POWERING RURAL TRANSFORMATION

How decentralized solar is reshaping livelihoods in India

21 CASE STUDIES FROM 5 STATES

ON THE COVER

A solar mini-grid embedded in the farmlands of Burhibir village in Jharkhand marks a quiet shift in rural development. Once constrained by unreliable electricity and subsistence livelihoods despite its proximity to district centres, the village adopted an enterprise-oriented solar power model that prioritised productive use over household lighting alone. By linking decentralized renewable energy with local entrepreneurship, shared governance, and partial risk-sharing, electricity became an economic asset—supporting skills, retaining youth, empowering women, and translating rural potential into sustained economic activity.

PHOTO COURTESY: BINIT DAS, CSE

POWERING RURAL TRANSFORMATION

How decentralized solar is reshaping livelihoods in India

21 CASE STUDIES FROM 5 STATES

Research Direction: Nivit Yadav

Author: Binit Das

Research support: Sayantika Mondal, Aashawari Das

Editor: Rituparna Sengupta

Cover: Ajit Bajaj

Production: Rakesh Shrivastava and Gundhar Das

The Centre for Science and Environment is grateful to Bread for the World (BfW) for their support.

The Centre for Science and Environment is grateful to the Swedish International Development Cooperation Agency (Sida) for their institutional support

Maps in this report are indicative and not to scale.

Citation: Binit Das 2026. *Powering Rural Transformation: How decentralized solar is reshaping livelihoods in India*. Centre for Science and Environment, New Delhi

Published by
Centre for Science and Environment
41, Tughlakabad Institutional Area
New Delhi 110062
Phones: 91-11-40616000
E-mail: cse@cseindia.org
Website: www.cseindia.org

CONTENTS

INTRODUCTION

1. RURAL ENERGY CHALLENGES

India achieved 100 per cent village electrification in 2018, but this milestone was limited in scope, requiring only 10 per cent household connections per village. Many rural areas continue to face unreliable electricity with frequent power cuts and weak infrastructure. Conventional grid extension remains economically unviable in remote, sparsely populated regions due to high operational costs and transmission losses.

2. DECENTRALIZED RENEWABLE ENERGY (DRE) SOLUTIONS

Solar costs dropped over 85 per cent between 2010–2020, making DRE systems like solar mini-grids increasingly viable. These solutions provide localized power generation that supports productive enterprises and income-generating activities beyond basic household lighting.

3. DEMONSTRATED IMPACT

Successful implementations show significant benefits: a solar mini-grid in Gumla reduced welding unit costs by two-thirds; women entrepreneurs doubled their output with solar-powered equipment; solar irrigation freed farmers from expensive diesel systems.

4. CRITICAL SUCCESS FACTORS

Community ownership,particularly through women-led collectives, ensures system sustainability. Technical training, flexible payment models, and advances in battery and monitoring technology have improved reliability and reduced costs.

5. REMAINING CHALLENGES

Policy gaps persist in integration with rural development programs, technical standards, and financing access. However, falling costs and demonstrated livelihood benefits create strong conditions for scaling DRE across India.

PHOTO COURTESY: BINIT DAS, CSE

Rural habitations where limited infrastructure shapes everyday energy choices and economic activity

THE CHALLENGE OF RURAL ENERGY POVERTY

Despite India's significant economic growth and technological advancement over the past decades, millions of rural households and enterprises continue to experience energy poverty. This fundamental constraint limits economic opportunities, restricts educational advancement and reinforces patterns of underdevelopment. The absence of reliable energy has curtailed productivity and economic diversification across large parts of rural India.

The country's achievement of 100 per cent village electrification in 2018 under the Saubhagya scheme marked a milestone, but the benchmark itself, which required connections for only 10 per cent of households in a village, exposed the limitations of this measure. A large number of households remained either unconnected or dependent on unreliable electricity supply, characterized by frequent power cuts, voltage fluctuations and weak distribution infrastructure. For rural entrepreneurs and small enterprises, this unreliable access to power has been a major obstacle to economic growth and service delivery.

Expanding electrification through conventional grid extension has proved difficult in many parts of rural India. Extending transmission lines to sparsely populated regions or remote areas with complex terrain has remained economically unviable. The operational costs of maintaining long-distance transmission networks and the technical losses incurred along the way have weakened financial viability for utilities. These structural issues have perpetuated the gap between urban centres with reliable power and rural communities still dependent on erratic supply.

EMERGENCE OF DECENTRALIZED RENEWABLE ENERGY SOLUTIONS

In recent years, a new approach to rural energy access has begun to take shape through Decentralized Renewable Energy (DRE) systems. The sharp decline in the cost of solar photovoltaic modules by more than 85 per cent between 2010 and 2020, together with advances in battery storage, inverter technology and remote monitoring systems, has created new opportunities to extend energy access beyond the limits of the central grid. DRE solutions, particularly solar mini-grids and distributed solar installations, have enabled localized power generation close to the point of use, reducing transmission losses and providing energy security to communities that were previously underserved.

This approach goes beyond the traditional idea of rural electrification as the provision of lighting or basic household services. It views energy access as the foundation for economic activity and livelihood transformation. Reliable and affordable power enables productive enterprises, supports agricultural mechanization, drives small-scale processing and expands opportunities for entrepreneurship. It recognises that sustainable rural development depends not only on the presence of electricity but on its capacity to support income-generating and value-adding activities.

Across India's diverse social and geographic contexts, DRE initiatives are demonstrating measurable change. In Karnataka's Chamarajanagar district, solar-powered roti-making machines have expanded women's food enterprises. In Jharkhand's Simdega district, community-owned solar mini-grids have mechanized agricultural processing that was once entirely manual. These experiences show how local generation and appropriate technology can unlock economic potential that had long remained untapped.

ECONOMIC, SOCIAL AND TECHNOLOGICAL TRANSFORMATION

Evidence from successful DRE interventions highlights their wide-ranging benefits. In Gumla district's Patratoli village, a 34 kWp solar mini-grid reduced the operational costs of local welding units by nearly two-thirds and improved reliability, allowing businesses to expand and create new employment. In Assam's remote aquaculture communities, floating solar systems have provided clean electricity while improving fish production through aeration systems, combining energy access with direct livelihood enhancement.

Women's economic participation has grown substantially where reliable electricity has become available. Mechanized equipment powered by solar energy has replaced time-intensive manual work, allowing women to take on new economic roles and extend their working hours. In Honganuru village of Karnataka, a solar-powered sewing machine enabled a tailor to double her output while continuing work after dark, generating an additional income stream that strengthened household security. These changes have had broader social effects, with women assuming leadership in community energy committees and gaining technical and financial management skills.

Agriculture has also been transformed by DRE applications. Solar irrigation pumps have freed farmers from expensive diesel systems and erratic grid connections, allowing continuous cultivation and crop diversification. In Uttar Pradesh's Chakanwala village, a solar-powered flour mill established by a local doctor demonstrated the viability of small-scale rural enterprises and inspired multiple replications within the same community.

The success of these systems has depended strongly on local ownership and community management. Models such as Jharkhand's *Urja Mandal* show that when women-led collectives are trained in technical operation, billing, and basic maintenance, systems remain functional and socially accepted. Financial models combining prepaid metering, flexible payment schedules and productive-use revenues have balanced affordability with sustainability. Advances in lithium-ion batteries, smart inverters and IoT-based monitoring have further reduced costs and improved reliability, extended system life and lowered maintenance requirements.

Policy, institutional gaps and the way forward

The policy environment for DRE in India has evolved over the past decade through dedicated renewable energy frameworks and state-level mini-grid guidelines and framework for promotion of DRE Livelihood application. However, significant policy and institutional gaps persist. Integration between DRE initiatives and wider rural development programmes remains limited and the absence of technical standards and tariff mechanisms continues to hinder progress. Coordination among ministries is weak, and long-term institutional structures to support DRE at scale are still emerging.

PHOTO COURTESY: TWINBORN HINGE, CUSTOMIZED ENERGY SOLUTIONS

Women engaged in traditional silk reeling inside the Productive Use Renewable Energy Centre (PUREC), Meghalaya

At the implementation level, constraints in technical capacity and financing continue to restrict growth. Rural areas often lack trained personnel for installation and maintenance, and many potential users remain unaware of the benefits of decentralized systems. Competition from subsidized grid power and fossil-fuel-based alternatives further weakens the commercial case for DRE. Access to credit for both system deployment and productive-use equipment remains a challenge.

Nevertheless, the conditions for expansion are highly favourable. Falling renewable energy costs, growing rural demand, and the demonstrated livelihood benefits of DRE together create a strong foundation for scale. Achieving this will require continued investment in technology, skill development and financial innovation, alongside policies that explicitly link DRE to livelihood generation.

This report presents a detailed examination of DRE interventions for livelihood enhancement across multiple rural contexts in India. Through field-based case studies, it documents the transformative outcomes achieved and the lessons that can guide replication. The evidence shows that decentralized renewable energy represents more than a technological alternative; it offers a pathway for inclusive economic growth grounded in local ownership, environmental sustainability and community empowerment. As India seeks to meet its renewable energy goals while ensuring equitable development, DRE systems provide a tested and scalable approach to bridging the energy access divide and advancing rural transformation.

Walking the last mile of energy access—mini-grid integrated into local service delivery

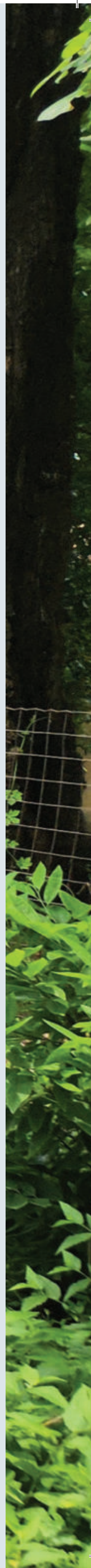
PHOTO COURTESY: BINIT DAS, CSE

ENERGY IN PRACTICE: STORIES OF RURAL TRANSFORMATION

This section brings together **21 case studies from Jharkhand, Meghalaya, Assam, Uttar Pradesh**, and **Karnataka**, documenting how **decentralized renewable energy (DRE)** interventions are strengthening rural economies and livelihoods. These examples illustrate how reliable, affordable power, when aligned with local enterprise and community participation, translates national renewable energy goals into real, measurable change.

Across regions, DRE has powered transformations that reach far beyond electrification. In **Jharkhand**, solar mini-grids operated by women's collectives are powering local markets and small enterprises, replacing diesel generators and building sustainable business ecosystems. In **Meghalaya**, solar-powered silk reeling and weaving units are reviving traditional eri silk production while improving income security for women artisans. **Assam's** hybrid solar aquaculture systems are modernizing fish farming practices, improving yields and reducing environmental impacts. In **Uttar Pradesh**, a doctor's investment in a solar-powered flour mill yielded strong personal returns while building a wider solar-based agricultural processing network benefiting the community. In **Karnataka**, solar mechanization in food processing and dairy operations has enhanced productivity, created local employment, and reduced energy costs.

Documenting these small-scale and individual stories is crucial to understanding how renewable energy intersects with local economies and livelihoods. The stories that follow provide concrete evidence of how decentralized renewable energy can build economic resilience, expand rural opportunity, and align India's clean energy goals with inclusive development.



JHARKHAND

COMMUNITY OWNED MINI GRIDS AND LOCAL GOVERNANCE IN JHARKHAND

JHARKHAND
Simdega district,
Bolba Block
Sugadongar village

"For six years, government poles stood near our village like broken promises. Officials said 42 families weren't worth the investment. So we stopped waiting and built our own grid. Today, the Saur Urja Samiti manages billing, maintenance, expansion and planning. We were never too small, they were simply thinking too centrally."

Lilavati Devi,
President of the Chandra Muni Saur Urja Samiti, Sugadongar

PARAMETER	DETAILS
Location	**Sugadongar village:** Bolba Block, Simdega District, Jharkhand; 45 km from district headquarters **Bandatoli village:** Simdega district; 43 km from district headquarters
Implementation partners	**Lead organization:** Transform Rural India Foundation (TRIF) **Funding partner:** Tata Capital **Technical partner:** Gram Oorja Solutions Pvt. Ltd. **Community partner:** Chandra Muni Saur Urja Samiti (70 per cent women members)
Project highlights	**Solar PV capacity:** 9.9 kWp for Sugadongar (42 households), 9.9 kWp for Bandatoli (48 households) **Inverter capacity:** 10.4 kVA; **Battery capacity :** 750 Ah
Cost of project, financing bank and rate of interest	The solution emerged through the collaborative vision of the Transform Rural India Foundation (TRIF), with funding from Tata Capital and technical expertise from Gram Oorja Solutions Pvt. Ltd.
Land owner and rental model	Community-rented land for solar installations (Rs1000 per month); infrastructure with poles and distribution networks installed; control rooms constructed with community labour participation
Project timeline	**Total duration:** 4–6 months per village
Tariff model	**Per household connection fee:** Rs 1,500 (paid in 3 installments) **Monthly tariff:** Rs 100 fixed charge + Rs 10/kWh **Includes:** 4 LED bulbs, 2 plug points, 1 energy meter per household
Monthly expenditure and income	**Operator salary and land rent:** Rs 400 per month and Rs 600 respectively for 15 years. **Insurance pool:** Solar Grid Suraksha Samiti collected Rs 2.62 lakhs from 60 mini-grids and spent only Rs 60,000 on repairs
Economic impact on livelihood	**Agriculture:** Farmers reduced irrigation costs by 90 per cent, saving about Rs 27,000 annually by replacing Rs 3,000 monthly kerosene expenses with Rs 300 electricity bills (for 10 irrigation months). **Enterprise:** Dhaneshwar Singh charges Rs 2 per kg for grinding grains, earning about Rs 120 per hour against an electricity cost of Rs 30, making a net profit of Rs 90 per hour. With current operations of around 20 hours a month, this translates into roughly Rs 2,400 in revenue and Rs 1,800 in monthly profit, with scope for tripling income with surges in customer demand
Challenges and learnings	**Success factors:** 100 per cent household participation, 4–6-month community engagement, 70 per cent women members, participatory construction approach **Technical reliability:** Maximum 1–2-hour fault resolution, local operator training, spare parts availability

BACKGROUND

In the heart of Jharkhand's Simdega district, where 92.8 per cent of the 0.6 million population lives in villages spread across 451 settlements, two remote communities, Sugadongar and Bandatoli, remained without electricity for decades. Located 45 kilometres from the district headquarters, these villages exemplify the challenges faced by many rural settlements across India—complete isolation from the electrical grid that powers urban life.

Simdega's demographic profile reflects deep economic vulnerability. Nearly 65 per cent of the population belongs to tribal communities, and 62.7 per cent lives below the poverty line. Agriculture is the main source of livelihood for 52.8 per cent of residents, followed by manual labour at 49.3 per cent. In villages like Sugadongar and Bandatoli, 69.5 per cent of households are nuclear families, and 5.2 per cent are headed by women who often shoulder both domestic and income-generating responsibilities in difficult conditions.

The terrain itself told a story of geographical isolation. Rocky landscapes rising more than 200 meters above sea level, poor road access, and the complete absence of mobile network coverage made these villages invisible to development initiatives. Sugadongar, located in Malsara Panchayat of Bolba Block, is home to 42 families, while Bandatoli has 48. Both lie along the buffer zone of the Ushakothi Wildlife Sanctuary and the Bamra–Gangpur Forest, where human–elephant conflict is a frequent threat.

A quiet lane in Bandatoli

Bandatoli lane lined with mud houses that reflect traditional rural life

For generations, life here followed the rhythm of natural light. Women spent long hours manually processing paddy, a labour-intensive task that consumed time otherwise available for income or childcare. Men travelled to distant markets for grain hulling and wheat grinding. Children studied by dim kerosene lamps, and the elderly retired soon after sunset as darkness curtailed all activity.

Yet beneath this apparent simplicity lay a deep yearning for progress. Some families had attempted to install individual solar panels, small 5 to 50-watt systems costing between Rs 2,000 to Rs 5,000, but these provided only enough power for two LED bulbs for a couple of hours, and failed entirely during cloudy days when batteries couldn't charge adequately.

THE PROBLEM

The lack of reliable electricity posed a series of interlinked challenges that affected several aspects of life in Sugadongar and Bandatoli. Without power, daily survival revolved around manual labour, limited opportunities, and isolation from the wider world.

Women bore the brunt of this energy poverty. Each day, they spent six to eight hours manually processing paddy—a task that mechanized mills could complete in an hour. The work was exhausting and time-consuming, leaving them with little opportunity to pursue income-generating activities or participate in household decisions. This persistent 'time poverty,' trapped families in subsistence living, with no space to diversify livelihoods or plan for the future. Farmers faced similar difficulties. Those who could afford diesel pumps for irrigation spent nearly Rs 3,000 a month, about Rs 27,000 a year, excluding the non-irrigation months, while others had no choice but to depend on rain-fed cultivation, which kept yields low and incomes uncertain.

The absence of electricity also took a heavy toll on education and social life. Children's study hours ended with sunset. The local school offered classes only up to Grade 8, while higher education required a seven-kilometre journey to Bolba; a difficult prospect given poor lighting and unsafe roads. The lack of access reinforced social stigma. As one elderly woman from Sugadongar recalled, neighbouring villages mocked them as 'lazy' and 'unambitious'. Young people struggled to find marriage partners in electrified communities, as their unelectrified status became synonymous with backwardness and neglect.

Health and safety concerns compounded these hardships. In the complete darkness that blanketed the villages at night, human-elephant encounters were common and night-time medical emergencies were equally dangerous. Without lighting, families could not travel safely or receive timely treatment, and women faced heightened risks during childbirth. Indoors, the use of kerosene lamps also exposed residents to harmful fumes, causing respiratory illnesses.

Communication and access to information were almost non-existent. With no electricity to power mobile devices or enable network connectivity, villagers remained cut off from weather forecasts, market prices, government schemes, and emergency alerts. This information gap reinforced economic vulnerability.

Years of petitions to local authorities, including the Panchayat Pradhan, MLA, and electricity department, brought no results. Government poles were installed near Sugadongar, yet actual connections never materialized even after six years of formal requests. Officials often cited the small population size as a reason the villages were 'economically unviable' for grid extension.

Families continued to rely on costly kerosene for lighting, spending large shares of their meagre income on dim, polluting fuel. Renting diesel generators for community events cost between Rs 5,000 and Rs 8,000 a night, turning simple celebrations into unaffordable luxuries. This dependence on inefficient and expensive energy sources entrenched poverty further: without electricity, income opportunities were limited, and without income, investment in better energy options was impossible.

The cycle was self-perpetuating, with energy poverty reinforcing economic and social exclusion. Breaking it would require more than just a technical fix; it demanded a solution that addressed the intertwined realities of infrastructure neglect, economic stagnation, and the social costs of being left in the dark.

APPROACH AND IMPLEMENTATION

The solution emerged from the collaborative effort of the Transform Rural India Foundation (TRIF), supported by Tata Capital and executed with technical expertise from Gram Oorja Solutions Pvt. Ltd. The initiative went far beyond installing solar panels; it evolved into a holistic community development model integrating the social, economic, and technical dimensions of rural electrification.

Community-centric planning and participation

TRIF recognized that sustainable electrification could succeed only through genuine community ownership. The process began with deep engagement, identifying villages through grassroots networks such as block markets where residents from distant areas gathered. This ensured that interventions reached truly isolated communities rather than politically connected ones. Villages with partial infrastructure, like poles but without connections, were prioritized as they already indicated administrative recognition but a lack of execution. Completely unelectrified settlements were approached with separate resource planning.

Once identified, the project required full community participation. Every household nominated a representative to attend meetings, ensuring that decisions reflected collective consent. TRIF teams educated villagers on the hazards of kerosene and diesel, demonstrated the benefits of solar energy, and discussed both the potential and the limitations of mini-grids compared with main-grid connections. Transparency in these discussions-built trust and enabled informed decision-making.

