels powering the irrigation pumps in Simdega, Jharkhand *Photo credit: Dheeraj Gupta | WRI India*

Case Study 4

NGO-driven DRE installations to strengthen local agriculture value chain in Khunti, Jharkhand

Livelihoods context

Khunti district in Jharkhand, just 40 km from the state capital Ranchi, falls in the Eastern Plateau and Hill agro-climatic zone, and is inhabited predominantly by Munda tribal communities engaged in small-scale farming, livestock rearing, and the collection of minor forest produce. Despite the wealth of natural resources, the region has long grappled with poverty and limited access to basic agricultural infrastructure, especially for irrigation, storage, value addition, market linkages, and other mechanization. This gap is exacerbated by the unreliability of grid electricity, which continues to hinder rural productivity and livelihoods.

This case study highlights the interventions of an NGO working in the Murhu and Khunti blocks of Jharkhand since 1994. In 2015, the NGO led the implementation of 'The Lakhpati Kisan' program, designed by CINI and Tata Trusts, to address critical gaps across the agriculture and non-timber forest produce (NTFP) value chains. Through partnerships with the state government, other NGOs, and enterprises, the intervention focuses on integrating decentralized renewable energy (DRE) into various stages of agriculture value chains, including irrigation, cold storage, and forest-based livelihoods like lac cultivation.

This value-chain approach was aimed at improving agricultural productivity and reducing dependence of farmers on diesel-based systems, and at the same time, enhancing income security and resilience to climate change for farmers in the region.

About the technology intervention

A set of DRE-enabled livelihood technologies was designed to meet agricultural needs in an area with unreliable electricity. For irrigation, the NGO has facilitated the installation of 126 solar-powered lift irrigation systems with capacities ranging from 3 HP for seepage wells and ponds to 5 HP along riverbanks, each powered by 3–5 kW solar panels with Universal Solar Pump Controllers and lightning arrestors. The units use 110 mm diameter PVC pipes to carry the water to the distribution outlets, after which plastic distribution pipes are used. These units irrigate 2–3 acres daily, covering 100 villages, and operate 6–8 hours daily. These systems do not have a battery backup. A Remote Monitoring System (RMS) is installed to enable real-time tracking and management of pump performance.

For post-harvest handling of crops, a 5 MT solar-powered cold storage unit developed by Ecofrost and supported through a philanthropic organization was established at the Khunti Agriculture Department campus in 2019. It is primarily used for storing crops like tomatoes, peas, drumsticks, and mangoes. The unit

maintains a temperature range of 2–13°C, with adjustable humidity via a mobile application. It retains temperature for 36 hours during power outages. Additionally, 43 solar-powered lac pruners[5], battery operated for 1-hour cycles, facilitate efficient lac harvesting on Ber and Palash trees, replacing traditional axes.

Implementation model

The NGO's implementation approach follows a value chain model and is engaged with the community through FPO/FPC to strengthen backward and forward farm linkages to community-based institutions, i.e. SHGs, PGs, and FPCs, and to enable women to take the lead in transforming agricultural systems.

The NGO collaborates with women-led Murhu Nari Shakti FPC (registered in 2018) to implement the intervention. Water user groups comprising 6 to 10 members manage LI units, selected based on land proximity and SHG recommendations, ensuring equitable water access. The NGO provides training for operation and maintenance.

The FPC operates cold storage, managing crop collection through PGs, market identification, and transport. Market linkages through National Agriculture Market (e-NAM) and Mother Dairy enable the sale of sweet corn, peas, and jackfruit, though private commission agents pose challenges. Other livelihood components, such as animal husbandry, are supported through decentralized infrastructure like solar lighting and portable vaccine carriers.

Champion farmers rent out lac pruners to other farmers at ₹100 per day.

Financial model

The lift irrigation systems are largely funded through grants from a philanthropic organization. Farmers contributed about 30 percent toward accessory costs like piping, fencing, and labour. Extended Annual Maintenance Contracts (AMCs) for technical servicing were ensured through a technical partner. The philanthropic organization facilitated insurance coverage for 2,500 lift irrigation systems cumulatively from its different sites. The units are owned and operated by WUGs, charging individual farmers ₹50 per hour for irrigation.

The cold storage unit is fully grant-funded. The philanthropic organization contributes 80 percent and another non-profit organization providing technical support covers the remaining 20 percent.

For Kharif of 2023, storage averaged 678 kg (max 4,320 kg). The facility is now operated by the FPC using a margin-based model, where a 0.5–1 percent margin is added to the production by FPC. This has helped eliminate direct rental charges and made the model more viable. The FPO has matured into one of the top-ranking entities under the Jharkhand State Livelihoods Promotion Society (JSLPS), boasting an impressive turnover of ₹4.58 crore with profits of
22.7 lakh.

For lac pruners, the capital cost was borne through project grants. Farmers generate income by renting pruners to other farmers, while the responsibility of maintenance lies with the tool-holding champion farmer.

Operations and maintenance

DRE systems are locally managed to promote sustainability with the combined efforts of the NGO and FPC. Water User Groups are responsible for maintaining the LI systems, and AMCs ensure vendor support for technical issues. Cold storage operations are monitored through a Monitoring Information System (MIS) system, although access to the RMS remains limited. Security challenges such as solar panel theft, damage to door handle and stone pelting of panel at cold storage persist. Additionally, there is absence of theft insurance.

Impact

The intervention has created livelihood opportunities for 6,000 households in Khunti, expanding irrigation to 30 percent of lands during Rabi and summer seasons, doubling cultivation areas, and enabling the cultivation of high-value crops like cabbage, peas, and watermelon. Cold storage has reportedly extended shelf life and reduced post-harvest losses by 30–45 percent for vegetables. Lac pruners streamline harvesting and boost incomes by ₹2,000 to ₹3,000 monthly for champion farmers. Women's roles in SHGs and FPCs have enhanced agency. The market links to Mother Dairy have ensured better prices for products such as sweet corn and peas. Solar technologies have cut diesel costs from ₹700 to ₹500 per month per farmer, promoting environmental sustainability. Despite challenges like theft and cold storage inefficiencies, the intervention fosters resilient, market-oriented livelihoods, with farmers achieving annual incomes of ₹1.2 to ₹1.6 lakh.



Solar-powered cold storage unit in Khunti district, Jharkhand

Photo credit: Amit Kumar | WRI India

Role of relational dimensions in shaping livelihood opportunities and outcomes

A central innovation has been the establishment of 126 solar-powered lift irrigation (LI) systems in Khunti and Murhu blocks of Jharkhand, where water user groups contribute to installation and manage operations. These systems have expanded the cultivable area across seasons, enabling multi-cropping of vegetables and promoting the cultivation of Flemingia semialata (commonly known as Winged-Stalk Flemingia in English, its local name include Bara solpan and Ban chola in Hindi and Chandan chabuk in Bengali) trees to support lac production. Similarly, the establishment of cold storage facilities, operated by FPCs, offers infrastructure for preserving perishable produce and adapting to fluctuating market prices; however, utilization remains a challenge due to technical constraints and low scale of aggregation. Small-scale farmers are often unable to commit to producing specific quantities of crops regularly, and cold storage in such complex contexts might need more careful consideration of what will work best.

What sets this intervention apart is the centrality of community institutions, SHGs, PGs, and FPCs across planning, implementation, and governance. These women-led platforms are not only driving the adoption of technology but also anchoring financial management, maintenance, and market engagement. The intervention has enabled access to schemes like PM-KUSUM and e-NAM, GIS-based micro-planning for aggregation, and linkages with bulk buyers like Mother Dairy. Improved irrigation facilities have made many farmers shift from traditional paddy-based farming to vegetables, pulses, lac, and fruits, contributing to increased incomes and resilience. Despite these gains, the intervention faces hurdles such as theft of solar panels and insurance gaps. The intervention also highlights inequities in access due to upfront investment requirements and persistent market barriers like commission agents.