Building trust through engagement and exposure

When TRIF's Anil Xaxa first visited Bandatoli in October 2023, he found the village empty as everyone was working in the paddy fields—a pattern that shaped the entire engagement process. Recognising rural rhythms, he scheduled meetings at 6 a.m. before fieldwork and 8–10 p.m. after the day's labour, showing respect for community routines. This flexibility helped establish early credibility. Villagers were initially sceptical, having seen many unfulfilled promises from government and private actors. Some assumed TRIF would collect fees and disappear. The insistence on total participation caused frustration at first, but Anil persisted, knowing that partial involvement often led to future conflict or misinformation.

To deepen understanding, TRIF organized exposure visits for six villagers comprising three men and three women from each site to neighbouring villages with functional mini-grids. Witnessing operational systems firsthand and speaking with peers who had faced similar challenges proved more persuasive than presentations. These visits dispelled misconceptions, demonstrated tangible benefits, and turned early adopters into ambassadors for replication across the region.

Stacked battery bank forming the backbone of mini-grid in Sugadongar

Technical design and local management

The technical framework balanced robustness, scalability, and autonomy. Sugadongar's 9.9 kWp installation, launched in November 2024, was built with a 5 kW connected load, allowing future expansion. TRIF installed new poles and distribution lines instead of using government infrastructure; an approach that raised costs but prevented administrative disputes and ensured long-term independence.

Operation and maintenance were decentralized for resilience. Unlike centralized grids with long delays, mini-grids were designed for rapid local response. TRIF trained local operators to manage basic faults and stocked spare parts within the village to guarantee one-to-two-hour resolution times.

Financially, the model balanced affordability and sustainability. Each household contributed an application fee of Rs 1,500 in three instalments and paid a tariff of Rs 100 plus Rs 10 per kWh, which was far below previous energy costs yet sufficient for maintenance. Land for the plant was rented at Rs 600 per month, and the operator received Rs 400. Every connection included four LED bulbs, two plug points, and a meter. Post-paid digital meters with readings on the 26th and payments by the 6th of each month aligned billing with rural cash flows.

The village solar mini-grid and control room, powering nearby homes

Institutional structures ensured accountability. The Saur Urja Samiti, with 70 per cent female members, managed operations, finances, and conflict resolution, giving those most affected by energy poverty a decisive voice. The Solar Grid Suraksha Samiti introduced a collective self-insurance mechanism: 60 mini-grids pooled Rs 2.62 lakh in the first year and spent only Rs 60,000 on repairs, proving both reliability and cooperative risk management.

IMPLEMENTATION ON THE GROUND

In Sugadongar, work began in September 2024 with surveys and community mapping. Local leader Lilavati Devi, who was later elected Samiti President, first learned about mini-grids from a neighbouring village and contacted TRIF herself, signalling organic demand. The first community meeting introduced system design, connection procedures, and costs; the second, in October, established the Chandra Muni Saur Urja Samiti through democratic elections. The community took time to reach full consensus, adding a 10 per cent capacity buffer for future households.

Implementation drew heavily on local labour. In Bandatoli, villagers built the control room, mounted panels, erected poles, and laid cables. Two residents with basic electrical knowledge received hands-on training from TRIF to assist with wiring and meter installation. This participatory construction reduced costs, created ownership, and built technical familiarity that later proved essential for system upkeep.

The remoteness of both villages created logistical hurdles. Equipment was carried manually across rough terrain with no road access or mobile connectivity, forcing on-site coordination. System design accounted for local conditions: installations were fortified against elephant movement, and lightning protection with automatic disconnection was built in to safeguard during storms.

A newly wired home shows how solar power brings reliable lighting indoors.

Training, capacity building, and livelihood integration

Before inauguration, every household attended safety training covering equipment handling, troubleshooting, and emergency procedures. Operators such as Vinod Minz received intensive instruction on system operation, maintenance, meter reading, and billing, followed by monthly refresher sessions at TRIF's offices. Committee members were trained in financial management, leadership, and planning. The 70 per cent female representation in governance required cultural sensitivity but ultimately strengthened inclusion and transparency.

The electrification strategy embedded livelihoods into its design. Power allocation included irrigation pumps, agro-processing units, and small enterprises so energy access could drive economic gains. Farmers began installing 1.5 HP submersible pumps to improve irrigation; one household converted its tubewell into a shared system supplying both irrigation and drinking water to neighbouring families. Reliable electricity also enabled crop diversification, allowing the cultivation of potatoes, tomatoes, brinjal, and other vegetables, and supported value-added processing such as Mahua seed oil extraction, which previously required long trips to Odisha mills. These developments reflected how the project viewed energy not as an end but as a foundation for long-term livelihood growth.

From trust to transformation

Implementation spanned four to six months, a pace slower than purely technical installations but necessary for social readiness, institutional maturity, and community ownership. The process culminated in village inaugurations that residents described as historic milestones. For many, turning on an electric bulb marked their first encounter with artificial light. The event symbolized collective achievement, self-reliance, and the beginning of a new phase of rural progress.

A quiet cluster of village homes

RESULTS AND IMPACT

The installation of solar mini-grids in Sugadongar and Bandatoli reshaped every dimension of village life. Reliable electricity triggered a wave of social, economic, and environmental transformation that exceeded expectations and redefined what rural self-sufficiency could look like.

Economic and agricultural transformation

Access to dependable power brought immediate financial relief. Farmers who once spent Rs 3,000 a month on kerosene for irrigation now operated electric pumps at Rs 300, saving nearly Rs 27,000 annually. Electrification also enabled crop diversification by moving beyond paddy and new growing seasons through summer irrigation. Several households installed 1.5 HP submersible pumps, with one family converting its tubewell into a shared system that supplied both irrigation and drinking water.

Women's economic participation rose dramatically as time-consuming manual labour was replaced by electric equipment. Paddy processing and wheat grinding, once full-day tasks, could now be completed in hours. Enterprises like Dhaneshwar Singh's solar-powered 3 HP rice-hulling and flour mill demonstrated the new economic potential—processing 60 kilograms per hour at a Rs 30 energy cost, earning Rs 90 in revenue, and creating consistent profits.

Entrepreneurs operating a solar-powered grain processing unit

Social and educational empowerment

For students, electrification transformed study routines. Lighting extended study hours beyond sunset, improving academic performance and confidence. As Bhagyavati Devi noted, the mini-grid was "a blessing for students." The sense of pride and dignity among residents replaced years of social stigma from being labelled "backward." With electricity, marriage prospects and inter-village relations improved, giving younger generations renewed social standing.

Health, safety, and environmental gains

Kerosene lamps vanished almost overnight, cutting indoor air pollution and respiratory ailments, especially among women and children. Electric lighting reduced human-elephant conflicts and improved safety after dark, while refrigerators allowed safe storage of medicines and perishables. Medical emergencies could now be managed at night, and better illumination encouraged more women to seek timely healthcare.

Institutional and community development

Electricity transformed the way communities organized themselves. Meetings once limited to daylight now took place in the evenings, broadening participation and decision-making. The Saur Urja Samitis evolved from energy committees into local development institutions addressing livelihoods, savings, and planning. Festivals became affordable again with costs dropping from Rs 5,000–8,000 for diesel generators to Rs 300–500 for solar-powered lighting, and restoring collective celebration and social cohesion.

Sustainability, innovation, and replication

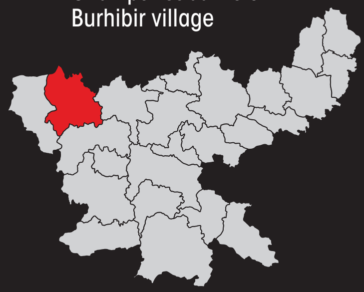
The mini-grids spurred technological adoption, with households purchasing fans, televisions, and refrigerators and planning for digital tools like photocopying and online education. Enterprises expanded into high-value processing—Mahua pickle, Chironji seed, turmeric, safflower oil, and moringa powder—capturing local value once lost to distant markets.

Financially, the model proved resilient. The Solar Grid Suraksha Samiti pooled Rs 2.62 lakh from 60 mini-grids in its first year, spending only Rs 60,000 on repairs; by the second year, collections rose to Rs 3 lakh. Payment compliance remained high, showing both affordability and trust.

Most importantly, the success of Sugadongar and Bandatoli inspired replication across the region. Nearby villages approached TRIF to develop their own systems, proving that decentralized renewable energy can break energy poverty and drive inclusive growth.

HOW SOLAR MINI-GRIDS CREATED FIVE ENTERPRISES

JHARKHAND
Palamu district,
Chainpur subdivision
Burhibir village



"The 50-50 cost share worked really well. If TRIF paid for everything, people might not take care of the equipment. However, we couldn't afford the whole expense. Splitting the cost gave entrepreneurs real ownership without heavy debt. When everyone invests, everyone feels responsible—and that's what makes a cooperative succeed."

Anuj Kumar Yadav,
Landowner of the solar mini-grid

PARAMETER	DETAILS
Location	Burhibir village, Chainpur subdivision, Palamu district, Jharkhand. Located 10 km from sub-district headquarters and 12 km from district capital Daltonganj.
Implementation partners	**Funding partner:** World Resources Institute (WRI) **Local implementation**: Transform Rural India Foundation (TRIF) **Technical partner:** Gram Oorja Solutions Pvt. Ltd. **Program design:** WOW Hub (Work, Opportunity, and Well-being) Network **Government coordination:** Jharkhand State Livelihood Promotion Society (JSLPS)
Project highlights	16.5 kWp solar mini-grid with 27.6 kWh battery capacity. 5 enterprises established: Common service centre, sewing centre, flour mill, paper plate manufacturing, dal mill community-owned through Swa Rojgar Srijan Samiti (7-member committee)
Cost of project, financing bank and rate of interest	**Total project cost**: Rs 23 lakhs **Funding:** 100 per cent grant funding by WRI channelled through TRIF Equipment cost-sharing: 50 per cent entrepreneur contribution, 50 per cent grant from WRI-TRIF No bank financing or interest rates involved
Land owner and rental model	**Land and provider:** 6 decimals provided by entrepreneur Anuj Kumar Yadav **Rental arrangement:** Rs 1,000 per month **Approval:** Unanimously cleared by Gram Sabha **Ownership:** Infrastructure held collectively through village committee
Project timeline	April 2024: Solar power system installation completed May 2024: Distribution lines completed, enterprises became operational
Tariff model	**Consumer tariff:** Rs 5 per unit **Billing system**: Monthly billing on the 20th of each month **Usage**: Currently 23–25 units per day (35 per cent of generation capacity)
Monthly expenditure and income	**Monthly revenue**: ~ Rs 3,800 from electricity charges **Entrepreneur Incomes**: CSC (Rs 20,000–25,000/month), sewing (Rs 7,500-36,000/month), flour mill (Rs 6,000–7,500/month), paper plate manufacturing (Rs 10,000–13,000/month), dal mill (Rs 3,000/month) seasonal operation, affected by monsoon humidity) **Operating expenses**: Land rent (Rs 1,000/month), operator salary (2000/month)
Economic impact on livelihood	**Direct beneficiaries**: 5 entrepreneurs generating steady incomes **Indirect benefits**: 180+ households accessing local services, eliminating travel costs and time **Women's empowerment**: Female entrepreneurs (Nagwanti Devi, Satwanti Devi) gained economic independence
Challenges and learnings	**Infrastructure opposition**: Initial resistance to power line routing through agricultural fields required multiple community meetings and compromise solutions, needed creative solutions like providing free connections to resolve landowner objections **Seasonal variations**: Dal mill faced challenges during monsoon due to humidity affecting processing **Technical resilience**: 3-day continuous rain temporarily exhausted battery capacity **Key learnings**: Community consultation essential, flexible implementation approach needed, 50:50 cost-sharing builds ownership, diverse enterprise portfolio spreads risk, strong governance structure crucial for sustainability

BACKGROUND

In the heart of rural Jharkhand, nestled within the Chainpur subdivision of Palamu district, lies Burhibir, a village that embodies both the challenges and untapped potential of rural India. Located 10 kilometers from the sub-district headquarters and 12 kilometers from the district capital of Daltonganj, this small village of more than 180 households reflects the complex realities facing rural communities across the country.

Burhibir's social composition captures Jharkhand's characteristic diversity, with 587 residents belonging to Scheduled Castes and Scheduled Tribes. Yet beneath this diversity lies a stark educational divide: only 40.17 per cent of residents are literate, with male literacy at 49.51 per cent and female literacy at just 29.80 per cent. These figures reveal represent generations limited by poor access to education and opportunity.

Despite these challenges, Burhibir retains a sense of vitality. Nearly 140 children under six fill the lanes with energy and promise, symbolising the community's hopes for a better future. The village has a functioning panchayat office, an Anganwadi centre, and a Sahodaya School up to Class 10. However, students seeking higher education must travel 12 kilometres to Daltonganj by auto-rickshaw or bus, exposing the persistent geographical and infrastructural barriers to rural advancement.

Economically, Burhibir relies on subsistence agriculture and small-scale seasonal work. Farming during the monsoon provides limited sustenance, while the rest of the year is marked by underemployment. The absence of local enterprises forces residents to travel

Solar panels and control room supporting enterprises in Burhibir

long distances for basic services such as milling, tailoring, or document processing, costing both time and income.

Burhibir's transformation began in 2023 when the Transform Rural India Foundation (TRIF) identified the village during its work in the Chainpur block. The selection was deliberate, as Burhibir combined community readiness, geographical suitability, and the presence of young entrepreneurs willing to take measured risks. Existing engagement with government schemes such as PM-KUSUM, along with educated residents like 24-year-old Anuj Kumar Yadav, a diploma holder in computer applications, created the right conditions for experimentation and innovation.

THE PROBLEM

Burhibir faced a persistent struggle with unreliable electricity that limited both livelihoods and local enterprise. The village was connected to the national grid, but daily power cuts lasting two to four hours were common. During the summer and monsoon months, outages stretched even longer as the grid infrastructure came under stress. For residents, this meant living with constant uncertainty as machines stopped mid-operation, lights went out during work hours, and business plans were repeatedly stalled.

This unreliable supply held back small-scale entrepreneurship. Women like 56-year-old Nagwanti Devi, an experienced tailor with consistent demand for her work, had to rely entirely on manual equipment. Her earnings and output remained low because she could not use electrical sewing tools regularly. Farmers faced similar difficulties. With no local milling facilities, they travelled long distances to process grain, losing both productive hours and money. Rajesh Chaurasia, a 26-year-old who wanted to open a flour mill, realized that without steady power, it would be impossible to run a viable business.

The situation created a deadlock for rural entrepreneurs. Viable businesses needed dependable power, yet the low economic base of the village made investment in alternative systems, like diesel generators, unaffordable. These challenges were compounded by limited technical knowledge, weak market access, and restricted exposure to new business models. Even those with innovative ideas lacked networks and information to turn them into functioning enterprises.

Educated young people began migrating to towns in search of better prospects, leaving behind a community with shrinking capacity for local economic activity. Access to banking, document processing, and government schemes required frequent trips to Daltonganj, adding travel costs and excluding women and elderly residents from essential services. Over time, the village's development potential remained locked behind the same barrier of energy insecurity that discouraged initiative and drained opportunity.

APPROACH AND IMPLEMENTATION

Integrated model for rural enterprise development

The initiative in Burhibir brought together renewable energy infrastructure, entrepreneurship, and community empowerment. Developed through collaboration between the World Resources Institute (WRI), Transform Rural India Foundation (TRIF), and the WOW Hub (Work, Opportunity, and Well-being) Network, it combined global expertise with local implementation capacity.

The programme focused on creating a solar mini-grid dedicated to enterprise use rather than household consumption. This targeted approach maximized resources for direct livelihood impact. The 16.5 kWp photovoltaic system included 30 solar modules of 550 Wp each and a 27.6 kWh battery bank of 10 solar batteries (12V, 230 Ah each), ensuring a consistent power supply.

Identifying entrepreneurs and building ownership

Entrepreneurship was at the core of the initiative. Rather than prescribing enterprises, TRIF and WRI consulted extensively with villagers to identify individuals with both aptitude and relevant skills. The selection process emphasized diversity in enterprise types and inclusivity across gender and social groups.

Financial sustainability was ensured through a 50:50 cost-sharing mechanism. Entrepreneurs contributed half the equipment cost, while WRI and TRIF provided the rest through grants. This ensured affordability, commitment, and long-term accountability.

Community governance and institutional mechanisms

Local ownership was formalized through the creation of the Swa Rojgar Srijan Samiti (Self-Employment Creation Committee), a seven-member body overseeing grid operations, tariff collection, and enterprise coordination. The committee included the Panchayat head, entrepreneurs, and JSLPS representatives, combining administrative oversight with community participation in decision-making.

Training, capacity building, and market linkages

Recognising that infrastructure alone would not ensure sustainability, the programme included extensive training in enterprise management, equipment operation, and basic maintenance. Each entrepreneur developed a business plan with geo-tagged locations and financial projections.

Market linkage support was provided by TRI's field representative, Chandan Prajapati, who facilitated connections with suppliers and customers and supported ongoing business development. This ensured that productive capacity was matched with market access.

IMPLEMENTATION JOURNEY

Implementation began in September 2023 with assessments of solar potential, community readiness, and enterprise feasibility. Coordination with JSLPS ensured alignment with existing government programmes. A Gram Sabha held on January 25, 2024, at the Burhibir Panchayat Bhawan formalized project approval, with six decimals of land allocated for the solar plant and five entrepreneurs selected.

Community leadership played a central role. Anuj Kumar Yadav offered his land for the solar plant at a rent of Rs 1,000 per month, ensuring community ownership.

The team responsible for operating the solar system that powers the village

Managing challenges through consensus

Initial construction faced objections from villagers concerned about power line routes through farmland. TRIF and Gram Oorja facilitated a series of meetings involving Panchayat and JSLPS representatives to find a resolution. The community ultimately agreed to route lines through the edge of Tongri hamlet. When a local resident, Lalji Mochi, objected to power lines crossing his property, TRIF addressed the concern by offering him and the Panchayat Bhawan free solar connections. This resolution reinforced trust and inclusivity.

Enterprise selection and operationalization

Five entrepreneurs—Rajesh Kumar Chaurasia, Anuj Kumar Yadav, Nagwanti Devi, Balaji Chaurasia, and Satwanti Devi—underwent three days of intensive training on equipment use, business management, and maintenance. A final procurement meeting on March 5, 2024, finalized machine purchases under the cost-sharing model after review of quotations and specifications.

Project completion and governance framework

By May 2024, the Rs 23-lakh project was fully operational. Funded by WRI and implemented through TRIF, it comprised the solar generation system, distribution network, and enterprise installations. The Self-Employment Creation Committee assumed responsibility for grid and enterprise management, establishing a sustainable community-led energy and business ecosystem.

RESULTS AND IMPACT

The solar mini-grid initiative in Burhibir has reshaped the village's social and economic landscape. By May 2024, all five enterprises were operational, creating a new local economy where residents once relied entirely on external services and employment. The project delivered measurable financial gains, strengthened community governance, and demonstrated how reliable renewable energy can drive inclusive rural transformation.

Economic performance and enterprise outcomes

The most immediate impact has been steady income generation across the five supported enterprises.

- Anuj Kumar Yadav's Common Service Centre now earns Rs 20,000–25,000 monthly, offering bill payments, government scheme facilitation, banking services, and digital transactions. The centre has eliminated residents' need to travel to Daltonganj for routine services.

- Nagwanti Devi's sewing centre shifted her from manual work to mechanized production, earning Rs 250 daily on average and up to Rs 1,200 during festival seasons. She now caters to clients from neighbouring villages and plans to expand into a commercial boutique.

- Rajesh Chaurasia's flour mill meets local processing needs for wheat, barley, and sattu at Rs 2–Rs 3 per kg, generating Rs 200–Rs 250 daily. Its 14-kg-per-hour capacity suits local demand and saves farmers transport costs.