About the anchor organization

Nav Bharat Jagriti Kendra (NBJK), is a grassroots nonprofit organization founded in 1971 in Bihar (now Jharkhand), committed to empowering rural communities through holistic development. It works across sectors like health, education, livelihoods, disability inclusion, and governance with a strong focus on marginalized populations. NBJK combines community-based approaches with institutional partnerships to drive sustainable and inclusive change across eastern India.

Case Study 5

Enterprise-led Farming-as-a-Service model powering irrigation and cold storage in Bahraich, Uttar Pradesh

Livelihoods context

Paragiproha, a remote agrarian village in Nanpara block, Bahraich, Uttar Pradesh is located in the middle Gangetic plain agro-climatic zone, is home to 80 households primarily dependent on farming for their livelihood. Farmers cultivate paddy in Kharif, maize, wheat, and beans in Rabi, and hybrid maize in Zaid season. The community faces critical livelihood constraints due to limited irrigation facilities for farming, making them dependent on costly diesel pumps for irrigation. Farmers also experience low returns on their traditional crops, driving and increasing youth migration due to a lack of income opportunities in agriculture.

In this setting, a Farming-as-a-Service (FaaS) company introduced solar-powered irrigation, cold storage, and agro-processing solutions aimed at improving productivity, reducing drudgery and crop spoilage, lowering costs, and enabling income generation. Their model is based on pay-per-use clean energy services, where farmers pay for the service each time they use it, while the capital costs and operations & maintenance are borne by the company.
This removes the upfront technology acquisition cost barrier for these products. The company also offers Climate-smart Farm Advisory to train farmers on modern scientific agronomic techniques, aimed at boosting farmers' yield and incomes. Farmers receive training on crop diversification, precise application of inputs, adaptation to climate stresses, and sustainable farming techniques.

About the technology intervention

Irrigation: In 2022, the company installed eight solar pumps in Paragiproha, forming four irrigation paired units serving groups of 15 farmers, each within a 400-meter radius.

Agro-Processing: The irrigation water is sold at fixed tariffs that are 20–60% cheaper than traditional diesel-powered pumps, offering immediate cost savings for low-income farmers. The company offers a pay-per-use solar-powered service for agro-processing called "Oojjwal". Customers are charged per kilogram of produce processed at tariffs that are 25 percent lower than existing market rates. It installs pulverizers for flour milling or spice grinding and other agro-processing appliances that are physically connected to the solar water pumps described above and run off the same solar PV generation system. The pulverizer runs when the solar pumps are not operational, by diverting the solar power generated by the pump PV panels, without the need for additional PV capacity. This secondary service increases the energy and capacity utilization of the system, reduces the payback period, and strengthens economic viability. For every 3 irrigation units, 1 pulverizer has been installed. A pulverizer can grind 80 kg of wheat or 40 kg of maize per day.

Cold Storage: The company set up a 5 MT solar-powered cold storage at the farm gate in Bahraich in 2022 to minimize post-harvest losses, enhance food security, and increase farmers' incomes.



Ground-mounted solar panels powering farm-based livelihood technologies in Bahraich, Uttar Pradesh

Photo credit: Amit Kumar | WRI India

Implementation model

The FaaS company identifies diesel-dependent sites through community consultations and needs assessments and then sets up solar irrigation systems with ongoing technical support and maintenance. The assets are installed across 1-5 km of farmland, supported by a local field team. The 5 HP solar pumps are situated near the farmland, identified through thorough demand assessments and technical audits. Groups of 15-20 small and marginal farmers with adjoining land farmers can access irrigation services by becoming members, paying a one-time joining fee of ₹1,000, along with usage-based charges which are based on the cubic meters of water discharged. Typically, the landowner who hosts the system is appointed as the operator. In return, they receive a fixed monthly honorarium and a commission on service fee collections, as well as rent for the use of their land.