Common Service Center of Anuj where villagers access banking and digital services

Nagwanti running her stitching business from home with skill and dedication

- Balaji Chaurasia's paper-plate unit introduced the area's first disposable tableware facility, producing plates and bowls priced between Rs 0.30 and Rs 1 each. Raw materials come from Garhwa, 35 km away, with a scrap buy-back system that reduces waste and adds value.

- Satwanti Devi's dal mill serves local pulse producers despite seasonal constraints caused by humidity. Though profits are lower, the service fills a vital niche in local food processing.

Together, these enterprises have built a resilient rural micro-economy that keeps value and employment within the community.

Community benefits and social change

Local access to services has drastically reduced time and transport costs. Women have benefited most, both as entrepreneurs and as customers who now find tailoring, milling, and government services within the village. The CSC's digital facilities have improved access to financial systems and welfare schemes, strengthening inclusion.

The success of women-led enterprises has challenged traditional gender roles and encouraged other women to explore entrepreneurship. Youth migration has slowed as young residents see viable livelihood opportunities locally. The collective success has sparked interest in replication among neighbouring villages

Technical and financial sustainability

The 16.5 kWp mini-grid has shown high reliability even through monsoon conditions, with usage averaging 35 per cent of capacity (about 23–25 units daily). A three-day stretch of heavy rain briefly depleted battery reserves, but power supply was restored quickly, confirming system resilience and adequate storage.

The Self-Employment Creation Committee manages grid operations and finances. Daily meter readings at 10 a.m. maintain transparency, and monthly meetings on the 20th review performance and address issues. Users pay Rs 5 per unit, with revenue deposited in the committee's Bank of India account, ensuring funds for maintenance and future upgrades.

Expansion potential and demonstration effect

Current utilization leaves room for new enterprises to join the network without additional capital investment. The model's effectiveness has drawn interest from nearby villages, positioning Burhibir as a demonstration hub for rural enterprise development. Exposure visits are being planned to showcase how renewable energy and entrepreneurship can jointly drive inclusive growth.

Solar-powered milling machines of Rajesh supporting local farmers and households

Balaji running a paper plate manufacturing unit

Lasting transformation

Beyond electrification, Burhibir's progress represents a systemic shift from energy scarcity to self-reliant economic productivity. The combination of reliable power, community ownership, and diversified enterprise activity has created the foundations of sustained local prosperity. As these five ventures expand and inspire others, Burhibir stands as evidence that decentralized renewable energy, paired with human initiative and cooperative governance, can deliver durable rural development

FROM DIESEL DEPENDENCE TO SOLAR INDEPENDENCE IN RURAL JHARKHAND

JHARKHAND
Gumla district,
Patratoli village
Kotam village
Panso village

"The Saur Urja Samiti taught us something unexpected: managing electricity bills makes you better at managing everything else. Our monthly meetings aren't just about meters and tariffs anymore. We discuss crop planning, savings groups, and school improvements. Reliable power didn't just end darkness—it lit up our capacity to organize and govern ourselves."

Lilavati Topo,
President of the Rani Urja Mandal, Patratoli.

PARAMETER	DETAILS
Location	Three villages in Gumla District, Jharkhand: Patratoli (17 km south of Gumla town, Raidih block), Kotam (23 km northwest of Gumla town), and Panso (20 km from Gumla town). Combined population: ~5,200 residents across 1,205 households in predominantly tribal areas (68 per cent tribal population).
Implementation partners	**Funding partner:** Development Alternatives (DA), HSBC **Primary partners**: Mlinda Sustainable Environment Pvt Ltd (MSEPL) as RESCO **Local partners**: Rani Urja Mandal Mahila Samiti (Patratoli), Gaumela Gabbie Vikash Producer Company Ltd. (Kotam) **Government coordination**: Jharkhand State Livelihood Promotion Society (JSLPS), Nawagarh Cluster Level Federation (CLF) **Technology partners**: Nunam (IoT-enabled second-life batteries), Sustain Plus.
Project highlights	**Capacity:** 34 kWp solar mini-grids at each location; 545Wp Waaree/Vikram bifacial solar modules; 1550 Ah lithium-ion batteries **Innovation**: Women-led community ownership model, prepaid smart metering with Bluetooth and 4G connectivity.10-year warranty on batteries and inverters, 5-year on charge controllers.
Cost of project, financing bank and rate of interest	**Financing**: HSBC blended financing **Equipment financing**: Mlinda's programs (e.g., Rs 22,000 down payment + Rs 9,400/month instalments for flour mill equipment). No bank financing or interest rates involved
Land owner and rental model	**Land acquisition**: 15-year lease agreements with private landowners at Rs 1,500 monthly rent. **Community support**: Gram panchayat facilitation agreements for distribution line rights-of-way. **Ownership structure**: MSEPL owns generation infrastructure as RESCO, community organizations own distribution assets and operations.
Project timeline	Kotam: Operational since June 2024. Patratoli: Operational since March 2025. Panso: Implementation completed by Feb 2025. Trial Period: 20-day free electricity trials for commercial users to demonstrate capabilities.
Tariff model	Wholesale rate: Rs 5 per kWh (MSEPL to community organizations). Retail rates: Rs 15 per kWh (community organizations to consumers). Billing: Prepaid smart meter system with mobile app recharging.
Monthly income and expenditure	**Income:** Kotam generates a monthly revenue of Rs 38,600 from recharges. **Expenditure:** The major costs include Rs 2,000 for diesel backup, Rs 13,645 payable to MSEPL, Rs 7,500 as operator salary, and Rs 1,500 for land rent, bringing total monthly expenses to Rs 24,645. **Net surplus:** After meeting all operational costs, Kotam records a surplus of Rs 13,955 per month. **Observation:** With 70–80 per cent capacity utilization, the model ensures financial sustainability.
Economic impact on livelihood	**Micro-enterprise growth:** Entrepreneurs reported an average income rise of 30 per cent. **Women's empowerment:** Collective members saw a projected income increase of 50 per cent. **Commercial savings:** Electricity expenses fell from Rs 15,000–17,000 (diesel) to just Rs 3,000–5,000 (solar). **Examples:** Irfan Hajam's welding shop doubled its capacity, while Hasib Ansari's flour mill processed 1,750 kg weekly, earning Rs 35,000 monthly.
Challenges and learnings	**Seasonal fluctuations:** Revenue dips during monsoon months highlight the need for careful cash flow management. **Market access:** Farmer–trader dependencies restricted raw material supply for local entrepreneurs. **Community engagement:** Low literacy levels (42.4–65.3 per cent) required patience, demonstration-based methods for awareness and adoption. **Success factors:** Women's leadership, community ownership, integrated business support, reliable long-warranty equipment, prepaid billing, and anchor commercial loads ensured financial viability.

BACKGROUND

Nestled in the heart of Jharkhand, Gumla district embodies both the richness of India's tribal heritage and the persistent challenges of rural development. Formed from Ranchi district in 1983, Gumla is home to a 68 per cent tribal population, primarily Oraon, Munda, Ho, and Santhal communities, whose livelihoods remain deeply tied to the land. The district headquarters, Gumla town, anchors a largely agrarian landscape where villages still struggle with unreliable electricity.

Despite decades of rural electrification efforts, many settlements continue to experience energy poverty that constrains livelihoods and hinders economic growth. Agriculture, dependent on erratic rainfall and low productivity, sustains most families but yields modest returns, with average annual household incomes of just Rs 10,000–15,000. To supplement this, communities depend heavily on non-timber forest products such as mahua, tamarind, lac, sal leaves, and bamboo, contributing 16–26 per cent of household earnings.

Educational barriers compound these economic constraints. Literacy rates in villages range from 42.4 per cent to 65.3 per cent, below the state average of 66.4 per cent, limiting residents' ability to adopt new technologies or diversify income sources.

Amid these challenges, the villages of Patratoli, Kotam, and Panso stand out as stories of transformation, demonstrating how decentralized renewable energy and innovative livelihood solutions can empower remote communities and redefine rural resilience in Jharkhand.

Quiet stretch of Patratoli, capturing daily life along the main road

1. PATRATOLI: WOMEN-LED SOLAR TRANSFORMATION

The problem

Patratoli village, located about 17 kilometers south of Gumla town in the Nawagarh area of Raidih block, exemplified the energy challenges confronting rural enterprises across India. Home to over 300 households, the village was technically electrified but suffered from erratic supply and low voltage—conditions that crippled local businesses forming the backbone of its small economy.

The marketplace ran on diesel. Four generator sets powered clusters of commercial establishments, forcing entrepreneurs, from welders to oil expeller operators, to depend on costly, polluting energy. Among them, Irfan Hajam, a metal fabricator and welder with a decade of experience, spent nearly Rs 15,000 a month on diesel to operate his cutters, grinders, and welding machines. Frequent generator breakdowns meant full days lost traveling to Gumla or Ranchi for repairs, halting production and eroding customer trust.

The wider market suffered similar setbacks. Medicine shops, photocopy centers, and Common Service Centers all faced high operating costs and unreliable power, stifling local economic growth. Even households struggled. Though grid connections existed, voltage fluctuations and frequent outages rendered them unreliable. Families invested in costly inverter-battery systems priced around Rs 30,000, which could not sustain heavy loads like pumps or mixers, leaving them without dependable power during crucial hours.

APPROACH AND IMPLEMENTATION

The Urja Mandal Model Innovation

The model's innovation lay not in its technical components but in its recognition that sustainable rural development required addressing energy, economic, and social challenges simultaneously.

The Public-Private-Community partnership framework distributed risks and responsibilities among partners with complementary strengths. Development Alternatives provided overall project leadership and rural development expertise, HSBC contributed financial resources, MSEPL invested in generation assets and delivered technical implementation and maintenance capabilities, and local institutions like Jharkhand State Livelihoods Promotion Society (JSLPS) and Nawagarh Cluster Level Federation (CLF), facilitated government linkages and policy support.

Women's leadership formed the cornerstone of the approach, acknowledging that sustainable change in rural communities required local ownership and management. The Rani Urja Mandal Mahila Samitis were designed not just as operational entities but as platforms for women's economic empowerment and leadership development.

The technical approach prioritized reliability, scalability, and remote management capabilities. Advanced monitoring systems enabled real-time oversight from centralized locations, reducing operational costs while maintaining service quality. The prepaid

The control room featuring mural on women's leadership and empowerment

Members of the Rani Urja Mandal and MSEPL staff at the 34 kWp mini-grid plant

metering infrastructure simplified billing and collection processes while providing users with transparent energy cost management.
Financial sustainability received careful attention through diversified revenue streams and community ownership of assets. The model anticipated seasonal variations in energy demand and included provisions for capacity expansion based on growing consumer needs.

Site selection and strategic approach

Recognizing these multifaceted energy challenges, Mlinda Sustainable Environment Pvt Ltd (MSEPL) identified Patratoli as an ideal location for implementing their innovative model, a public-private-community partnership developed with Development Alternatives (DA). The solution went beyond electricity provision; it aimed to create a comprehensive ecosystem for rural development centered around reliable, clean energy access.

The Urja Mandal initiative represented a paradigm shift in rural electrification strategy. Instead of top-down infrastructure development, the model empowered local women collective to manage and operate solar mini-grids, ensuring community ownership and sustainable operations.

Site selection followed rigorous criteria balancing technical feasibility with social-impact potential. Patratoli's proximity to Gumla town offered logistical advantages, while its concentrated commercial activity provided immediate anchor loads necessary for financial viability. The presence of diesel generators created a clear target market for conversion, with potential for immediate impact on operational costs and environmental outcomes.

Solution design

Central to the solution design was the establishment of the Rani Urja Mandal Mahila Samiti, a women-led collective supported by Jharkhand State Livelihood Promotion Society (JSLPS), that would own and operate the distribution infrastructure. This approach addressed multiple objectives simultaneously: ensuring local ownership, promoting gender equity, building technical capacity within the community, and creating sustainable revenue streams for women entrepreneurs.

The technical solution involved installing a 34 kWp solar mini-grid with remote monitoring, prepaid metering, and flexible load-management systems.

Inside the control room where inverters and lithium-ion batteries manage the village's load

Implementation and execution

Implementation began with extensive community engagement and capacity building. The Rani Urja Mandal members received training at nearby operational mini-grids, gaining hands-on experience in technical concepts, maintenance, consumer query handling, recharging, and failure response.

Ms. Lilavati Topo, President of the Rani Urja Mandal, led the learning process. Training covered technical operations, business management, customer service, and financial planning.

Physical installation started in early 2025 using 545 Wp Waaree bifacial modules positioned for optimal generation. Infrastructure included lithium-ion batteries with 10-year life, inverters with equivalent warranties, and remote monitoring for real-time generation-consumption tracking.

Construction prioritized local involvement, engaging village laborers and using locally manufactured fly-ash bricks. MSEPL, as the Renewable Energy Service Company (RESCO), handled generation infrastructure, while the Rani Urja Mandal assumed responsibility for transmission, distribution, metering, and customer service.

Land acquisition followed a collaborative approach: the landowner agreed to a 15-year lease at Rs 1,500 per month, and the gram panchayat provided a facilitation agreement for installation of poles and distribution lines.

A key strategy involved offering initial 20 days of free electricity to commercial users, allowing them to experience performance benefits over diesel systems.

The prepaid metering system added further innovation. Smart meters with Bluetooth connectivity enabled easy recharging. Ms. Madhuri Devi, a Self-Help Group and Farmer Producer Organization member, mastered the tablet-based recharge system, generating unique codes transmitted to meters via Bluetooth proximity.

RESULTS AND IMPACT

The transformation in Patratoli became visible within months of the mini-grid's commissioning in March 2025. By August, it served 45 commercial users and four domestic connections, reflecting rapid adoption and growing confidence in solar-powered electricity.

The commercial impact was immediate. Irfan Hajam's welding workshop saw a major leap in efficiency: "Earlier I used to wait and do work one by one, but now I can run multiple machines—cutting and welding—simultaneously," he noted. His monthly energy expenses dropped from Rs 15,000 on diesel to about Rs 5,000 for solar power, cutting costs by two-thirds. Consistent supply eliminated downtime from generator breakdowns, allowing him to meet orders on time, expand operations, and plan for an additional grid connection.

Across the market, diesel generators fell silent. Shops that once spent Rs 50–60 daily on batteries and LED lamps switched to reliable electricity. A local boiler meat shop installed a refrigerator to sell cold drinks, adding new income streams. The shift to solar energy revitalized small businesses, improving productivity, working hours, and profitability.

Irfan at his mini-grid-powered workshop where daily metalwork and repair jobs are carried out

PHOTO COURTESY: TWINBORN HINGE, CUSTOMIZED ENERGY SOLUTIONS

Oil pressing and packaging supported by reliable electricity access

The financial structure proved sustainable. Commercial users saved Rs 10,000–12,000 monthly, while the *Rani Urja Mandal* generated steady revenue sufficient to cover operations and build reserves. The system maintained over 80 per cent capacity utilization, above typical rural electrification averages.

For households, the mini-grid provided affordable, dependable energy. Recharges of Rs 200–300 per month replaced Rs 30,000 inverter setups that couldn't power heavy appliances. Families could now run pumps, coolers, and multiple devices simultaneously.

The *Rani Urja Mandal Mahila Samiti* demonstrated strong financial and operational management. Members held monthly reviews with MSEPL to reconcile accounts, update consumer databases, and address grievances. Even during monsoon-related disruptions that required diesel backup, the collective managed cash flows effectively through security deposits and recovered costs during high-demand periods.

By combining reliability, affordability, and community-led governance, the Patratoli mini-grid established a benchmark for decentralized rural electrification, proving that women-led clean energy enterprises can deliver both economic and operational sustainability.

KOTAM: AGRI-BUSINESS EMPOWERMENT THROUGH SOLAR ENERGY

The problem

Kotam village, positioned 23 kilometers northwest of Gumla town, presented a different set of challenges despite sharing similar demographic characteristics with Patratoli. As the largest among the three villages over 3,000 residents living in 562 households, Kotam had better literacy rates at 65.3 per cent, yet still faced significant energy access challenges that hindered economic development.

The village's size and relative connectivity advantages masked underlying issues that prevented local enterprises from flourishing. While public bus services connected Kotam to Gumla town, the energy infrastructure remained inadequate for supporting the scale of commercial activity that the village's population and market presence could potentially sustain.

Commercial establishments in Kotam faced the familiar challenge of unreliable grid electricity supplemented by expensive diesel generators. The village market, which served surrounding settlements, struggled to maintain consistent operations due to power supply interruptions. Local entrepreneurs found themselves constrained by energy costs that consumed disproportionate portions of their revenues, limiting their ability to invest in business expansion or equipment upgrades.

The agricultural sector, which formed the economic backbone for most households, faced additional challenges. Oil expelling operations, flour mills, and other agro-processing activities essential for value addition remained dependent on fossil fuel-based power sources or operated at suboptimal levels due to grid electricity limitations.

JHARKHAND: FROM DIESEL DEPENDENCE TO SOLAR INDEPENDENCE

The entrance to the 34 kW mini-grid powering homes and businesses in Kotam

Approach and implementation

Building on lessons learned from the past implementation, the Kotam project adopted a refined approach that emphasized community ownership from the outset. The Gaumela Gabbie Vikash Producer Company Limited (GGVPCL) emerged as the local institutional partner, under leadership of MSEPL and Sustain Plus, representing a farmer producer organization with established credibility and operational experience in the village.

MSEPL's role as RESCO provider ensured technical expertise and equipment quality, while GGVPCL assumed responsibility for community engagement and operational management.

Pankaj, appointed as the plant operator, received comprehensive training covering grid operation, maintenance protocols, customer service, and safety procedures. His accommodation in a small room at the mini-grid site ensured round-the-clock availability for system monitoring and emergency response.

The distribution network design prioritized comprehensive village coverage. Unlike many rural electrification projects that focus primarily on household connections, the Kotam approach emphasized commercial establishments while ensuring that virtually the entire village could access three-phase electricity supply.

The pricing strategy reflected lessons learned about balancing affordability with sustainability. MSEPL sold electricity to GGVPCL at Rs 5 per kWh, enabling the FPO to offer competitive rates to consumers while maintaining operational viability.

Pankaj, the plant operator oversees daily operations of the mini-grid system

Technical solution

The technical solution involved a 34 kWp solar mini-grid installation completed in June 2024, featuring 545 Wp half-cut mono PERC bi-facial Vikram solar modules. The system design incorporated innovative elements including agrivoltaics, with cultivation of urad dal and green peas beneath the solar modules, demonstrating the potential for land-use optimization.

A significant experimental component involved the deployment of IoT-enabled second-life lithium-ion batteries sourced from Tata Motors through Nunam's technology platform. This approach addressed multiple objectives: reducing battery costs, promoting circular economy, extending the lifecycle of automotive batteries, and testing innovative storage solutions for rural applications.

The system architecture included a 1550 Ah battery bank providing 75 kWh storage capacity with a warranty of 2500 cycles, equivalent to approximately seven years of operation. IoT-based monitoring enabled real-time data transfer, allowing remote monitoring of charging and discharging patterns at the cellular level.

The battery management system included sophisticated temperature control measures. Recognizing that energy density drops when ambient temperatures exceed 38-40°C, the control room included air conditioning systems to maintain optimal operating conditions. The AC units, operating from 12 pm to 4 pm during peak summer months, consumed 5 kWh of electricity but prevented 10 kWh of energy loss, resulting in net savings of 5 kWh while extending battery and inverter lifespans.

Rows of lithium-ion batteries storing energy to keep the mini-grid running through the night

Results and impact

Within its first year, the Kotam mini-grid delivered measurable economic and environmental outcomes. Serving 129 residential and commercial consumers, it achieved an 80 per cent capacity utilization factor, reflecting strong local demand and efficient load management.

Financial performance underscored the model's sustainability. Data from earlier months show that GGVPCL generated Rs 38,600 in monthly recharge revenue, covering operating costs—Rs 13,645 paid to MSEPL, Rs 7,500 operator salary, Rs 1,500 land lease, and Rs 2,000 diesel backup—with sufficient surplus for maintenance and expansion.