To address post-harvest losses, the FaaS company installed solar-powered cold storage units for horticultural produce, targeting small and marginal farmers as well as petty traders. At the site visited, the cold store was initially established at the farm gate with a group of 20 farmers. However, due to low utilization, it was later relocated to the local mandi, where 20 traders became members and ensured higher capacity use. To formalize participation, each member paid a one-time fee of ₹1,000 to access storage services.

Financial model

For irrigation services, the company adopted a membership-based model, requiring farmers to pay a one-time joining fee of ₹1,000, along with usage-based charges of ₹4 per unit of water consumed. The cold storage service followed a pay-per-use model, where farmers were charged on a per-day, per-crate basis. The initial pricing ranged from ₹10–20 per kilogram for crate capacities of 10, 15, and 20 kg. To improve utilization, this was later revised to ₹5, ₹7.5, and ₹10 per crate, with seasonal promotional offers introduced to attract more users. For agro-processing services, farmers paid ₹2 per kilogram, while the operator received a 30 percent commission. Although the agro-processing facility saw lower usage during the summer, it continued to provide the operator with supplemental income and convenient local processing options

Operations and maintenance

The company handles the operations and maintenance of the solar assets to ensure longevity of their 15-20-year lifespan. For lean operations, the company adopts a cluster approach, with each cluster consisting of 4 solar pumps and 2 agro-processing units. Two operators from the local community manage each cluster, while every 10 clusters are supported by one solar technician and one customer success team. This structure creates local employment while ensuring efficient operations. It enables timely payment collection, servicing, and maintenance to minimize downtime, and continuous customer feedback to improve performance. The company manages regular repairs, provides quick resolution of technical issues, and relies on a small, multi-skilled field operations team to deliver reliable after-sales service.

Impact

The interventions demonstrate impact across the agricultural value chain. At the production stage, solar irrigation coupled with Climate-Smart Farmer Advisory coupled with Climate-Smart Farmer Advisory systems enabled farmers to shift from wheat to hybrid maize, a higher-value cash crop, with yields improving to 10 quintals per bigha compared to 3–4 quintals for wheat. The switch from diesel to solar also reduced irrigation costs from ₹700 to ₹600 per bigha, making cultivation consistently profitable, even though farmers sold slightly below the MSP at ₹2,200 per quintal. Their approach lowers input costs, increases irrigation access, and reduces reliance on diesel and chemical inputs—bringing greater financial and operational efficiency to farming. Despite these gains, youth migration persists, driven by the pull of stable daily wages in cities over seasonal farm incomes.

Moving to the post-harvest stage, agro-processing services such as local grain and spice grinding reduced travel burdens and improved access, but limited and seasonal demand constrained utilization, leaving machine operator incomes low. This highlighted the importance of bundling services and stimulating demand to ensure economic viability and scaling potential.

Together, these outcomes illustrate that while solar interventions enhance productivity and reduce costs, long-term success requires robust financial planning, stronger market linkages, and deeper engagement with users across the entire value chain.



Oorja's solar pumps are managed by a locally hired Operator who takes care of the day-to-day operations, service issues and collections. Operators are supported by a network of Customer Success Officers and engineers.

Photo credit: Soumya Khandelwal | Acumen

Role of relational dimensions in shaping livelihood opportunities and outcomes

The FaaS company interventions illustrate how relational dynamics shape livelihood opportunities and outcomes. The pay-per-use solar irrigation model reduces entry barriers for small and marginal farmers, offering a more inclusive alternative to diesel pumps by lowering costs and enhancing productivity. In the integrated agro-processing services, the model enhances solar energy utilization, shortens payback periods, strengthens financial viability, and contributes to rural infrastructure development. The cold storage intervention revealed gaps in product-market fit. Despite tailored pricing and relocation efforts, low and irregular utilization reflected systemic constraints such as fragmented production, technical breakdowns, risk aversion, and behavioral biases, and farmer perceptions of high cost. Seasonal demand variation, inability to get a grid connection, reliability challenges, and competition from larger cold storage units added to the challenges facing the unit. Even after relocation and tariff revisions, several units had to shut down, mirroring similar experiences in Bihar's Samastipur and Muzaffarpur districts.