Entrepreneur Hasib Ansari, operating a solar-powered flour mill financed through Mlinda, illustrated the transformation. After paying a Rs 22,000 down payment and Rs 9,400 monthly installment for his Kolkata-manufactured centrifugal machine, he processed 1,750 kg of wheat weekly (×50 kg/hour) and earned Rs 35,000 per month at Rs 5 per kg. His monthly electricity bill of Rs 7,500 replaced diesel expenses exceeding Rs 3,000 for just two market days, reducing costs while improving reliability and profit margins.

Electricity use patterns reflected productivity gains—27 kWh on market days and 8 kWh on regular days. Consistent power eliminated downtime, stabilized output, and improved product quality.

Hasib milling raw grain into flour for nearby households in Kotam

The shift from diesel to solar brought immediate environmental benefits, reducing noise and air pollution while cutting local carbon emissions. The agrivoltaic layout added another dimension of sustainability, enabling crop cultivation beneath the solar arrays and optimizing land use.

The project's visibility generated a demonstration effect across nearby villages within a three-kilometre radius, where entrepreneurs and households began seeking similar systems after observing Kotam's operational success and cost efficiency, marking the start of a wider regional transition toward community-led, clean energy enterprises.

PANSO: ANCHOR LOADS DRIVE MINI-GRID VIABILITY

The problem

In Panso village, located approximately 20 kilometers from Gumla town with 1,915 residents in 343 households, 75-year-old Sudhim Ansari embodied the challenges faced by rural entrepreneurs operating small-scale agro-processing businesses. His flour mill, equipped with a 10 HP motor capable of processing 100 kg per hour, served the village's grain processing needs but struggled under the burden of expensive diesel-based power generation.

Running costs for diesel generators consumed substantial portions of his revenue, limiting his ability to invest in equipment upgrades or business expansion. The unreliability of diesel generators created additional operational challenges, with breakdowns disrupting service and disappointing customers who depended on timely grain processing.

Old Sudhim standing outside his traditional brick-and-mud home

The village's literacy rate of 42.4 per cent, the lowest among the three case study locations, created additional barriers to adopting new technologies or business practices. Traditional approaches to commerce and reluctance to embrace change complicated efforts to introduce innovative solutions.

Sudhim's situation reflected broader challenges facing elderly entrepreneurs in rural areas. While possessing decades of experience in their trades, they often lacked exposure to modern business practices, financial planning, or technology adoption that could enhance their operational efficiency and profitability.

Approach and implementation

The solution for Panso required a patient, relationship-building approach that acknowledged the unique demographic and cultural characteristics of the village. The mini-grid implementation strategy emphasized demonstration of benefits rather than technical explanations, recognizing that practical experience would prove more convincing than theoretical advantages.

MSEPL's approach focused on identifying anchor loads that could provide immediate and substantial energy consumption, ensuring that the mini-grid's financial viability while serving community needs. Sudhim's flour mill represented an ideal anchor load - an established business with predictable energy requirements and immediate potential for cost savings.

The system design needed to accommodate the substantial power requirements of a 10 HP motor while providing flexibility for future expansion.


Milling operations continuing even after dark with improved energy access

The prepaid metering system installation enabled precise monitoring of energy consumption and simplified billing processes. Sudhim's monthly recharge of approximately Rs 15,000 provided transparency in energy costs while ensuring consistent power supply for his operations.

Results and impact

The transformation in Sudhim's business operations demonstrated the immediate impact of reliable, affordable electricity access. His flour mill operations expanded significantly, with market day processing reaching 1,300-1,400 kg and generating sales revenues of Rs 3,000-3,500. The reliability of solar power enabled him to commit to consistent service delivery.

The economic benefits extended beyond cost savings to operational flexibility and business planning capability. "Earlier I used to spend significant money on diesel, but now with cheaper solar mini-grid electricity, I'm thinking of adding one more machine which will double my production capacity," Sudhim shared, reflecting the confidence that reliable energy access instilled in his business planning.

The success at Panso illustrated its adaptability to different village contexts and demographic profiles. Despite lower literacy rates and traditional business practices, the practical benefits of reliable, affordable electricity proved compelling enough to drive adoption and support sustainable operations.

UTTAR PRADESH

SOLAR-POWERED FLOUR MILL TRANSFORMS RURAL ECONOMY

UTTAR PRADESH
Amroha district,
Dhanaura tehsil
Chakanwala village

"The *atta chakki* is so simple to operate that my daughters and other family members run it effortlessly. The additional income has made them more self-reliant—women and children no longer need to depend on me for small expenses or daily needs."

Dr. Idresh Hassan,
47-year-old physician

PARAMETER	DETAILS
Location	**Chakanwala village**, Dhanaura tehsil, Amroha district, Uttar Pradesh. Located 36 km from Amroha town.
Implementation partners	Self-funded initiative by Dr. Idresh Hassan (47-year-old physician). No external partners or subsidies involved.
Project highlights	• 17.5kW solar PV array (30 modules of 585 Watt each) with VFD inverter (15kW/20HP)
	• Battery-less operation reducing costs and maintenance
	• Dual functionality: Flour mill (10HP motor) + Irrigation pump (7.5HP)
Cost of project, bank finance and rate of interest	**Total Cost:** Rs 3,40,000
	Financing: Self-funded, no bank loans or external financing
Land owner and rental model	Dr. Hassan installed system on his own roof and operates the mill directly. Complete ownership model with no rental arrangements, ensuring full control over operations and revenue streams.
Project timeline	**Implementation:** January 2025
	Current Status: 9+ months of successful operation
Monthly expenditure and income	**Processing rate:** Rs 8 per 5 kg, with 200 kg/hour capacity
	Operations: 6–7 hours daily, processing 10–12 quintals
	Economics: Rs 3.4 lakh investment recovered in 8 months, with minimal expenses and sustainable income thereafter
Economic impact on livelihood	**Primary Impact:** Complete ROI in 8 months, sustainable additional income
	Family Benefits: Financial support for 4 children's education, enhanced family security, women's economic empowerment through independent operation
	Community Benefits: Reliable, affordable grain processing replacing costly diesel alternatives
Challenges and learnings	**Challenges:** High upfront cost (Rs 3.4 lakh), technical complexity requiring training, limited local expertise, seasonal demand variations
	Key learnings: Battery-less operation reduces costs while maintaining functionality; VFD integration crucial for heavy-duty operations; demonstration effect powerful for community adoption
	Success factors: Personal investment avoided bureaucratic delays; transparent pricing-built customer trust
	Replication: 7 other households installed similar systems following success

BACKGROUND

In the heart of Uttar Pradesh's fertile Terai region lies Chakanwala, a modest village that embodies both the aspirations and challenges of rural India. Located in the Dhanaura tehsil of Amroha district, the village is home to over 6,600 residents spread across two distinct settlement clusters: Chakanwala and Chakan Bala Must.

The village presents a familiar rural tableau; agriculture as the primary livelihood, with wheat and rice grown for subsistence while vegetables provide cash income. Like many rural areas in Uttar Pradesh, the village grapples with challenges that have persisted for decades: erratic electricity supply, limited economic opportunities, and the continuous migration of youth to urban centers seeking better prospects.

The village's infrastructure reflects these realities. While literacy stands at 47.78 percent overall, a stark gender divide persists with men at nearly 59 percent literacy compared to women at barely 35 percent. Educational facilities include a Primary School, two Madrasas, and the Kisan Adarsh Inter College for secondary education, though access remains uneven across the community.

Chakanwala's dirt and partial construction roads reflect villages where missing infrastructure creates both problems and possibilities.

Chakanwala's link to the outside world runs through the crucial Chakanwala Road, a narrow but vital artery that carries goods, patients, and students to nearby towns. It is the village's lifeline for trade, healthcare, and education, connecting it to Gajraula junction 18 kilometres away, where four daily trains depart for Dhanaura and adjoining markets. This modest network sustains the community even as it underscores Chakanwala's isolation and dependence on the world beyond its fields.

In this village lives Dr. Idresh Hassan, a 47-year-old physician who runs a small clinic along this road. A family man with dependents, Dr. Hassan represents the educated middle class of rural India. His children attend local schools, and like many rural households, the family relies on several income streams to meet both everyday needs and the steady climb of aspiration.

Recent surveys show that over 94 per cent of rural households in Uttar Pradesh face daily power outages, with 65 per cent experiencing three or more interruptions lasting over two hours. The main causes include network overloading, aging infrastructure, frequent transformer failures, and power theft through unauthorized connections.

THE PROBLEM

The most persistent challenge that Dr. Hassan and his community faced was an unreliable electricity supply that had plagued the village for decades. Despite the introduction of grid power in 1997, reliable and continuous electricity remained elusive in the village. The village typically received only 12-15 hours of electricity per day, with frequent outages, particularly during daylight hours when commercial activities were most active.

For Dr. Hassan, unreliable electricity was not just an inconvenience but a roadblock to his economic advancement. He had long wanted to set up a small flour mill (*atta chakki*) to supplement his medical income. The village and its neighbouring hamlets had a steady demand for grain processing, and such a venture could have provided both extra income and a useful community service.

But the frequent power cuts and low-voltage conditions made the plan untenable. Traditional mills require steady electricity to run, and interruptions would halt work, frustrate customers, and result in losses. Diesel generators offered little relief as their fuel costs were high and operations unsustainable.

The alternatives available to villagers were no better. Diesel-operated processors charged premium rates and sometimes engaged in questionable practices, keeping back 50 grams for every 500 grams of grains processed as additional payment. This practice not only increased costs for villagers but also bred mistrust in the processing services.

Dr. Hassan's struggle to expand his livelihood pointed to a deeper structural problem. Unreliable electricity was slowing the village's economy, disrupting small enterprises, interrupting irrigation, and forcing daily life to adjust constantly to the uncertainty of power cuts. With electricity tariffs increasing from Rs 6–7 to Rs 11–12 per unit—a jump of about 35 percent—the cost of backup power through diesel generators became increasingly prohibitive for most villagers.

APPROACH AND IMPLEMENTATION

Dr. Idresh Hassan began exploring alternative ways to power his proposed flour mill in 2021. Solar energy emerged as the most promising solution, offering reliable, grid-independent power. His research took him to Amroha, 40 kilometres away, where he studied solar photovoltaic (PV) systems and learned about panel efficiency, inverter technology, and system sizing. Though initially complex, his educational background helped him grasp the essentials.

The major challenge was cost. While solar PV technology was proven, the initial investment was beyond a rural doctor's budget. Aware that solar prices were declining globally, Dr. Hassan decided to wait for a more viable opportunity. By 2024, falling PV costs and rising electricity tariffs made the investment feasible. Confident in the technology and seeking to avoid subsidy-related delays, he used his own funds to finance the project, ensuring complete control over system design and implementation.

Dr Hassan's house where solar power now supports both household needs and farm operations

Dr. Hassan operating solar-powered flour mill

He installed a 17.5 kW solar PV array with 30 modules of 585 watts each (649 watts BNPI), designed to operate a 10 HP flour mill motor and a 7.5 HP water pump for irrigation. Including irrigation capacity increased both system utility and returns. A key component was a 15 kW (20 HP) variable frequency drive (VFD) inverter that enabled precise motor speed control for heavy-duty milling operations. The VFD operated on three-phase 415 V DC input and adjustable 0–415 V AC output, allowing flexible speed variation. It met the differing speed requirements for grain cleaning, grinding, and sieving, reduced mechanical strain through soft starts and smooth acceleration, and protected the machinery from overloads, over-voltage, and phase loss, which are common in rural areas.

To cut costs further, Dr. Hassan implemented the system without battery storage, relying entirely on real-time solar generation. This eliminated the recurring maintenance and replacement costs of batteries, which typically require renewal every five to seven years.

In January 2025, Dr. Hassan invested Rs 3,40,000 of his personal savings to bring his vision to life. The installation, coordinated with suppliers in Amroha and technical experts, involved mounting 30 panels for optimal sunlight and integrating the inverter and VFD systems for safety and efficiency. One key challenge was adapting the setup

Doubling as shade and drying space for daily household use

Inspecting the pump system powered by his solar installation to handle the heavy, intermittent loads of flour milling. The VFD proved indispensable, enabling smooth operations despite frequent start–stop cycles.

Dr. Hassan introduced a transparent pricing model of eight rupees for processing five kilograms of grain, significantly cheaper than diesel mills that charged by withholding 500 grams per five kilograms. He prioritized consistency and reliability to build community trust, and the system's steady performance quickly demonstrated its value.

Alongside the mill, he installed a 700-watt solar system at his clinic, complete with a panel, inverter, and battery to power two LED bulbs, two fans, a mobile charging point, and a small vaccine refrigerator. This smaller setup showed how solar energy could meet varied needs across domestic and professional use. Dr. Hassan also trained his daughters to operate the mill, ensuring that the investment served the entire family and could be managed independently.

Through careful planning, technical learning, and personal investment, Dr. Hassan created a model of sustainable, community-serving entrepreneurship rooted in renewable energy.

RESULTS AND IMPACT

The results of Dr. Hassan's solar flour mill exceeded even his expectations. Within eight months of operation, he had recovered his entire Rs 3,40,000 investment.

The operational improvements were immediately visible. Dr. Hassan now processes 10–12 quintals of grain daily within six to seven hours of operation, achieving a grinding rate of 200 kilograms per hour while serving customers from Chakanwala and neighbouring villages. The reliable solar-powered system ensures consistent service throughout daylight hours, when energy generation is optimal, allowing customers to depend on uninterrupted mill operations.

The economic impact extended beyond simple payback calculations. The additional income from the flour mill supplemented Dr. Hassan's medical practice, providing essential financial support for his family, particularly for his children's education. The new income stream also improved the family's financial stability.

From an operational perspective, the system has required no maintenance after seven months of continuous use. The solar panels, regularly cleaned and maintained, continue to function at peak efficiency. This level of reliability contrasts sharply with the frequent breakdowns and high running costs of diesel generators and grid-dependent systems.

The benefits to the community have also been significant. Villagers now have access to reliable and affordable grain processing services without the uncertainty and added expense of diesel-operated alternatives. Transparent pricing and consistent service have built customer trust and loyalty within the community.

Dr. Hassan's success has also encouraged wider adoption of solar technology in the village. Seven other entrepreneurs have now installed similar solar-powered flour mills and irrigation pumps, creating a growing network of small-scale solar businesses.

The social impact within Dr. Hassan's own family has been particularly meaningful, allowing his family members operate the chakki and fostering economic self-reliance.

This change represents a broader transformation in household dynamics, as income generation becomes more distributed and family members gain greater confidence and independence.

In field observations, the system's reliability has been evident. Even during grid outages of more than an hour, the solar-powered mill continues to operate without interruption.

According to Lajja Devi, the Sarpanch of Chakanwala, "Most villagers use solar pumps for irrigation. Seven households have installed solar-powered flour mills. These systems work effectively and significantly reduce electricity bills."

CONCLUSION AND PATHWAYS TO SCALE

Dr. Idresh Hassan's solar flour mill stands as a powerful example of how decentralized renewable energy can transform rural economies. His initiative demonstrates that with individual determination, appropriate technology, and thoughtful planning, it is possible to overcome long-standing infrastructural and economic barriers in rural India.

The success of his project stemmed from several deliberate choices. By investing his own savings, Dr. Hassan avoided bureaucratic delays and maintained full control over system design and execution. Operating without battery storage reduced costs and maintenance needs while still meeting operational requirements. Integrating advanced technology such as the variable frequency drive (VFD) system proved that rural enterprises can effectively deploy sophisticated equipment when supported by technical understanding and training.

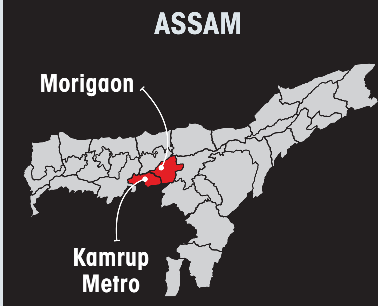
The impact of his work extended far beyond his own household. His success inspired at least seven other entrepreneurs in Chakanwala to install solar-powered mills and irrigation systems, creating a local demonstration effect that continues to ripple through the community. Yet, this experience also highlights the challenges to scaling such efforts. Limited technical expertise for installation and maintenance, outmigration of skilled youth, and seasonal demand fluctuations remain barriers that must be addressed for wider replication.

The long-term reliability of Dr. Hassan's system, expected to last 25–30 years, offers sustained energy security and a dependable income source. Scaling such models across rural India will require coordinated technological, financial, and institutional strategies. Advances such as brushless DC motors, improved grinding mechanisms, and multifunctional systems can enhance efficiency and profitability. Flexible credit, consumer financing, and incentives for early adopters can broaden access. Equally critical is building local technical capacity for installation and maintenance, ensuring both sustainability and rural employment.

Dr. Hassan's story demonstrates how reliable, affordable solar energy can empower rural entrepreneurs, strengthen social resilience, and spark community-wide transformation—offering a practical roadmap for sustainable rural development.

ASSAM

AEDA'S FLOATING SOLAR INITIATIVE REVOLUTIONIZES RURAL AQUACULTURE



"Before solar aerators, our ponds supported maybe 1,000 fishes per tank. Now we stock 2,000 because continuous oxygenation keeps water quality high even at double density. That is twice the productive capacity from the same tank. The real constraint was not the pond size but energy access to power the equipment that maximizes what the ponds can produce."

Jyotish Talukdar, Director,
Kalong–Kapili Integrated Aquaculture Centre

PARAMETER	DETAILS	
Location	Thanagarha village, Morigaon district, Assam	Bagibari village, Kamrup Metro District, Assam
Implementation partners	**Public sector**: Assam Energy Development Agency (AEDA) - policy support and coordination **Technical expertise**: Quant Solar (IIT Guwahati-incubated startup) **Community**: Local residents	**Public sector coordination**: Assam Energy Development Agency (AEDA); **Technical expertise**: Quant Solar; 100 per cent grant funding for ornamental breeding system: SELCO India; equal partnership for biofloc system: NABARD-SELCO India
Project highlights	10.5 kW capacity system; indigenous design using bamboo frames and HDPE drums; served 15 off-grid households; Powered lighting, fans, and pond aerators	Comprehensive floating solar-aquaculture integration facility; 10 kW floating solar plant with 30 modules of 330W each; 600 Ah batteries; multiple demonstration systems: mini-RAS (6 × 335 Wp panels), solar-based ornamental breeding system (680 Wp, four 170W panels), solar-powered biofloc system, Solar feed mill, hybrid solar dryer (50 kg capacity, 30W panel)
Cost of project, financing bank and rate of interest	**Total investment**: Rs 12-15 lakh by Quant Solar (capital investment and technical expertise); public-private-partnership model; community cost recovery through tariff payments	**Total investment**: Rs 14 lakh by Quant Solar for floating solar plant; Additional systems funded through grants from SELCO India and NABARD-SELCO India partnership; Primarily private investment and grant funding
Land owner and rental model	Land/water body owned by 15-household community in Thanagarha; no rental model—community members were both owners and beneficiaries; Water body utilized for dual purpose: fishing livelihood and energy generation	Land owned by Kalong-Kapili; no rental payments - facility established at Kalong-Kapili's own premises; water body utilized for dual purpose: energy generation
Project timeline	**Project initiation**: 2017; Success prompted survey of nine additional sites for replication; led to establishment of Kalong-Kapili centre concept	Floating solar commissioning: January 2022
Tariff model	**Initial tariff**: Rs 8 per unit; **Reduced tariff**: Rs 5 per unit; Tariff enabled cost recovery for Quant Solar while keeping energy affordable for community; covered operations and maintenance expenses	Revenue model covers maintenance, operations, and equipment replacement; sustainable financing without continuous subsidies
Monthly expenditure and income	**Income sources**: Tariff payments from 15 households; fish survival rates increased significantly; doubled stocking densities leading to higher yields. **Expenditures**: Operations and maintenance	**Revenue sources**: Fish stocking and breeding density doubled; Savings from eliminated diesel expenses. **Major expenditures:** Ongoing maintenance and cleaning (twice monthly); system repairs and replacements
Economic impact on livelihood	Household electrification provided lighting and fans to 15 families; aquaculture survival and stocking doubled, boosting yields and incomes. Diesel costs eliminated; mechanization, skills in installation/ maintenance improved living conditions and wellbeing.	Fish stocking doubled; farmers independently adopted solar pumps; 24/7 power enabled aeration and training. Over 10,000 farmers trained, 350 CRPs created, and state governments showed interest in wider replication.
Challenges and learnings	Remote grid extension was unviable, so bamboo and HDPE drums enabled a low-cost, adaptable system for seasonal water changes. Success relied on community-built infrastructure, affordable tariffs, indigenous materials, and local capacity building.	Inverter faults, a brief fire, dust, algae, and wildlife damage challenged operations; vendor delays stalled panel replacement. Solutions included cleaning and cable protection. **Key learnings**: strong maintenance, dual-purpose floating panels, diverse demos, hands-on training, and risk-sharing models.

1. THE PIONEER PROJECT: AEDA'S JOURNEY WITH THANAGARHA VILLAGE

In the remote village of Thanagarha in Assam's Morigaon district, fifteen households lived in near-complete isolation. The community, dependent entirely on a single pond for its fishing-based livelihood, lacked road access, communication links, and electricity. Without power, families relied on daylight for all work and occasionally used small diesel aerators for their ponds. The absence of energy access prevented the adoption of modern aquaculture techniques, restricted access to training programmes, and curtailed opportunities for income diversification.

This reality reflected thousands of similar settlements across Assam where energy poverty created cycles of underdevelopment. Without reliable electricity, fish farmers could not mechanize operations, install aeration or pumping systems, or use modern cold storage facilities. The resulting low fish survival rates and yields suppressed household incomes and reinforced dependence on traditional methods.

The problem

Extending the main grid to small, scattered settlements like Thanagarha was technically complex and economically unviable. Diesel generators, though functional, were expensive to operate, polluting, and inconsistent with the state's renewable energy goals.

The lack of electricity severely limited local aquaculture development. Poorly oxygenated ponds reduced fish survival, and the absence of cooling and lighting prevented productivity gains. For AEDA, the challenge lay in creating an affordable, sustainable, and locally adaptable energy system that could strengthen livelihoods.

A quiet village road stretching toward Thanagarha

Approach and implementation

AEDA responded in 2017 with a pioneering experiment: Northeast India's first floating solar power plant. The 10.5 kW system, installed on Thanagarha's pond, reimagined the water body as both a productive aquaculture site and a renewable energy platform.

Design and technology

AEDA collaborated with Quant Solar, an IIT Guwahati–incubated startup, to design an indigenous floating solar structure using locally available materials. Bamboo frames crafted by village carpenters formed the base, and HDPE drums provided buoyancy, ensuring affordability and easy maintenance.

Partnership and financial model

The project followed a Public–Private Partnership model integrating public coordination, private investment, and community participation. Quant Solar contributed Rs 12–15 lakh as capital investment and technical expertize, while AEDA provided policy support and coordination. The community contributed through a tariff-based payment mechanism that covered operations and maintenance.

The tariff, set at Rs 8 per unit and later reduced to Rs 5, enabled cost recovery for Quant Solar while keeping energy affordable.

Implementation process

Construction actively involved local residents, who learned to assemble, install, and maintain the floating system. The design allowed for seasonal water-level variations and was anchored to withstand monsoon conditions. Once operational, the system powered lighting and fans for all 15 households and ran pond aerators that improved water oxygenation. Fish survival rates increased significantly, and families were able to double stocking densities, leading to higher yields and household income.

The project's success drew attention from state authorities, prompting AEDA to survey nine additional potential sites for replication.

Results and impact

The Thanagarha pilot demonstrated that renewable energy could drive both social and economic transformation in off-grid communities. Electrification improved household living conditions, enabled mechanized aquaculture, and doubled fish production capacity. The floating solar system became a model for sustainable rural electrification.

Encouraged by this success, AEDA expanded the concept through its flagship Kalong–Kapili Integrated Aquaculture Centre, established in January 2021 at Bagibari near the agency's headquarters. The centre evolved into a full-scale training and demonstration hub linking renewable energy, aquaculture innovation, and farmer capacity building.

2. THE KALONG–KAPILI INTEGRATED AQUACULTURE CENTRE

System design and technologies

Commissioned in January 2022, the facility housed a 9.9–10 kW floating solar plant with 30 modules of 330 W each, supported by additional solar-based systems designed to demonstrate varied renewable energy applications in aquaculture:

- A solar-based ornamental breeding and mini recirculatory aquaculture system, funded entirely by SELCO India, used 680 Wp capacity from four 170 W panels and a four-battery bank (400 Ah total). It powered two 35 W DC aerators through a 20A, 12V charge controller.

- A mini Recirculatory Aquaculture System (RAS) with 6 × 335 Wp panels demonstrated advanced closed-loop water filtration that reused water while maintaining high stocking densities through mechanical and biological filters.

- A solar-powered biofloc system, installed through an equal partnership between NABARD–SELCO India and the Kalong–Kapili centre, showcased environmentally friendly aquaculture in which beneficial microorganisms converted fish waste into protein-rich bioflocs consumed by cultured fish. This system substantially reduced water exchange requirements and nutrient loss.

Floating solar panels installed on a pond of Kalong–Kapili Integrated Aquaculture Centre to power fish farming

- Additional renewable-linked subsystems included a solar feed mill for producing nutritionally balanced fish feed, and a hybrid solar dryer with 50 kg capacity connected to a 30-watt, 12V panel. The dryer used black-box thermal design principles to trap solar radiation and circulate warm air via DC fans, effectively removing moisture from feed and produce while maintaining nutrient quality.

Implementation

Before full deployment, feasibility testing was conducted using temporary panels and a DC pump to assess performance. The project faced several technical setbacks: inverter faults in March 2022, a minor fire due to loose connections in November 2023, and maintenance issues such as dust accumulation, algae growth, and wildlife interference with underwater wiring. Regular cleaning schedules and cable protection systems were instituted. One damaged panel remained unreplaced due to vendor delays, highlighting the need for better logistics management.

Training, outreach, and multiplier effects

The centre rapidly became a regional hub for aquaculture capacity building. Over 10,000 farmers from Assam, Odisha, Bihar, and Arunachal Pradesh were trained in solar-powered aquaculture techniques. Around 350 Community Resource Persons (CRPs) were developed to serve as local trainers, extending adoption through peer learning.

Continuous power supply enabled round-the-clock training, reliable aeration, and uninterrupted hostel and kitchen operations. Solar aerators improved pond oxygen levels, allowing fish stocking densities to double—from 1,000 to 2,000 fish per tank—according to farm in-charge Amulya Deka. Farmers began replicating technologies independently; one farmer installed a 200 W DC pump with three 600 W rooftop panels after witnessing the demonstration, reducing energy costs.

Broader adoption and policy relevance

The Kalong–Kapili model attracted attention from other northeastern states. Governments of Arunachal Pradesh and Nagaland expressed interest in replicating the aqua-entrepreneur model with AEDA's technical support. The project also demonstrated added ecological benefits, such as floating panels that reduced pond temperature during heatwaves, stabilizing aquatic ecosystems while maintaining power generation efficiency.

Strategic relevance and climate resilience

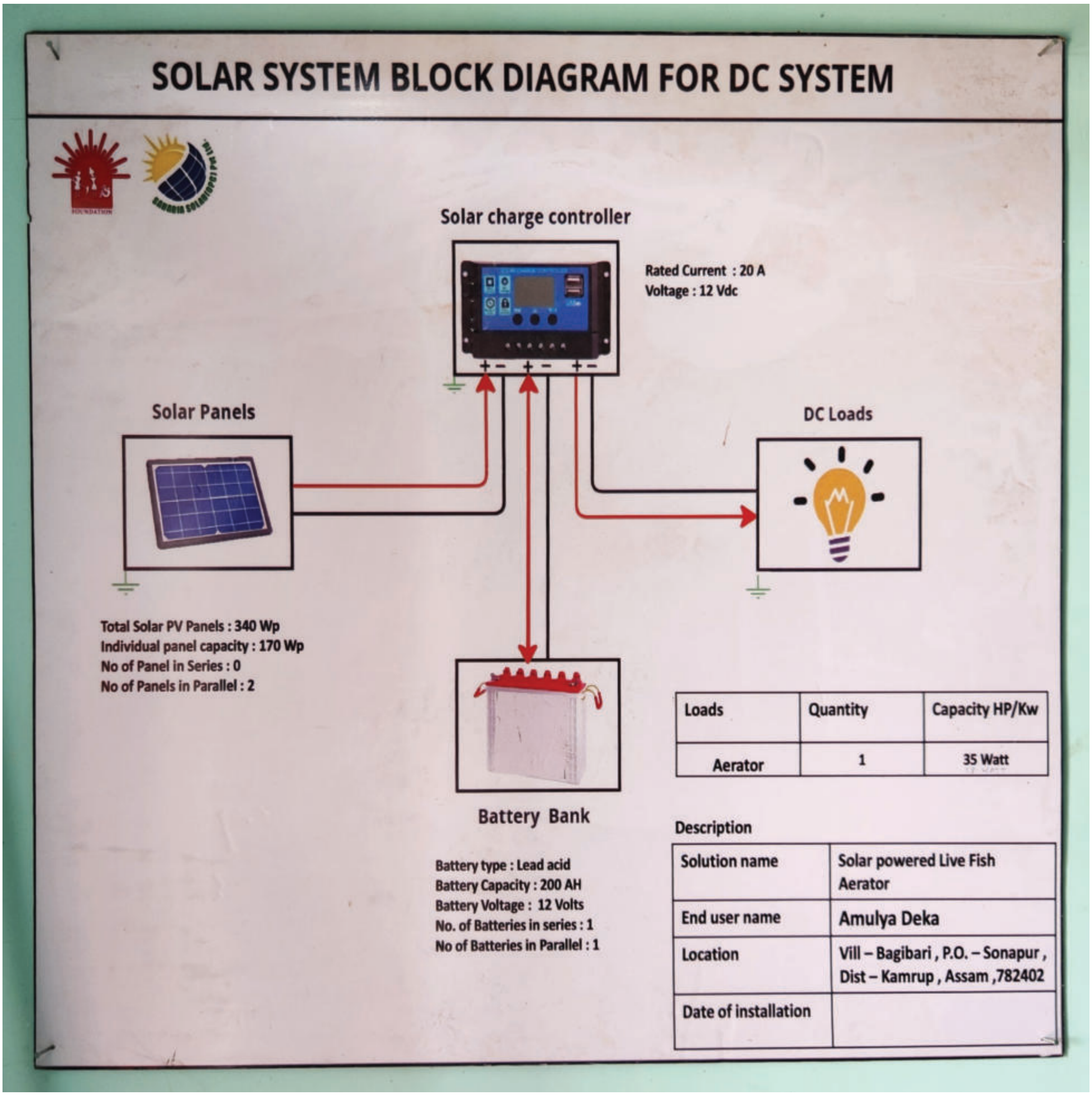
Kalong–Kapili Director Jyotish Talukdar highlighted that Assam's growing drought stress threatens both agriculture and aquaculture. During the critical breeding months of April to June, solar-powered aerators help regulate pond temperatures, while solar refrigeration supports post-harvest management by improving cold storage and reducing losses.

ASSAM: AEDA'S FLOATING SOLAR TRANSFORMS RURAL AQUACULTURE

Solar-powered Recirculating Aquaculture Systems (RAS) fish tanks set up under shade nets for improved aquaculture

CONCLUSION

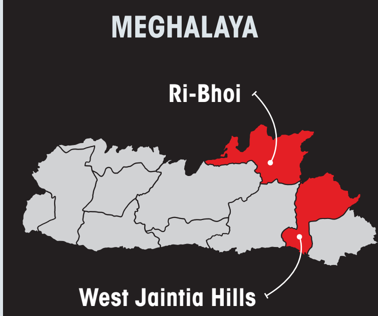
AEDA's pioneering initiatives in Thanagarha and Kalong–Kapili illustrate how renewable energy can drive inclusive, sustainable rural transformation. By merging technological innovation with community ownership, the agency created models that deliver reliable energy, enhance productivity, and build local resilience. The projects show that decentralized solar systems, whether floating on ponds or powering integrated aquaculture centres, can simultaneously advance energy access, environmental sustainability, and livelihood security across Northeast India.



Display explaining the solar-powered aeration system

MEGHALAYA

DECENTRALIZED SOLAR ENERGY STRENGTHENS MEGHALAYA'S LIVELIHOOD ECOSYSTEMS



"The Multi-Purpose Cooperative Society model ensures we collectively own the machines, share maintenance costs, and negotiate better prices together. One woman with solar equipment improves her own income, but sixty-four women organized through cooperatives can transform an entire sector's economics. Productive energy use works when it's embedded in cooperative structures that distribute benefits equitably, building collective bargaining power."

Victoria Syiem,
a weaver from Mawlong

PARAMETER	DETAILS
Location	**Multiple sites across Meghalaya:** • Umden village (Ri-Bhoi district) – silk spinning • Mawlong village, Umdohkha area (Ri-Bhoi district) – silk spinning and weaving • Sohkhar village (Ri-Bhoi district) – tailoring • Wahiajer village (West Jaintia Hills) – tailoring and food processing **Expansion coverage:** East and West Khasi Hills, East and West Jaintia Hills, all five Garo Hills (North, East, South, West, Southwest), and Nagaland
Implementation partners	**Primary implementer**: CES CAREs (Customized Energy Solutions) **Government/Institutional**: Meghalaya Basin Management Agency, United Nations Development Programme (UNDP) **Technology suppliers**: Resham Sutra (silk machines), Dharambir (food processing machines) **Financial support**: Small Industries Development Bank of India (SIDBI), Global Wheels Foundation (expansion funding)
Project highlights	**Silk production (Umden and Mawlong):** • Established Productive Use Renewable Energy Centre (PUREC) in October 2024 • Solar-powered Resham Sutra Abha Eri silk spinning machines (15W, 12V DC motor, 40Wp solar panel, 18Ah battery, charge controller) • Six-day training for 36 women initially, expanded to 64 weavers (aged 18-66) • Output increased 6-fold: from 100g/week (manual) to 600g coarse thread or 240g fine thread per week • 10 compact Eri spinning machines + 3 solar sewing machines installed **Tailoring (Sohkhar and Wahiajer):** • Solar-powered sewing machines (12V × 100Ah system with rooftop panel and battery) • Eliminated grid dependency, enabled evening work • 6-monthly maintenance schedule **Food processing (Wahiajer):** • Solar-powered multipurpose food processing machine (Dharambir V20 model) • 10-day training in machine operation and production optimization • Enabled consistent processing for pickles, candies, sauces, juices, millet chips, pineapple wine, soaps, shampoos
Cost of project, financing bank and rate of interest	**Equipment costs:** • Silk reeling machines: Rs 20,000 each • Solar sewing machines: Rs 50,000 each (with panels and batteries) • Food processing machines: Provided through UNDP grant **Financing model (50:50 funding):** • Beneficiary contribution: Rs 25,000 • CES subsidy: Rs 25,000 • Payment structure: Rs 3,000 upfront + Rs 1,000 monthly EMI for 22 months • Supported through UNDP grants and SIDBI financing • No specific interest rate mentioned
Land owner and rental model	**Cooperative ownership model:** • Multi-Purpose Cooperative Societies (MPCSs) provide facilities and manage operations • Ensures collective ownership and shared responsibility rather than individual ownership • Community workspace for training and operations • Local management and maintenance handled through cooperatives
Project timeline	**October 2024:** PUREC establishment **Initial deployment:** 30 silk production units **Late 2024:** Expansion to 50 additional units (Global Wheels Foundation funding) **April 2025:** Solar sewing machines introduced in Sohkhar **May 2025:** First earnings from Sohkhar tailoring operations **January 2025:** Food processing training completed in Wahiajer **By late 2024:** 210 productive-use machines deployed across Meghalaya and Nagaland (30 for silk production) **Target by 2027:** 20kg silk production per household annually, potentially creating 100,000 jobs

PARAMETER	DETAILS
Monthly income and profit	**Expenditure:** • Machine EMI**:** Rs 1,000/month for 22 months after Rs 3,000 upfront • Maintenance: Six-monthly servicing included in project • Raw material costs vary by sector **Silk spinning income:** • Coarse thread: Rs 2,700–3,000/kg; fine thread: Rs 4,000–5,000/kg • Average output: 2 kg coarse thread → ~Rs 5,500/month • Baseline income before solar: Rs 2,400/month **Silk weaving income:** • Wage rates**:** Rs 600/shawl; Rs 300/muffler; Rs 4,000–6,000/dhara • Product sale values: Shawls Rs 2,500–3,000; mufflers Rs 1,200–1,500; dharas Rs 15,000–20,000 **Tailoring income:** • Regular**:** Rs 8,000–10,000; summer: Rs 12,000–15,000; winter peaks: up to Rs 20,000 • Early-stage earnings (Sohkhar): Rs 1,100–1,300 **Food processing income**: • Rs 5,000–6,000/month from diversified products
Economic impact on livelihood	**Income transformation:** • Silk workers' monthly earnings rose from Rs 2,400 to Rs 5,500, with potential to reach 2–4x through spinning and weaving • Tailors earn Rs 8,000–10,000 monthly, with seasonal peaks up to Rs 20,000 • Food processors in remote villages earn Rs 5,000–6,000 despite weak-grid conditions **Value chain control:** • Earlier sold raw cocoons at Rs 700–1,000/kg to Assam • Now produce yarn locally at Rs 2,700–5,000/kg, retaining value within Meghalaya • Reduced reliance on expensive Assam mill yarn **Social benefits:** • Women balance home and income • Youth engaged in family enterprises • Traditional crafts preserved • Energy independence strengthened • Cultural tourism emerging • 210 machines deployed; roadmap targets 100,000 jobs by 2027
Challenges and learnings	**Challenges:** • High upfront costs (Rs 25,000–50,000) remain burdensome despite subsidies • Limited market access and frequent unsold inventory in remote villages • Gaps in bookkeeping, marketing, and business planning skills • Difficulty balancing traditional methods with modern technology • Small local markets requiring external linkages • Dependence on professional packaging and labelling services • Time pressures for women managing childcare, household duties, and enterprises **Learnings:** • Flexible financing and cooperative models improve viability • Integrated technical and business training is essential • Solar power ensures energy independence in weak-grid areas • Technology strengthens, not replaces, traditional practices • Cooperative ownership supports sustainability and knowledge sharing • Women-led enterprises flourish with appropriate tools and training • Scheduled maintenance enhances long-term performance • Continuous monitoring enables adaptive improvements • Cultural authenticity paired with efficiency strengthens market appeal

1. UMDEN: SOLAR INNOVATION REVITALIZES MEGHALAYA'S SILK VILLAGE

In Umden, a hill village in Meghalaya's Ri-Bhoi district, women have generationally spun Eri silk, also known as *peace silk*. This ethical silk-making practice is central to community life and identity. Yet production long relied on manual spinning wheels, limiting output to 300–600 grams of yarn per week. The physically demanding work and low income drove younger women away, threatening a centuries-old livelihood.

Local producers also faced structural inequities. They sold raw cocoons for Rs 700–1,000 per kilogram to processors in neighbouring Assam, who used mechanized mills to produce high-quality yarn retailing for Rs 3,500–5,000 per kilogram. The value addition, and profit, remained outside Meghalaya.

To address these challenges, a coalition of organizations launched the Productive Use Renewable Energy Centre (PUREC) in October 2024. The partnership brought together CES CAREs (implementer), the Meghalaya Basin Management Agency, UNDP, Resham Sutra, and SIDBI.