These cases suggest that while irrigation and agro-processing services hold strong potential for scaling—especially if supported with procurement linkages, community co-design, and bundled services—cold storage viability is more likely through aggregator-led or institutional models that stabilize demand and balance risks for farmers or petty traders.

About the anchor organization

Oorja Development Solutions Limited is a farming-as-a-service company that works at the intersection of sustainable agriculture and clean energy. Oorja provides solar-powered irrigation and climate-smart farmer advisory services to smallholder farmers in India. They have championed the pay-per-use model that removes the upfront cost barrier for low-income farmers, making solar technology accessible to the last farmer in the line.

Case Study 6

NGO-led cold storage and milk chiller initiative through dairy cooperative in Bikaner, Rajasthan

Livelihoods context

In the hyper-arid landscapes of Bajju village, located 100 km west of Bikaner in Rajasthan's and falls under the Hyper-Arid Partly Irrigated Western Plain Zone. In this region camel herders and smallholder farmers face challenges preserving milk due to extreme temperatures and limited infrastructure. An NGO operating in the area since 1994 introduced a solar-powered dairy ecosystem through women-led cooperatives to enhance milk quality and reduce post-harvest losses in the dairy value chain. This case study highlights the NGO's efforts to foster self-reliance among camel herders and dairy farmers, particularly women, through DRE solutions, promoting sustainable livelihoods in Rajasthan's arid agro-climatic zone.

About the technology intervention

In October 2021, the NGO installed a 10 MT thermal storage-based cold storage unit at its Bajju site, supplied by Inficold Private Limited. Powered by solar panels and grid electricity, it features thermal energy storage for rapid cooling and power redundancy, maintaining milk quality during outages for up to 36 hours. It runs on a hybrid system powered by the grid and a 6 kW solar panel setup with tubular batteries (150Ah).

In November 2022, a Milko Chill Instant Milk Chiller (IMC), provided by Prompt Dairy Technology, was installed in the Bajju village chilling 500 liters per session using solar and grid power. The chiller played a vital role in maintaining the quality of camel and cow milk, crucial for the local dairy economy.

Both systems ensure low power consumption and compliance with food safety standards, preserving camel and cow milk for extended shelf life. The system is fitted with an RMS and includes surge protection, ensuring system reliability under fluctuating temperatures.



Solar panels powering a milk chiller unit in Bikaner, Rajasthan *Photo credit: Namrata Ginoya | WRI India*

Implementation model

The NGO runs the initiative through a cooperative. Farmers who volunteer to join contribute a nominal initial capital to become members. The technologies were conceptualized by the Desert Resource Centeri (DRC) to address the challenges of preserving dairy products in the region's extreme climatic conditions.

Site selections followed a milk feasibility survey, ensuring proximity to dairy farms, minimizing transport costs. The cold storage and chiller, owned by the NGO, are operated by a paid dairy head, with community members, primarily women herders, contributing 30 percent of installation costs upfront or in installments. The NGO provides training for operation and maintenance, with an in-house electrician troubleshooting issues via video calls with Inficold or Prompt engineers.

Financial model

The IMC system costs approximately ₹6.5 lakh, and the cold storage unit costs around ₹20 lakh. Funding is mobilized through a mix of organizational and community contributions, with farmers contributing 15–30 percent of the capital cost. No government subsidies or external grants have been availed. Both systems follow a pay-per-use model. Milk is collected and chilled at the IMC before being transported to the NGO's bulk chiller units using steel cans. The operations are supported by a small logistics team, with transportation costs averaging ₹2.3 per liter. A pay-per-use model charges ₹0.5 per liter for chilling and ₹1.5 per liter for instant chilling. Cold storage is primarily used for cow and camel milk, which is collected from farmers at ₹30–42 per liter and sold at ₹50 per liter. Milk is marketed under the "Bahula" brand, sold via Urmul Dairy to local and larger markets.

Revenue from operations sustains basic O&M and repair costs, which cost ₹3,000 to ₹5,000 per quarterly vendor visit. The NGO procures cow milk at ₹35–42 per liter and camel milk at ₹30 to ₹40 per liter based on fat content, selling at ₹50 per liter, yielding a 20 to 40 percent profit margin for farmers. This increases the annual income of herders from ₹50,000 to ₹70,000 from milk sales. Transport costs of ₹2.3 per liter via steel cans are managed by the NGO's Bahula brand.

Operations and maintenance

The systems are maintained through a mix of vendor support and in-house troubleshooting. The IMC is equipped with an RMS that sends performance data to the vendor. When warranty coverage expires, the NGO's in-house electrician often coordinates with vendor engineers via video calls to resolve minor issues. The cold storage operates daily, storing around 1000 cubic feet of produce, with issues typically addressed within 2 days.

Impact

The intervention has extended the shelf life of camel and cow milk, allowing the NGO to offer consistent, high-quality dairy products in the market. The NGO reports an increase in the income of women herders, which were the primary users and the procured milk were marketed under the brand name Bahula. By improving collection logistics, reducing spoilage, and ensuring timely chilling, the NGO has added value for both producers and end-consumers. Revenue from chilled milk sales, cheese sales, and daily operations supports local livelihoods and feeds back into system upkeep. The NGO plans to expand the initiative to a neighboring village and establish collection centers to enhance financial sustainability. Partnerships with the state animal husbandry department were underway during the time of the study.

Role of relational dimensions in shaping livelihood opportunities and outcomes

The model is anchored through a cooperative wherein the farmers contribute 30 percent of the capital either upfront or through EMIs and are minimally involved in O&M. The NGO manages the technology and operations, and daily operations are overseen by a dairy head appointed by the NGO. The NGO is deeply embedded in the socio-economic milieu of the region, and the intervention has been designed in a participatory manner. However, the physical infrastructure is owned by the NGO, highlighting the limited asset-building potential of this intervention for the cooperative farmers.

Livelihood outcomes have been promising, and farmers have reported increased incomes, and the sale of milk under the "Bahula" brand has created a reliable market. However, long-term sustainability is challenged by post-



Instant milk chilling machine in Bikaner, Rajasthan *Photo credit: Namrata Ginoya | WRI India*

warranty high maintenance costs and limited evidence of women's active ownership or leadership in managing the units. Despite these gaps, the initiative demonstrates a scalable example of how a nominal pay-per-use model enables resource-constrained farmers to access technology. It also illustrates the potential of DRE to transform rural value chains in challenging agro-climatic zones by expanding livelihood opportunities.

About the anchor organization

Urmul Seemant Samiti, established in 1994, is an NGO dedicated to empowering rural communities in Bikaner and Jaisalmer, Rajasthan, through innovative, localized solutions. Operating in the hyper-arid western plain region, Urmul promotes dairy, agriculture, and health initiatives, emphasizing women's leadership via cooperatives. In Bajju, Urmul's solar-powered cold storage and milk chilling intervention, supported by the Desert Resource Center, enhances dairy livelihoods for camel herders. With plans to expand to Cheemana and strengthen market linkages, Urmul drives sustainable development.

Conclusion

The case studies demonstrate that PURE interventions have the potential to transform rural livelihoods by strengthening multiple forms of livelihood. A common thread across all cases is that clean energy solutions not only reduced dependence on costly fossil fuels but also created essential infrastructure in underserved rural areas. This infrastructure is particularly impactful through technological interventions such as solar irrigation pumps and agro-processing—including solar dryers, rice mills, oil expellers, groundnut decorticator or papad-making machines. These PURE applications enabled year-round cultivation, lowered irrigation costs, diversified crop production, improved farm productivity, reduced farmers' drudgery, and created livelihood opportunities.