PUREC introduced solar-powered silk reeling machines developed by Resham Sutra, each equipped with a 15W, 12V DC motor, 40Wp solar panel, 18 Ah battery, and charge controller, ensuring operation even during cloudy days or outages. A six-day training programme for 36 women aged 18–66 covered machine handling, business planning, and cooperative management. The output tripled, from 300 grams to 1,000 grams of yarn weekly, raising average monthly earnings from Rs 2,400 to Rs 5,500 and improving yarn quality for higher-value markets.

Lush paddy fields surrounded by forested slopes on the way to Umden

MEGHALAYA: SOLAR POWER STRENGTHENS LOCAL LIVELIHOODS

Productive Use Renewable Energy Centre (PUREC) promoting renewable-energy-based livelihoods in Umden

The centre installed ten compact Eri spinning machines, three solar sewing machines, and related infrastructure. Equipment cost Rs 20,000 for silk reeling units and Rs 50,000 for solar sewing machines, supported by a 50:50 funding model; beneficiaries paid Rs 25,000 while CES subsidized the rest.

Encouraged by these results, the Global Wheels Foundation funded 50 additional units, doubling PUREC's scale. By late 2024, operations expanded beyond Ri-Bhoi to the East and West Khasi Hills, East and West Jaintia Hills, and all five Garo Hills (North, East, South, West, Southwest). The cooperative model, run through Multi-Purpose Cooperative Societies (MPCSs), ensured local management, maintenance, and shared ownership.

PUREC's decentralized approach brought environmental and social co-benefits. Solar power enabled energy independence and reduced fossil fuel dependence, while cultural tourism emerged as a new income stream as visitors witnessed the full silk-making process. Continuous monitoring tracked machine use, performance, and income trends, keeping interventions adaptive and efficient.

By 2024, 210 productive-use machines were deployed across Meghalaya and Nagaland, including 30 for silk production. The roadmap targets 20 kilograms of silk per household annually by 2027, potentially creating 100,000 jobs and tripling earnings in the sector. Umden's experience now serves as a replicable model linking renewable energy with rural enterprise and traditional craftsmanship.

Women working at a solar-powered tailoring unit

2. LASUBON PHAWA: A SOLAR-POWERED SUCCESS STORY

In the remote hills of Wahiajer village in West Jaintia Hills, where electricity remains unreliable, 42-year-old Lasubon Phawa has turned a simple passion for food processing into a thriving business supporting her family of six.

Her journey began in 2019, when she sought to create new income opportunities alongside her husband's single income. Determined to learn, she attended every available vocational training programme, mastering food products such as candies, pickles, juices, and sauces, and later branching into soaps and shampoos made from local wild essences and natural preservatives.

For years, power shortages constrained her growing enterprise. Food processing demanded steady electricity for heating, steaming, and operating machinery, but frequent outages made it difficult to maintain quality or output. This changed in October 2024, when she received a solar-powered multipurpose food processing machine (Dharambir V20 model), supplied by Customized Energy Solutions through a UNDP grant.

In January 2025, Lasubon completed a 10-day training programme conducted by Customized Energy Solutions. The sessions covered both machine operation and production optimization, peeling, juice extraction, essence isolation, heating, and steaming, all adapted for solar-powered systems. With consistent energy access and technical training, her business expanded rapidly.

Lasubon inside her small village; her processing and sales unit stocked with homemade products

Today, Lasubon produces a wide range of goods—pickles, candies, sauces, juices, millet chips, and pineapple wine, alongside handmade soaps and shampoos. She also runs a momo and chowmein shop, incorporating her own sauces to reduce waste and diversify income. When she needs professional packaging or labelling, she collaborates with local cybercafés and third-party vendors, showcasing an adaptive business approach.

Her ventures now generate a monthly income of Rs 5,000–6,000, a meaningful livelihood improvement for her village context. However, market access remains a challenge. Local demand is limited, often resulting in unsold stock, which she offsets by using excess sauces in her food outlet.

Lasubon recognizes that bookkeeping and business management are her next learning goals. She has received diary management training and plans to involve her children in operations as they grow, ensuring continuity and professionalization.

Her story highlights how renewable energy, skill development, and persistence can overcome rural infrastructure constraints. By combining solar technology with traditional food processing, Lasubon Phawa has built a viable, sustainable enterprise that demonstrates how decentralized energy access can enable value-added rural entrepreneurship.

Solar-powered multipurpose food processing machine (Dharambir V20) used by Lasubon


Shelves filled with pickles, sauces, juices, spices, and other value-added products

3. AMRITA PHAWA: EMPOWERING LIVELIHOODS THROUGH SOLAR-POWERED TAILORING

In the hill village of Wahiajer in West Jaintia Hills, Meghalaya, 57-year-old Amrita Phawa has built a livelihood grounded in skill, perseverance, and service. As the sole earner supporting her daughter and four grandchildren, she divides her day between public service and her passion for tailoring.

For the past decade, Amrita has worked as a Public Works Department supervisor, overseeing community cleaning from 8 AM to 3 PM. But it is in the evenings, behind her sewing table, that her craft truly thrives. With 19 years of tailoring experience, she has earned a reputation for precise stitching, creative design, and a rare expertise in sewing machine repair, setting her apart in her community.

Until recently, her work was limited by both manual equipment and unreliable electricity. Using a pedal-operated sewing machine meant constant physical strain, while power outages confined her work to daylight hours. The introduction of a solar-powered sewing machine, equipped with a rooftop panel and battery system, marked a turning point. Freed from grid dependency, Amrita could now work after dark, maintaining consistent quality and output.

Her productivity and income grew steadily. Monthly income now averages Rs 8,000–10,000, rising to Rs 12,000–15,000 in summer and up to Rs 20,000 during the winter wedding season. The improved reliability and flexibility have not only strengthened her

Amrita standing outside her home


Amrita's sewing work underway inside the household tailoring unit

family's finances but also enhanced her reputation for timely delivery and high-quality work.

Amrita's next goal is expansion. She envisions establishing a dedicated tailoring outlet and training other women to form a collective capable of fulfilling bulk orders, creating livelihood opportunities beyond her own household.

Her story illustrates how simple renewable energy interventions can have profound social impact and enable rural women to enhance productivity, sustain livelihoods, and balance their roles as workers, caregivers, and community leaders.

Solar monitoring and control system installed by Customized Energy Solutions

4. THERMALLY KHYMDEIT: STITCHING DREAMS WITH SOLAR-POWER

In Sohkhar village of Meghalaya's Ri-Bhoi district, 45-year-old Thermally Khymdeit balances household chores with a quiet determination to create something more. Her family of four lives modestly, with firewood still fuelling daily cooking even as an unused LPG cylinder sits nearby, yet her ambition extends far beyond the rhythms of rural life.

Tailoring had long been an occasional pursuit, limited to repairing torn garments or sewing baby clothes for neighbours, yet Thermally envisioned turning it into a sustainable family business with her son. That opportunity arrived in April 2025, when representatives from UNDP and Customized Energy Solutions (CES), in collaboration with the Multi-Purpose Cooperative Society (MPCS) and Productive Use Renewable Energy Centre (PUREC), introduced solar-powered sewing machines to her village.

Brightly painted home of Thermally, equipped with a rooftop solar panel

Her first experience with the new 12V × 100 Ah solar-powered machine was transformative. It operated smoothly and silently, enabling her to work after sunset, something the unreliable grid had never allowed. Scheduled six-monthly maintenance assured her of long-term functionality.

By May 2025, Thermally earned Rs 1,100 in her first month. It was a small but significant proof that her investment could yield returns. She used June to refine her craft, dedicating four to five hours daily to improving cutting precision and stitching quality. By July, she was earning Rs 1,300 through consistent tailoring orders for women's dresses, baby clothes, and repair work, building a loyal customer base through word-of-mouth.

The once-daunting monthly Rs 1,000 EMI soon became routine, sustained entirely by her earnings. More than financial relief, the machine brought independence and dignity, allowing her to work at her own pace and on her own terms.

Thermally now dreams of expanding into a full-fledged tailoring shop, training her son to join her in business. Although her schedule is split between childcare, household work, and income generation, leaving little time for further training, she remains committed to growth.

Each evening, as she powers down her solar machine, Thermally closes the day having stitched not just fabric, but the foundation of a more secure and self-reliant future for her family. Her story stands as a testament to how renewable energy access, inclusive financing, and women's entrepreneurship together enable sustainable rural transformation.

Thermally working from her sunlit living room workspace

5. VICTORIA SYIEM: WEAVING TRADITION WITH SOLAR INNOVATION

In the rolling hills of Meghalaya's Ri-Bhoi district, where mist gathers over terraced fields and old traditions endure, the practice of eri-culture and handloom weaving remains a lifeline for many families. The silk produced here, known locally as *ryndia* and elsewhere as *Ahimsa silk*, is unique in India. It is extracted without harming the larvae, reflecting the community's philosophy of living in harmony with nature. This gentle craft has always been women's work in Meghalaya, passed through generations as both livelihood and legacy. For elderly women and young mothers, it offers a rare form of income that allows them to stay rooted in home and community while contributing meaningfully to family welfare.

In Mawlong village within the Umdohkha area of Ri-Bhoi, 43-year-old Victoria Syiem carries this legacy forward. She manages a household of nine, including five children, while also working as a skilled weaver and natural dyer. Her craft, that she picked up from her mother through observation and long practice, has shaped her identity. For more than two decades, Victoria worked entirely by hand, using a traditional spindle to produce just 100 grams of yarn per week. The work was physically taxing and slow, but it kept alive the intricate artistry that defined her community's heritage.

Victoria wove shawls, mufflers, and *dharas* that carried the tribal identity of Ri-Bhoi's people. Yet, despite the beauty of her work, the economics of manual production offered

Community members walk through the settlement towards the training centre

little reward. Days of spinning yielded meagre returns, and inconsistent electricity made it impossible to adopt powered equipment. Local weavers were forced to buy mill-spun yarn from Guwahati at Rs 4,000–5,000 per kilogram, eroding profits and leaving artisans dependent on external markets.

This reality began to shift in 2024, when Customized Energy Solutions (CES) brought a new idea to Mawlong: solar-powered silk spinning machines. Supported by UNDP and implemented through local women's cooperatives, the project aimed to modernize eri silk production without displacing traditional knowledge. Victoria was one of the participants selected for the three-day training programme, where CES technicians demonstrated how solar power could drive spinning machines using clean, renewable energy.

Each participant learned to operate the Resham Sutra Abha Eri Silk Spinning Machine, a compact unit connected to a 40-watt solar photovoltaic system. For Victoria, who had longed worked to the slow rhythm of the hand spindle, the hum of the solar motor was transformative. The machine multiplied her efficiency sixfold. In the same week she once spent to produce 100 grams, she could now spin 600 grams of coarse thread or 240 grams of fine thread, expanding her capacity and product range.

The economic change was equally striking. Coarse thread now sells for Rs 2,700–3,000 per kilogram, and fine thread for Rs 4,000–5,000 per kilogram. With an average monthly output of two kilograms, Victoria earns around Rs 5,500 from spinning alone; an income

Community shed with portable solar panels kept outside to power the spinning machines

that once seemed unimaginable from traditional methods. The fine threads, with higher counts of five to six, also opened access to new markets beyond local fairs and cooperatives. Today, Victoria operates five solar-powered spinning machines, housed in a small community workspace where she also trains other women. This collective approach ensures that knowledge and opportunities continue to circulate locally. The machines' battery-backed systems allow uninterrupted operation, even during cloudy days or power cuts, ensuring consistency that hand-driven methods could never achieve.

Yet, spinning is only one part of Victoria's enterprise. She continues to weave shawls, mufflers, and dharas—products that turn raw yarn into finished pieces of high market value. Two kilograms of yarn can yield five shawls priced at Rs 2,500–3,000 each or seven to eight mufflers at Rs 1,200–1,500 each. A single dhara, woven from one kilogram of yarn, sells for Rs 15,000–20,000. When weaving on commission, Victoria earns Rs 600 per shawl, Rs 300 per muffler, and Rs 4,000–6,000 per dhara, depending on complexity and design.

The transformation in productivity was immediate and dramatic. Where Victoria had once struggled to produce 100 grams of yarn in a week, she could now produce 600 grams of course thread or 240 grams of fine thread in the same timeframe. This amounted to a nearly six-fold increase in output. More importantly, the solar spinning machines allowed her to produce both fine and coarse thread counts, something manual spinning had never permitted. The fine threads, with their five to six thread count, commanded premium prices in the market, while the coarse threads with their 60-thread count served different market segments.

Victoria guides local women as they operate solar-powered spinning machines during training

This dramatic increase in productivity opened new economic possibilities for Victoria's family. Spinning rates varied depending on thread quality, with course thread earning Rs 2,700 to Rs 3,000 per kilogram, while fine thread commanded Rs 4,000–5,000 per kilogram. Victoria's average monthly output of two kilograms of course thread generated approximately Rs 5,500 in spinning income alone.

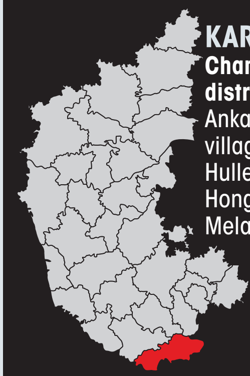
The solar-powered spinning also solved a persistent problem in the region. Previously, local weavers sometimes had to purchase mill-spun yarn from Guwahati at costs of Rs 4,000–5,000 per kilogram when locally spun yarn was unavailable. Now Victoria and her fellow weavers could produce sufficient high-quality yarn to meet local demand while maintaining complete control over their supply chain.

Among the 64 weavers trained under this initiative, Victoria stands out as both practitioner and teacher. She embodies a model of inclusive innovation where solar technology complements rather than replaces traditional skill. Her five children witness her work daily, understanding how the rhythm of old crafts can align with the hum of new machines to build a sustainable future.

Victoria's transformation from spinning 100 grams of yarn manually to 600 grams through solar power, illustrates the profound potential of renewable energy in traditional livelihoods. Her story is not just one of personal advancement but of community resilience, cultural preservation, and women-led innovation in Meghalaya's silk heritage.

KARNATAKA

FROM TRADITIONAL CRAFTS TO MODERN SOLAR SOLUTIONS



"My solar-powered roti machine produces 1,000 pieces hourly—ten times of what manual work delivered. Within six months, profits fully repaid the bank loan. Now I employ twelve local women at Rs 300/day in structured jobs that didn't exist before. Productive solar use isn't charity, it's creating an entire local employment ecosystem around one mechanized, energy-independent food processing unit."

Mariswamy,
Founder, Nandus foods

PARAMETER	DETAILS
Location	Chamarajanagar District, Karnataka. Four villages studied: Ankanasettypura (1,476 residents), Hullepura (121 residents), Honganuru (6,539 residents), and Melajipura (3,498 residents)
Implementation partners	• **SELCO India:** Primary technology provider and installation partner for solar systems across all cases • **Sri Kshetra Dharmasthala Rural Development Project (SKDRDP)**: Financing partner for blacksmith case • **Karnataka Milk Federation (KMF)**: Market linkage for dairy farmer • **Self-Help Groups (SHGs)**: Community mobilization and support network
Project highlights	Four diverse solar-powered livelihood interventions: **Solar Roti Unit (Mariswamy):** 670W panels, 2×200Ah batteries, 25-year life, 4 hrs daily use, 2-day backup. **Solar Blacksmithing (Mahadeva):** 60W panel, 30Ah battery, 15A controller, 4–6 hrs direct use, 7–8 hrs backup. **Solar Tailoring (Ambika):** 60W panel, 60Ah battery, powers sewing machine with speed control. **Integrated Solar Dairy (Mahadev):** 2.5 kWp panels, 4×200Ah batteries, runs milking machines, pumps, foggers.
Cost of project, financing bank and rate of Interest	**Roti unit:** Rs 3,80,000 total investment (50 per cent government subsidy: 35 per cent central + 15 per cent state; 50 per cent personal contribution + bank loan through PMFME scheme at 6 per cent interest rate) **Blacksmithing**: Rs 15,000 through SKDRDP subsidy and loan structure **Tailoring**: Cost not specified, facilitated through SHG networks and SELCO India financing **Dairy**: 2.5kW solar system with government subsidies and cooperative linkages (specific costs not detailed)
Land owner and rental model	All beneficiaries own their operational land/premises: Mariswamy converted 1,800 sq ft ground floor of his home; Mahadeva operates from his traditional workshop; Ambika works from her residence; Mahadev owns 6-acre farm with dairy shed. No rental models involved - all represent owned asset development.
Project timeline	• **Roti unit**: Started 2014 in Mysore, moved to village 2015, solar installation recent years, loan repaid within 6 months • **Blacksmithing**: SELCO India intervention in 2021, immediate operational benefits • **Tailoring**: Solar installation in 2021, immediate productivity gains • **Dairy**: Transformation began 2023 with SELCO India support, comprehensive system implementation
Tariff model	No grid-tied systems - all operate as standalone solar installations with battery backup. Energy independence model rather than net metering or feed-in tariffs. Systems sized for captive consumption: 670W (roti), 60W (blacksmith), 60W (tailoring), 2.5kW (dairy).
Monthly income, expenditure	• **Roti unit:** Daily production 2,500-3,000 units at Rs 2.5 cost, Rs 5 selling price; 12 women employees earning Rs 300/day • **Blacksmithing**: Income increased to Rs 600-1,000 daily (eliminated Rs 300-400 daily labor costs) • **Tailoring**: Income doubled from Rs 600 to Rs 1,200 daily, production increased from 3 to 5-6 dresses daily • **Dairy**: Rs 2,100 daily milk sales + Rs 300 government incentive + Rs 630-840 additional from improved yields
Challenges and learnings	**Challenges:** Shifting from manual to electric methods, limited financing, lack of technical support in remote areas, workflow integration issues, and seasonal demand fluctuations. **Key learnings:** SHG networks ease adoption, training must go beyond installation, local financing works better, integrated solutions outperform standalone ones, and follow-up support ensures sustainability. Success lies in aligning technology with traditional practices, not replacing them.

BACKGROUND

Chamarajanagar District stands as one of Karnataka's most compelling examples of potential meeting adversity. Established on August 15, 1997, this southernmost district of Karnataka shares borders with both Tamil Nadu and Kerala. The region serves as a unique ecological corridor connecting the Western and Eastern Ghats, housing crucial protected areas including Bandipur National Park, Biligiri Rangaswamy Temple Tiger Reserve, and Cauvery Wildlife Sanctuary.

Despite its rich biodiversity and strategic location, Chamarajanagar faces significant economic challenges. Classified as one of Karnataka's most economically backward regions, it ranks lowest among all districts. The district's economy relies heavily on agriculture, with 74 per cent of the net sown area being rain-fed, making it vulnerable to monsoon variations. Of the district's 4.81 lakh workforce, 67 per cent work in agriculture as cultivators or labourers, highlighting the region's agricultural dependency. This economic landscape creates a perfect testing ground for sustainable development interventions that can preserve traditional livelihoods while introducing modern efficiencies.

1. MARISWAMY'S JOURNEY: FROM MANUAL ROTI MAKING TO SOLAR-POWERED ENTERPRISE, ANKANASETTYPURA VILLAGE

Ankanasettypura village, located 9 kilometers from the Chamarajanagar district headquarters, typifies the challenges faced by rural Karnataka's small-scale food

Mariswamy at his solar-powered enterprise in Ankanasettypura village processing sector. With a population of 1,476 (Census 2011), its economy reflects the district's agricultural base, where 87 per cent of farmers operate on holdings smaller than two hectares.

In this setting, 48-year-old Mariswamy emerged as an unexpected entrepreneur. An ITI-trained professional who had spent years at Automotive Axles Ltd. in Mysore, he grew weary of shift work and sought independence. Inspired by a friend's brother who had left a corporate job in Bengaluru to start a similar food venture in 2013, Mariswamy studied his operations and launched his own in late 2014.

Competition in Mysore proved stiff, prompting him to relocate in 2015 to his native village, where he converted the 1,800-square-foot ground floor of his home into a food processing unit. There, he obtained FSSAI and CSIR-CFTRI certification, securing the credibility needed to establish his enterprise in a largely untapped local market.

The problem

Traditional roti making in rural India had changed little over time, relying on manual techniques that demanded both skill and endurance. In Ankanasettypura, the challenge was particularly acute. Local demand for products like *holige* (coconut-stuffed sweet roti) and *papad* was rising steadily, driven by restaurants, caterers, and festive occasions, but production methods had not kept pace.

Mariswamy's early years as an entrepreneur were defined by hardship. Using manual tools and working with minimal capacity, he struggled to meet growing demand without compromising on quality. The physical nature of the work restricted daily output, while frequent power cuts confined operations to daylight hours. Scaling production while maintaining the traditional taste his customers expected became his greatest hurdle.

Every stage of production was labour-intensive—kneading dough to the right texture, portioning it evenly, flattening sheets, and managing delicate frying— were all done by hand. These slow, repetitive processes created severe bottlenecks. Despite having a strong local market, Mariswamy found himself unable to expand during festival seasons, when demand was highest and potential profits greatest.

Approach and implementation

Mariswamy's transformation from a small-scale food producer to a sustainable entrepreneur was built on a combination of technological innovation and renewable energy adoption. With support from Solar Light Private Limited (SELCO India), a pioneer in decentralized solar solutions, and financial assistance through the Pradhan Mantri Formalisation of Micro Food Processing Enterprises (PMFME) scheme, he mechanized his operations while ensuring energy self-reliance.

At the heart of the initiative was a solar-powered roti rolling machine system designed to reduce manual labour, enhance output, and maintain consistent product quality. The decision to adopt solar power was both economic and practical. Frequent power outages in rural Chamarajanagar made grid-based operations unreliable, while the cost of

Dough mixing machine in his solar-powered enterprise

conventional energy would have eroded profits. The solar installation, comprising 670-watt monocrystalline panels with a 25-year lifespan, two 200 Ah batteries for storage, and a hybrid charge regulator of 50 A 24 V, was configured to power the roti rolling machine and a dough-making unit simultaneously. Together, these handled kneading, shaping, rolling, and cutting, automating what had previously been manual, time-intensive tasks.

Implementation began with securing Rs 3,80,000 in total investment, half of which was subsidized under the PMFME scheme (35 per cent central and 15 per cent state government contributions). The remaining 50 per cent came from Mariswamy's savings and a bank loan, with the subsidy directly credited to his Aadhaar-linked account after repayment. SELCO India's technical team installed the system, ensuring precise solar alignment and seamless equipment integration. Vendor technicians trained Mariswamy and his two women employees in machine operation, maintenance, and safety procedures.

Once operational, the solar-powered unit delivered striking results. The machine could roll 800–1,000 rotis per hour, producing 2,500–3,000 pieces within just three hours of daily operation. Battery backup enabled four hours of use each day with up to two days of autonomy during cloudy conditions. The system ran entirely on solar power during daylight, while cooking processes requiring heat drew on scrap wood from local sawmills. The latter was an innovative use of waste material that reinforced circular economy principles.

Women operating a semi-automatic dough-pressing machine in the solar-powered food processing unit

Mariswamy stands beside his solar powered dough sheeter used for large-scale roti production

Rooftop solar panels installed above the processing unit supply daytime power for production activities

Mariswamy also planned for future expansion. The installation was designed to accommodate additional equipment, such as a poha-making machine, with solar panels positioned to support a potential second-floor extension. This foresight reflected a commitment to scalable, sustainable growth.

Product diversification strengthened the business model further. The system produced multiple varieties—maida, jowar, wheat, and millet rotis, alongside coconut-stuffed *holiges* and papads—each catering to specific market segments. Production cycles were aligned with seasonal demand, with *holiges* dominating wedding and festival seasons, while millet-based rotis met steady demand among health-conscious customers. Through this integrated approach, Mariswamy's enterprise evolved into a model of rural innovation, merging traditional food culture with clean energy and long-term economic resilience.

Results and impact

The financial results exceeded expectations. Within six months of operation, the business generated sufficient profit to completely repay the bank loan; an exceptional achievement for a rural microenterprise. The operational economics proved highly favourable: with production costs of Rs 2.5 per roti and selling prices of Rs 5, the business achieved a strong profit margin while remaining affordable for customers.

Production efficiency improved dramatically. The solar-powered system enabled daily production of 2,500–3,000 rotis compared to the previous manual capacity of only 200–

Women preparing rotis and parathas on a large tawa in kitchen unit

300 units. This ten-fold increase in productivity allowed the business to meet both regular orders from local hotels and restaurants and large bulk orders for marriages and religious gatherings.

Employment generation became a significant social outcome. The operation expanded from Mariswamy's initial solo effort to employing 12 local women, with plans to reach 50 by the end of 2026. These women work from 7:30 AM to 4:00 PM, earning Rs 300 per day in regular, structured employment that had not previously existed in the village. For many, this marked their first experience in organized food production, providing both income and valuable skill development.

Market expansion validated the business model's viability. Initially serving only Chamarajanagar district, the enterprise began planning expansion into neighbouring districts, reflecting strong growth potential. The sourcing of raw materials from Mysore due to quality requirements demonstrated integration with regional supply chains while maintaining high product standards.

The preservative-free products, with a seven-day shelf life, aligned with consumer preferences for healthy, traditional foods while enabling practical distribution and storage.

The success established Ankanasettypura as a recognized hub for traditional food products, creating wider economic opportunities. Local supply chains, transport networks, and associated services benefited from the business's growth, demonstrating the multiplier effects of sustainable, solar-powered rural enterprises.

2. REVIVING TRADITIONAL BLACKSMITHING THROUGH SOLAR INNOVATION, HULLEPURA VILLAGE

Hullepura village, with just 121 residents across 30 households (Census 2011), is the smallest among the case studies and reflects the challenges of traditional artisans in rural Karnataka. Located 17 kilometres from the district headquarters, its 75 workers, both main and marginal, indicate limited local employment opportunities.

In this setting, blacksmithing has long supported the agrarian economy by providing essential farm tools and household implements. For Mahadeva Shetty, a second-generation blacksmith with over two decades of experience, the craft was both livelihood and legacy. His skill and reliability attracted farmers from surrounding villages who depended on his timely repair and fabrication services.

Mahadeva maintained a steady stock of raw materials from nearby towns and often repurposed metal from discarded farm tools, ensuring uninterrupted service. This consistency and craftsmanship built strong trust among local farmers.

However, the traditional methods that defined his work also restricted growth. Manual forge-blowing was physically demanding, smoke-filled conditions created health risks, and dependence on seasonal labour reduced productivity. These factors limited his ability to expand his enterprise or improve his family's economic situation.

The problem

Mahadeva's blacksmithing enterprise faced growing operational and economic pressures. The manual blower system required to maintain furnace temperatures demanded continuous labour, costing Rs 300–400 per day. With daily earnings averaging Rs 1,000, labour expenses consumed nearly half his income, leaving only Rs 600 in hand.

When Mahadeva tried to reduce costs by having his wife assist with the manual blower, exposure to coal smoke led to respiratory issues that forced her to stop, highlighting the severe health risks of traditional blacksmithing in poorly ventilated spaces.

Labour reliability further complicated operations. During farming seasons, agricultural work drew away available labourers, and few were willing to take on the exhausting, monotonous task of furnace pumping. These disruptions often coincided with peak demand for agricultural tool repairs, leading to missed opportunities.
Economic instability compounded the problem. Fluctuating coal and gas prices made fuel costs unpredictable and profit margins uncertain. Combined with high labour costs, inconsistent manpower, and hazardous working conditions, the traditional model became increasingly unviable, even as market demand for blacksmith services remained strong.

The coal-based forge also filled the workshop with dense smoke and fumes, causing eye and breathing irritation and making it difficult to retain workers. The combined strain of

Mahadeva's thatched workshop fitted with a standalone solar panel that powers the blower for his traditional blacksmithing work

economic vulnerability and health hazards left Mahadeva's enterprise on an unsustainable path.

Approach and implementation

Mahadeva's blacksmithing transformation began in 2021 when SELCO India identified his operational difficulties during routine village visits. Mallikarjun, a SELCO India field representative, recognized how manual blowers, labour costs, and health risks constrained traditional blacksmiths and proposed a solar-powered motorized blower system to address these issues simultaneously. The goal was to remove dependency on labour, reduce health hazards, ensure consistent forge performance, and provide reliable, low-cost power independent of the grid.

The system design included a 60-watt solar photovoltaic panel positioned for optimal sunlight, a 100 Ah battery with safety locks to prevent theft, and a 15-amp charge controller to protect the battery and regulate power flow. The entire system was designed by SELCO with blacksmiths and is DC-operated to ensure maximum electrical efficiency and low cost. The motorized blower operated quietly and efficiently, providing steady air supply to maintain furnace temperature. The setup allowed 4–6 hours of direct use during sunshine and 7–8 hours with battery backup, comfortably meeting daily production requirements even under cloudy conditions.

Financing was facilitated through the Sri Kshetra Dharmasthala Rural Development Project (SKDRDP), whose flexible loan terms suited rural artisans. The total project cost of Rs 15,000 was covered through a mix of subsidy and credit, ensuring affordability. The repayment plan was structured so that the savings from avoided labour costs, which had previously been Rs 300–400 per day, could offset the EMI payments while still increasing Mahadeva's income.

Implementation began with a detailed assessment of Mahadeva's forge and energy needs. SELCO India technicians customized the installation for his traditional setup, integrating the new blower with existing tools. The panel and battery were securely placed, wiring insulated, and safety systems installed. Training covered daily operation, maintenance, and scheduling work to coincide with solar availability. Within weeks, Mahadeva adapted easily, reserving peak solar hours for heavy forging and using stored energy for lighter work.

SELCO India's follow-up visits provided continued technical support, ensuring the system operated efficiently and that Mahadeva's business faced no interruptions. The intervention demonstrated how renewable energy solutions, paired with accessible financing and on-ground training, could revitalize traditional crafts while making them safer, more productive, and economically sustainable.

Mahadeva working at his traditional forge, shaping tools using charcoal-fired heat

Results and impact

The impact of the solar-powered system on Mahadeva's livelihood was swift and far-reaching. His daily income rose to Rs 600–1,000, with higher earnings during Saturday markets when demand for agricultural tools peaked. The elimination of daily labour costs for operating the furnace saved Rs 300–400 per day, substantially increasing his net profits and financial stability.

Operational efficiency improved sharply. The motorized blower provided steady airflow and precise temperature control, enabling consistent forge performance and higher-quality output. This reliability allowed Mahadeva to deliver work on time, boosting customer satisfaction and ensuring repeat business from surrounding villages.

Health conditions improved significantly. With no manual blower to operate, exposure to smoke and dust reduced, creating a cleaner and safer workspace. The reduction in physical exertion also allowed Mahadeva to work longer, more comfortably, and with greater focus on craftsmanship rather than physical endurance.

The time and energy saved opened new economic avenues. Mahadeva diversified into small-scale tea vending, fish trading, and land cultivation, creating multiple income streams that reduced his household's vulnerability to market fluctuations. His improved economic position and the cleaner, more modern workshop elevated his standing in the community, turning him into a local example of how traditional artisans can thrive through renewable energy adoption.

Beyond personal gains, the benefits extended to the wider farming community. With Mahadeva's reliable services, farmers could maintain and repair tools promptly, improving regional agricultural productivity.

His success added to SELCO India's portfolio of over 4,000 similar installations across India, reinforcing the scalability of solar-powered artisan solutions. It also built confidence among rural banks and cooperatives to finance such ventures, paving the way for broader replication of sustainable livelihood technologies across India's traditional crafts sector.

3. EMPOWERING WOMEN THROUGH SOLAR-POWERED TAILORING, HONGANURU VILLAGE

Honganuru village in Chamarajanagar taluka represents the largest community in our case studies, with 6,539 residents distributed across 1,467 families. This substantial population creates a vibrant local economy with diverse needs and opportunities. The village's employment structure includes 2,950 total workers, with 1,484 main workers and 1,466 marginal workers, reflecting the mixed economic activities that characterize larger rural settlements.

Within this community, Ambika, wife of Maheshan, had been pursuing tailoring as a livelihood for over two decades. Her journey began in her youth when she learned the craft and gradually built a reputation for quality work among local customers. For twenty years, she had operated a manual pedal-powered sewing machine, relying entirely on physical strength to power her equipment while serving customers who needed blouses, petticoats, kurtis, and simple dresses.

Ambika's skill level was considerable, earned through years of practice and customer service. She understood the nuances of different fabrics, the requirements of various garments, and the seasonal patterns that drove demand in her community. Festival seasons brought orders for traditional clothing, while wedding seasons created demand for more elaborate ceremonial garments. However, her ability to capitalize on these opportunities was severely constrained by the limitations of manual equipment and unreliable electricity supply.

The broader context of women's economic participation in rural Karnataka made Ambika's situation particularly significant. Traditional gender roles often limited women's income-generating opportunities, and tailoring represented one of the few socially acceptable ways for women to earn independent income while maintaining household responsibilities. The success or failure of such enterprises had implications beyond individual economics, affecting women's empowerment and social status within their communities.

Maheshan and Ambika at their home in Honganuru

The problem

Ambika's challenges were rooted in the physical limits of manual sewing and the absence of reliable electricity in her area. Operating her pedal machine required constant physical effort, allowing her to complete only three dresses per day despite her experience. The strain restricted her to two or three working days a week, depending on her stamina and order flow, making it difficult to maintain a stable customer base or predictable income. Customers needing quick deliveries often turned elsewhere, affecting her reliability and market reach.

The lack of electricity confined her work to daylight hours, preventing her from extending production into evenings or early mornings, which were crucial during wedding and festival seasons when demand and potential earnings were at their peak. Fatigue also affected quality control: uneven pedal motion occasionally produced irregular stitching, forcing rework and reducing efficiency.

Financially, her ceiling was low. At Rs 200 per dress and three dresses per day, her maximum daily income was Rs 600. Working only 2–3 days a week meant weekly earnings rarely exceeded Rs 1,800. This limited income contributed modestly to household expenses but could not provide true economic independence. Repeatedly, Ambika lost higher-value orders priced at Rs 500–600 during peak seasons simply because her manual setup could not meet deadlines or volume demands.

Approach and implementation

Ambika's transformation began in 2021 when she learned about SELCO India Foundation's solar-powered sewing machine initiative through her sister and local Self-Help Group (SHG) networks. The SHG, seeing its potential for women's livelihoods, directly approached SELCO India to facilitate installations. This community-led engagement underscored how grassroots networks can effectively drive sustainable technology adoption.

The intervention focused on retrofitting Ambika's existing manual sewing machine with an electric motor powered by a standalone solar system, enabling her to keep her familiar setup while eliminating the physical strain of pedalling. The system comprised a 60-watt solar panel, a 60 Ah battery, and a charge controller that regulated current flow and safeguarded battery health. The electric motor, designed specifically for sewing machines, offered adjustable speed control for handling different fabrics and stitching requirements. This flexibility ensured improved precision without compromising craftsmanship.

Implementation began with a site and equipment assessment by SELCO India technicians to determine power requirements, machine compatibility, and solar panel placement. The installation positioned the panel for optimal sunlight, secured the battery with adequate ventilation, and protected all electrical components from dust and moisture. Ambika received hands-on training covering daily operation, power management, and basic maintenance. She learned to align heavy stitching with peak solar hours and use stored energy for evening work.

Ambika inside her home-based tailoring unit powered by a decentralized solar connection

Transitioning from manual to electric operation after two decades required adaptation. Ambika gradually adjusted to the motor's speed control and fabric handling, supported by SELCO India's technicians during the early phase. Quality control routines were refined to maintain stitching standards at higher speeds.

The system's battery capacity allowed Ambika to continue tailoring after her day job at Everest Industries, where she earned Rs 10,000 per month working in the factory kitchen. This enabled her to pursue a dual-income strategy, working at the factory during the day and engaging in solar-powered tailoring at night, which maximized both her productivity and financial stability. The SHG remained an active support hub, coordinating technical assistance and ensuring long-term system upkeep within the community.

Results and impact

Ambika's productivity transformation was swift and remarkable. Her daily output rose from three dresses to five or six, nearly doubling her efficiency without compromising quality. Mechanization enhanced her tailoring skills, allowing her to meet customer expectations while producing more garments. Flexibility also improved, as she increased her working days from two or three per week to four or five. Stored solar energy freed her from daylight constraints, enabling evening work after her factory shifts and significantly extending her productive hours.

The economic impact was profound. Her tailoring income doubled from about Rs 600 to Rs 1,200 per day, complementing her steady factory salary of Rs 10,000 per month. This dual-income approach created financial security and the ability to plan for the future. Seasonal demand further amplified her earnings—during weddings and festivals, she produced high-value garments that substantially boosted household income.

The benefits extended beyond finances. Reduced physical strain enabled longer hours, though her combined schedule remained demanding. Yet the trade-off was worthwhile, delivering unprecedented stability. Socially, Ambika became a role model as the first solar-powered tailor in her village, inspiring other women to adopt technology. Her success fostered new skills in scheduling, machine operation, and business planning, laying the foundation for future growth. Ambika now aspires to establish a tailoring outlet at her home, expanding opportunities for herself and other women in her community.

4. INTEGRATED SOLAR SOLUTIONS TRANSFORM DAIRY FARMING, MELAJIPURA VILLAGE

Melajipura village, located 14 kilometers from Chamarajanagar district headquarters near the Tamil Nadu border, is home to 3,498 residents across 717 households. Its proximity to the border enables active agricultural trade and market linkages, while its sizeable population sustains livelihoods in dairy farming, crop cultivation, and small-scale commerce.

Amid this landscape, Mahadev Swami emerged as a progressive dairy farmer managing 20 cows and exemplifying the aspirations of modern smallholders adapting traditional

Young dairy farmer at cattle shed preparing feed before the morning milking routine practices to meet market standards. Operating within the Karnataka Milk Federation (KMF) cooperative network, he relied on consistent milk production and quality to maintain his income. His six-acre holding supported fodder cultivation and offered access to water and transport facilities critical for dairy operations.

Yet persistent rural constraints such as unreliable electricity, labour-intensive processes, and seasonal fodder shortages limited efficiency and profitability. Across Chamarajanagar district, such challenges mirrored the broader tensions of opportunity and vulnerability within Karnataka's dairy sector: strong cooperatives and government incentives coexisted with climate and resource pressures. Mahadev's shift toward solar-powered, integrated dairy farming emerged as an innovative response to these structural barriers.

The problem

Mahadev's dairy enterprise grappled with a series of interlinked challenges that constrained both productivity and sustainability. The foremost issue was unreliable electricity, disrupting essential activities such as milking, water pumping, and feed processing. Manual milking was slow and labour-intensive, while irregular water supply during hot months compromised animal comfort and lowered yields.

Seasonal fodder scarcity compounded these difficulties. Green fodder cultivation depended heavily on the monsoon, leaving dry periods when feed quality and availability declined. Purchased fodder raised input costs and often reduced milk quality, making year-round consistency difficult to maintain.

Cattle resting in the shed equipped with a solar-powered fogger to provide relief during the summer heat

Labour shortages intensified the strain. Manual milking demanded two to three workers and up to 20 minutes per cow, limiting output and making it hard to sustain schedules during peak farming seasons when labour shifted to fieldwork.

Water use was inefficient across operations. Conventional irrigation wasted substantial quantities and distributed nutrients unevenly, while wastewater from the dairy unit was discarded instead of recycled, incurring both an environmental and economic loss.
Extreme heat posed a final, critical threat. With summer temperatures reaching 40–42°C, Mahadev lost five cows in one year to heat stress, while milk production dropped by about 30 per cent. Lacking reliable power for cooling systems, he faced recurring financial setbacks and risks to livestock welfare, underscoring the urgent need for a resilient, energy-secure system.