However, the impact of PURE interventions was not uniform or automatically scalable across the case studies. Their success depended heavily on the socio-economic contexts and the enabling ecosystem surrounding the technology and the intended scale and design of the systems. For example, individual entrepreneurs who served only local markets typically had systems sized for small-scale production, with single-phase machinery installed accordingly. With limited access to assured markets or robust input supply chains, and little focus on scaling operations, such interventions tended to remain at a subsistence level. By contrast, collectives were better positioned to operate at larger scales where institutional mechanisms such as buy-back schemes were present and technology adoption proved far more effective. These arrangements not only secured markets for produce but also gave collectives greater incentive to invest in and sustain the technology over time. Challenges regarding equitable benefit sharing among the collectives remained at an early stage or minimal.

The case studies also highlight that technology alone is insufficient. Anchor organizations implementing PURE solutions typically cover the capital expenditure for technology and installation but often underestimate the recurring costs of operation and O&M post-installation. Yet, support for O&M is critical both to enable farmers to adopt such solutions and to ensure the long-term sustainability of interventions. Interventions with O&M integrated into their design reported improved adoption and functioning. Sustained impact requires not just reliable after-sales service, but also farmer awareness of warranties and AMCs, along with institutional

linkages to markets, certifications. In their absence, even high-potential assets like cold storage risk underutilization, loss of trust, and eventual financial unsustainability. Additionally, environmental considerations, such as groundwater depletion risks in irrigation, need to be integrated into the design process. In majority of the case studies, we found limited integration with government schemes or institutional support, which restricts the intervention's alignment with broader rural development goals.

We have provided detailed key considerations for policymakers, technology providers, anchor institutions, and financial entities in the accompanying report "Lifting all boats: Productive use of renewable energy for sustainable livelihoods in India.", which can serve as a guide for translating these learnings into actionable strategies.

Overall, the cross-cutting lesson is that scaling PURE for livelihoods requires more than deploying technologies—it calls for holistic models rooted in local context, with community ownership, diversified revenue streams, and strong institutional and market connections. By embedding renewable energy into the social and economic fabric of rural communities, such interventions can build resilient, inclusive, and sustainable pathways for rural development. The cases, therefore, underscore that while PURE technologies can catalyze significant change, their transformative potential is realized only when paired with robust market linkages, institutional support, and ecosystem-level interventions.

While this compendium offers valuable insights, it is not exhaustive. Further evidence, particularly from diverse geographies and direct end-user perspectives, is essential to capture the full picture. Future work could deepen field-based research, strengthen market and institutional linkages, and explore innovative financing models through collaborations with practitioners, financiers, and policymakers.

Looking ahead, the opportunity lies in scaling sustainable and context-specific PURE solutions that foster equitable participation, especially of women and collectives, while embedding strong partnerships across the ecosystem. By engaging with these learnings and contributing to the next phase, stakeholders can help unlock the full potential of renewable energy in transforming agriculture and allied livelihoods.

Appendix:

Endnotes

1 Anchor institutions refer to entities or individuals that conceptualize or drive the implementation of PURE interventions on the ground. These institutions include, but not limited to, enterprises, individual farmers, farmer groups, non-governmental organizations (NGOs) and government agencies.

2 Joint Liability Group is an informal group comprising of 4-10 individuals coming together for the purpose of availing a bank loan for solar pump irrigation against a mutual guarantee. In this, the JLG group is responsible to pay the bank EMI based on their land holding and water usage.

3 A katha (or khata) is a traditional unit of land measurement used in India, but its value varies significantly by region. It is not an SI (International System of Units) standard. For example, 1 katha can be approximately 1361 square feet in Bihar, or 720 square feet in Kolkata. Understanding the specific regional definition is crucial for land transactions.

4 Line irrigation is a method where water is supplied through defined rows or pipes laid across the field. It can take the form of furrows, drip lines, or sprinkler laterals, ensuring controlled delivery of water directly to crops rather than flooding the entire field.

5 Lac Pruner

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