Approach and implementation

Mahadev's dairy transformation was implemented in partnership with SELCO India, combining renewable energy, resource management, and animal welfare into an integrated system. SELCO India provided technical expertise and helped him access government subsidies and cooperative linkages, ensuring the intervention addressed energy, water, fodder, and productivity challenges simultaneously.

At the centre of the model was a 2.5 kWp solar array installed on the dairy shed roof, which saved land for fodder cultivation and was connected to four 200 Ah batteries to ensure reliable backup. The system powered DC milking machines, water pumps, automated foggers, and lighting, removing dependence on unreliable grid power and diesel generators. Mahadev reported that DC-based milking machines were noticeably more comfortable for cattle, as conventional AC machines often operated with irregular—and at times excessive—pressure due to voltage fluctuations. DC systems with battery backup ensured stable, controlled performance, reducing stress on animals and improving overall milking conditions. The solar-powered milking machines reduced milking time to 3–4 minutes per cow, improved hygiene, and helped maintain milk quality. Auto-locking milk cans and air-pump systems further ensured purity during transport to the collection centre.

To address heat stress, Mahadev integrated a temperature-sensitive fogger that automatically activated at 28°C, preventing production drops during extreme heat.

Fodder management was redesigned for diversity and efficiency. His six-acre farm now grows Napier grass, paddy grass, and sweet corn in 75-day cycles across 0.5-acre plots, improving feed nutrition and increasing yields by 3–4 litres of milk per cow daily. A hydroponic system installed behind the dairy shed produces fresh green fodder year-round using recycled wastewater from cleaning and cattle washing. Drip irrigation across traditional plots minimized water use and ensured uniform nutrient distribution, while warm wastewater from cattle bathing in winter was redirected to irrigate sweet corn and hydroponic fodder, creating a circular resource loop.

Rooftop solar and water-heating system installed at the farm

Solar-powered milking machine that automates dairy operations

SELCO India further supported Mahadev in linking with veterinary services, accessing subsidies, and strengthening his connection to the Karnataka Milk Federation. The result was a self-sufficient, solar-powered dairy model that improved operational efficiency, reduced costs, and demonstrated how renewable energy can power sustainable rural enterprise.

Results and impact

Mahadev's solar-powered dairy has exceeded expectations, delivering measurable gains in productivity, income, and sustainability. With six lactating cows, the farm now produces 60 litres of milk daily, and solar-powered milking completes each cow in 3–4 minutes with high hygiene and temperature control.

Daily milk sales earn Rs 2,100 through the Karnataka Milk Federation (KMF) and an additional Rs 300 from state incentives. Improved nutrition from sweet corn fodder has raised yields by three to four litres per cow, adding Rs 630 to Rs 840 in daily income, or roughly Rs 25,000 more each month. Regular KMF payments and incentives have further stabilized household cash flow.

Solar integration cut operating costs by eliminating diesel expenses and reducing labour needs. Automated systems eased physical strain for the three-person team and improved productivity. The fogger system prevented heat-related cattle deaths, while improved feed and comfort boosted animal health and fertility, lowering veterinary costs.

Environmental benefits included zero fuel emissions, wastewater recycling, and hydroponic fodder cultivation ensuring year-round feed supply. SELCO India's biannual maintenance ensured reliability and system longevity.

Today, Mahadev's farm serves as a live demonstration site for neighbouring farmers. His model proves how renewable energy, integrated resource use, and effective policy support can transform smallholder dairy farming into a sustainable, high-yield enterprise.

CONCLUSION AND RECOMMENDATIONS

1. Key learnings: Group ownership through Self-Help Groups (SHGs) and Farmer Producer Organizations (FPOs) strengthens adoption and sustainability. Collective mechanisms improve credit access, reduce individual risk, and enhance bargaining power. The Urja Mandal model in Jharkhand exemplifies successful women-led energy management.

Moving from subsidy dependence to commercial viability is crucial. Users who invest financially demonstrate greater commitment and achieve better outcomes.

2. Critical success factors: Sustained usage requires access to working capital, raw materials, and output markets—not just technology installation. Strong market linkages for inputs and outputs are essential for solar-based enterprises to remain viable.

3. Recommendations: Policymakers must ensure inter-ministerial coordination and converge existing schemes to support DRE livelihoods. Technology manufacturers should provide complete operational information, training, and establish buy-back programs. Implementing organizations must assess market ecosystems before deployment and build local capacity. Financial institutions should treat DRE assets as mainstream credit portfolios with flexible repayment terms aligned to seasonal income cycles.

Floating solar panels mounted on a water surface, operating alongside an aeration system

PHOTO COURTESY: BINIT DAS, CSE

The case studies, spanning Karnataka's farmlands, Jharkhand's tribal interiors, Meghalaya's hills, and Assam's rural settlements, reveal a consistent finding: when solar energy combines with community ownership and entrepreneurial initiative, transformation follows. Decentralized renewable energy is not merely about electrification but about enabling productivity, ownership, and economic mobility.

LEARNING 1: GROUP OWNERSHIP THROUGH SELF-HELP GROUPS AND FARMER ORGANIZATIONS

Across locations, most renewable energy adopters were members of Self-Help Groups (SHGs) or Farmer Producer Organizations (FPOs). This pattern underscores that collective ownership strengthens both adoption and sustained use.

Group mechanisms improve access to finance since lending institutions prefer extending credit to collectives, reducing individual risk. They also enhance business viability by pooling savings, accessing government support, and enabling shared maintenance. The Urja Mandal model in Jharkhand demonstrates this clearly: women-led collectives not only managed solar generation and distribution but also built accountable, self-sustaining systems. When trained in both technical and business operations, these groups established institutions that continued to evolve with community needs. Collective ownership also improves bargaining power with suppliers and buyers, leading to better market outcomes.

LEARNING 2: MOVE FROM SUBSIDY DEPENDENCE TO COMMERCIAL VIABILITY

A central insight across sites is that users who contribute financially to their systems engage more consistently and achieve better results. Partial self- investment drives commitment to regular use and maintenance, leading to stronger economic outcomes.

Examples across states illustrate this principle. In Uttar Pradesh, Dr Idresh Hassan's solar flour mill recovered its Rs 3.4 lakh investment within eight months and inspired seven replications. In Karnataka, entrepreneurs like Mariswamy expanded solar-powered processing units and created employment because they had personal financial stakes in success.

Data from Jharkhand's Burhibir village and other sites demonstrate that even small rural enterprises can sustain commercial renewable-energy models when ownership is local and operational costs are transparent. Evidence contradicts the assumption that rural consumers cannot support market-based energy systems.

Scaling future interventions requires a deliberate shift from grant-heavy models to commercial deployments backed by targeted, evidence-based capital support. When users pay part of the cost, they assume ownership, maintain equipment better, and become advocates for adoption within their communities.

LEARNING 3: SUSTAINED USE THROUGH WORKING CAPITAL AND MARKET ACCESS

Many renewable-energy programs measure success by the number of installations rather than by sustained usage. Continuous operation depends on access to working capital, inputs, and markets. Without these, assets remain underused or idle, undermining creditworthiness and user confidence.

Field data show that users often discontinue operations due to lack of funds for raw materials or difficulty in selling outputs. Where these barriers are addressed, replication follows rapidly. Dr Hassan's flour mill in Uttar Pradesh, the mini-grids in Burhibir and Patratoli, and floating-solar pilots in Assam all triggered local replication because visible success reduced perceived risk.

Effective renewable-energy interventions must therefore link technology deployment to enterprise financing, supply chains, and product marketing.

LEARNING 4: STRENGTHEN MARKET LINKAGES

Technology alone cannot guarantee viability. Solar-based enterprises require functioning input and output markets. For instance, solar silk-reeling units depend on steady cocoon supply, while solar dryers and food-processing systems need reliable buyers and distribution channels.

In some regions, weak price realization for dried products reduced technology usage, highlighting the need for coordinated interventions that align production capacity with market demand. Successful enterprises demonstrate that renewable energy can drive value chains by lowering costs, improving quality, and reducing dependence on intermediaries.

THE POLICY COHERENCE GAP

State policies set capacity targets from renewable energy planning models while attempting to address livelihood outcomes governed by different economic and social logics. Bihar's Renewable Energy Policy 2025 exemplifies this tension. It defines technology categories (solar agriculture, distributed RE: on-grid and off-grid), establishes capacity targets with annual milestones, and specifies technical parameters for grid interconnection. Yet when addressing DRE livelihoods, the policy reduces to generic statements: "The State will promote decentralized and off-grid solar applications for creating livelihood opportunities as per MNRE guidelines." No operational definition of livelihood applications, no assessment of market demand for services, no financing architecture tailored to enterprise cash flows, no institutional mechanism ensuring installed systems remain operational beyond commissioning.

Jharkhand's Solar Policy 2022 creates provisions for off-grid solar applications including mini-grids and DRE livelihood applications. However, it remains silent on post-installation: how do community institutions managing these systems access working capital? What business development services support enterprise viability? How are input supply chains and output markets integrated rather than left to ad-hoc arrangements? Odisha's Vision 2036 and 2047 recognizes that "sustainable rural development requires more than access to electricity—it demands reliable, affordable energy that can power income-generating activities." This conceptual clarity doesn't translate into actionable mechanisms. The Vision delegates DRE livelihood implementation to unspecified "partner organizations," assumes "convergence" will occur through exhortation rather than institutional design, and provides no budgetary allocations, performance metrics, or accountability frameworks for livelihood outcomes.

STRUCTURAL OMISSIONS: THE MISSING MIDDLE

Three gaps prevent scale:

Firstly, the absence of differentiated intervention frameworks. All three state policies treat DRE livelihoods as monolithic, requiring uniform support. Field evidence reveals the opposite: solar flour mills in Uttar Pradesh demonstrated commercial viability with 8-month paybacks and required no subsidy; solar silk reeling in Meghalaya struggled with cocoon supply volatility; mini-grids in Jharkhand's Patratoli and Kotam enabled multiple enterprises but required upfront infrastructure investment; solar-powered mini-grids in Sugadongar and Bandatoli eliminated kerosene dependence but needed community institutional capacity building; solar food drying remained experimental with uncertain market acceptance. Policy must distinguish: (a) mature applications ready for commercial finance with credit enhancement, (b) emerging technologies requiring demonstration support and market development, (c) public infrastructure enabling multiple enterprises. No state policy makes these distinctions, resulting in over-subsidization of viable activities or under-support for innovations.

Secondly, the working capital financing void. Bihar's policy provides extensive capital incentives—100 per cent SGST exemption, stamp duty reimbursement, electricity duty waiver—yet offers zero provisions for working capital that determines whether equipment operates or sits idle. This gap is acute for mini and micro-grids: while Kotam's mini-grid demonstrates financial sustainability with 38,600 monthly revenue against 24,645 operational costs, this required Hasib Ansari's flour mill to secure working capital independently—22,000 down payment plus 9,400 monthly installments for equipment, plus capital for wheat procurement and customer credit. Nagwanti Devi's sewing center needed fabric inventory and thread supplies for continuous operation. These working capital requirements—30–40 per cent of establishment costs—fall outside renewable energy policy frameworks.

Thirdly, the institutional coordination deficit. All three policies acknowledge inter-departmental coordination—Bihar mentions "convergence of schemes," Jharkhand tasks JREDA with "coordination with implementing agencies," Odisha commits to "whole-of-government approach." None establishes permanent, empowered mechanisms with dedicated budgets from multiple departments, clear decision-making authority, performance metrics tied to livelihood outcomes rather than installation targets, and professional staffing with multi-year tenures. Transform Rural India Foundation's success in Jharkhand resulted from sustained, multi-stakeholder coordination. Without institutionalizing this, programs remain fragmented.

POLICY-PRACTICE MISALIGNMENT

Policies reward capacity addition over sustained operation. Bihar's policy bases benefits on commissioning dates and installed capacity—creating perverse incentives for rapid deployment regardless of viability. The provision that "RE projects commissioned during the operative period will be eligible for incentives for 25 years from commissioning" front-loads benefits to installation while providing no performance-linked rewards for enterprises generating sustained income, employment, or high utilization.

Monitoring frameworks reinforce this bias. State policy requires "real-time data pertaining to plant performance" but defines performance purely in technical terms—generation capacity, uptime, grid stability. No mandate tracks employment generated, household incomes affected, women's economic participation, enterprise survival rates, or productivity gains. Jharkhand allocates "minimum five per cent of total budget for R&D" including piloting, but lacks vision for translating pilots into scaled programs.

THE COMMERCIAL VIABILITY PARADOX

The most significant failure is continued reliance on subsidy-heavy models that undermine commercial sustainability required for scale. Field evidence shows entrepreneurs with personal financial stakes—Dr. Hassan's self-financed flour mill, Mariswamy's solar roti unit with 50 per cent personal investment, the 50-50 cost-sharing model in Burhibir and Umden—demonstrate superior commitment, maintenance discipline, and business acumen. Policies continue defaulting to high-subsidy approaches.

Odisha's framework offering "60 per cent subsidy for systems up to 3kW for off-grid projects" creates expectations that renewable energy livelihoods require permanent external support. Bihar's blanket incentives—100 per cent exemptions across categories—make no distinction between public goods (grid infrastructure) deserving full public investment and private enterprises that should transition to commercial viability.

Evidence from financially sustainable models is compelling: Kotam's mini-grid generates Rs 38,600 monthly against Rs 24,645 operating costs, producing Rs 13,955 monthly surplus while serving 129 consumers. TRIF's Solar Grid Suraksha Samiti collected Rs 2.62 lakh from 60 mini-grids, spends Rs 60,000 on repairs—demonstrating properly structured community systems achieve financial sustainability without permanent subsidies. Policies have not codified these lessons into graduated support frameworks.

THE PATH FORWARD

Transforming insights into actionable policy reform requires interventions across four dimensions:

Institutional architecture reform

States must establish permanent Livelihood-Energy Integration Cells with joint leadership from energy and rural development departments, authority to approve convergent budgetary allocations, and performance metrics tied to livelihood outcomes (income generated, employment created, enterprise survival rates) rather than capacity installed. Bihar's proposed "Bihar Akshay Urja Kendra" in each district requires operational substance—dedicated staff, district-level mapping of livelihood-energy opportunities, and coordination authority over department schemes.

Differentiated financing frameworks

Replace blanket subsidies with graduated support tied to technology maturity. Public investment should concentrate on: (a) network infrastructure enabling multiple enterprises—100 per cent public funding; (b) mature livelihood applications with demonstrated two-to-three-year paybacks—transition to credit guarantee mechanisms and interest subvention, partnering with NABARD and regional rural banks; (c) innovative applications and first-mover risks—50-60 per cent capital support bundled with buyer development, technical troubleshooting, and market intelligence. This three-tier framework should be explicitly adopted with clear graduation criteria.

Working capital integration mandates:

State policies must require any DRE livelihood intervention above 5 kW capacity includes pre-deployment assessment of working capital requirements, identification of input suppliers with documented price volatility, mapping of output markets with buyer commitments, and bundled financing providing both equipment capital and working capital with repayment aligned to production cycles. Bihar's "convergence of schemes" should be operationalized around working capital: if MNRE supports solar food processing equipment, the Department of Food Processing Industries must commit to off-take or buyer connections, NABARD/rural banks must provide working capital loans, and Agriculture Department must ensure raw material supply access.

Performance-based monitoring and adaptation:

State policies should mandate quarterly tracking of: utilization rates (operating hours, production volumes), income effects (enterprise revenues, household income changes, employment generated), sustainability indicators (maintenance performed, local service availability, community institution functionality). Low utilization of mini-grid generation capacity leads to high tariff rates, undermining affordability. When fixed infrastructure costs are spread across limited consumption, per-unit charges become prohibitive, discouraging further use—creating a self-reinforcing cycle of underutilization and unaffordability. Utilization monitoring is therefore critical not just for tracking impact but for ensuring financial sustainability and tariff viability. Odisha's commitment to "real-time monitoring and planning tools" and "performance dashboard for transparency" must extend beyond energy metrics to livelihood outcomes. States should publish annual DRE Livelihood Report Cards with: technology-wise utilization rates, enterprise survival rates beyond year three, average income effects per installed kW, and case studies of both successes and failures with lessons learned.

THE CENTRAL GOVERNMENT'S ENABLING ROLE

While state governments bear primary implementation responsibility, the central government must provide enabling frameworks. MNRE should establish a dedicated DRE Livelihood Mission focused on technology-livelihood demonstration centers across diverse agro-climatic zones, innovation challenge funds testing emerging applications with 70 per cent capital grant plus three years operating support, and rigorous impact evaluation partnerships with research institutions. MNRE should facilitate interstate learning networks, develop standardized monitoring frameworks adaptable to state contexts, and create incentive structures rewarding states for livelihood outcomes rather than capacity installation.

MNRE must coordinate with the Ministries of Rural Development, Agriculture, Food Processing, Tribal Affairs and Skill Development to create convergent implementation guidelines yielding joint scheme design, shared budgetary allocations requiring multi-ministerial approval, common performance metrics forcing accountability for integrated outcomes, and interstate competitions rewarding best livelihood-energy convergence models.

CONCLUSION: POLICY READINESS FOR SCALE

The question isn't whether DRE can transform livelihoods—field evidence confirms it can. The question is whether policy frameworks enable this transformation at scale. State policies create legal authorization and basic incentive structures but lack the institutional depth, financing sophistication, and ecosystem coordination required to move from pilots to paradigm shifts.

Bihar, Jharkhand, and Odisha have articulated visions and established policy foundations. The next phase demands operational translation: converting broad commitments into specific institutional mechanisms, replacing blanket subsidies with differentiated frameworks, integrating working capital and market linkages as non-negotiable components, and reorienting monitoring toward livelihood outcomes.

India's renewable energy transition can either remain a power sector achievement with limited rural economic impact, or become a catalyst for inclusive prosperity. Six hundred million rural Indians deserve policies matching their entrepreneurial energy with institutional frameworks worthy of their potential. The evidence exists, successful models are documented, and policy gaps are identifiable. What's missing is political and administrative will to close them.

When this transition occurs, India's 600 million rural residents won't merely consume clean energy—they'll produce with it. Scattered pilots will transform into a national movement where every village becomes a site of energy-enabled enterprise, every mini-grid anchors productive activity clusters, and every installed kilowatt translates into expanded opportunity. The choice before policymakers is clear: continue incremental programs delivering modest impacts, or embrace systemic reform positioning DRE-enabled livelihoods as central to India's renewable energy transition and rural prosperity agenda.

This report examines the role of decentralized renewable energy (DRE) in enhancing rural livelihoods through detailed case studies that highlight both its transformative potential and the practical challenges of implementing community-centred renewable energy solutions across diverse rural contexts. Drawing on 21 case studies across five states, it documents a range of solar-powered initiatives—from solar mill operations in Uttar Pradesh to mini-grids in Jharkhand and floating solar projects in Assam—that are reshaping rural economies where conventional grid infrastructure has proved inadequate.

Through analysis of interventions across five distinct geographical and socio-economic settings, the report distils key lessons, identifies scalable models, and offers actionable guidance for policymakers, development practitioners, and private sector actors working to expand rural energy access and sustainable economic growth. Beyond providing reliable electricity, these solutions enable new local enterprises, improve agricultural productivity through solar irrigation, and strengthen community ownership and long-term sustainability. Women's empowerment emerges as a significant outcome, with decentralized systems supporting increased workforce participation and leadership among women in local institutions.

By documenting real-world impacts alongside implementation realities, the report provides both evidence and a practical blueprint for scaling up DRE solutions, making it a valuable resource for those engaged in India's clean energy transition and rural development.

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phone: 91-11-40616000 Fax: 91-11-29955879
Website: www.cseindia.org