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Solar Energy Improves the Livelihood of Rural Populations: Case Study of Green India Initiative PVT. LTD. & the Solar Man of India

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Abstract

Rural livelihoods in India suffer from unreliable energy, limited access to productive technologies, and weak market connections. Decentralized solar energy (DRE) provides a way to overcome these challenges by offering reliable, clean power close to demand centres and enabling productive uses of energy (PUE).

This paper explores whether and how solar energy can enhance rural livelihoods. It does so by combining global and Indian evidence along with a focused case study on Green India Initiative Pvt. Ltd. (GII) and its founder-director, Dr. Sachin Yashwant Shigwan, known as the Solar Man of India. The paper employs a mixed-methods approach that includes literature synthesis, program mapping, and outcomes reported by practitioners. It uses a framework based on livelihoods capitals (human, social, physical, natural, financial) to analyse the impacts. The findings show that solar energy significantly improves livelihoods when systems are designed for productivity and integrated into markets, finance, and maintenance networks.

The GII case highlights scalable features such as appliance bundling, women's enterprise models, anchor-load strategies, and remote monitoring. These features convert watts into steady income, job growth, and resilience. The paper concludes with recommendations on policy, finance, and operations to expand productive DRE across rural India while managing environmental and social risks.

Keywords:

decentralised renewable energy, rural livelihoods, productive use of energy, mini-grids, Green India Initiative, Dr. Sachin Yashwant Shigwan, India

1. Introduction

Access to reliable electricity is seen as essential for modern economic activity and social development. In rural India, the expansion of the grid has resulted in impressive electrification rates, yet the quality of service—such as hours of supply, voltage stability, and reliability—is often inadequate for productive activities. Diesel generators fill the gaps but come with high costs and environmental harm. Meanwhile, rural households and small businesses face significant post-harvest losses, seasonal unemployment, limited cold chains, and time-consuming chores, especially for women. Decentralized solar energy (DRE)—including solar home systems (SHS), solar pumps, mini- and micro-grids, solar cold chains, and large-scale institutional systems—has advanced technologically and economically over the past decade. Declining module prices, affordable batteries, smarter controls, and innovative business models like pay-as-you-go and energy-as-a-service have made solar energy viable for widespread rural use. However, whether solar energy actually improves livelihoods depends on design choices. These include whether the systems support productive uses, how they are financed, how maintenance is guaranteed, and how issues of gender and inclusion are handled. This research investigates whether solar energy can enhance the livelihoods of rural populations. We address this question by combining global and Indian evidence with a detailed analysis of efforts led by Green India Initiative Pvt. Ltd. (GII) and Dr. Sachin Yashwant Shigwan's leadership. The paper maps different types of interventions to livelihood capitals, examines impact mechanisms, documents outcomes reported by practitioners, and identifies enabling conditions and risks for scaling efforts.

2. Conceptual Framework:

Mapping Energy to Livelihood Capitals

We adapt the sustainable livelihoods framework (DFID, 1999) to evaluate how solar energy influences the five capitals that support rural livelihoods:

- **Human capital:** time use, health, skills, educational outcomes.
- **Social capital:** institutions, networks, collective action (SHGs, FPOs).
- **Physical capital:** energy infrastructure, machines, irrigation equipment, refrigeration.
- **Natural capital:** water resources, soil health, local air quality.
- **Financial capital:** income, savings, creditworthiness, asset accumulation.

Our theory of change connects inputs (finance, technology, capacity building) to activities (electrification, deployment of PUE appliances, market connections). These then create outputs (hours of reliable power, functioning appliances), leading to outcomes (increased productivity, new enterprises, women's empowerment) and long-term impacts (poverty reduction, resilience). Feedback loops—like tariffs funding operations and maintenance, community governance improving compliance, and appliance revenue enhancing repayment capacity—play a crucial role in determining sustainability.

3. Literature Review

3.1 Global evidence on DRE and livelihoods

Cross-country evaluations of rural electrification and DRE consistently show positive effects on welfare when energy access is reliable and appliances support productive activities. Studies indicate improvements in household welfare (reduced kerosene use, extended productive hours), education (increased study hours), and income growth for small enterprises when electricity is dependable and appliances are accessible. However, programs focused solely on hardware often do not achieve lasting benefits. Evidence highlights the importance of complementary finance, after-sales service, and business development support for sustainable livelihood improvements.

3.2 Indian context

India's national programs, like rural electrification schemes and PM-KUSUM for solar pumps, show both potential and challenges. Solar pumps lower diesel uses and fuel costs, but they can threaten groundwater if not managed well. Mini-grid pilots have created businesses and income opportunities where anchor loads and appliance financing are present. Solar projects in institutions such as schools and primary health centres are linked to better service delivery. The research highlights the effectiveness of interventions focused on productive use of energy and stresses that scaling up needs clear institutions, tariffs that reflect service quality, and structures for long-term operation and maintenance.

3.3 Gaps and debates

There are ongoing discussions about managing groundwater with solar pumps, the economics of mini-grids as the central grid grows, and how to ensure affordability for the poorest. Studies show a need for strong monitoring, evaluation, and learning frameworks, along with long-term independent evaluations to confirm claims made by practitioners.

4. Methodology

This study uses a mixed-methods approach that includes:

1. A synthesis of peer-reviewed studies, sector reports, and program evaluations on decentralised renewable energy and livelihoods.

2. An analysis of the Green India Initiative, including organisational literature, project briefs, and outcomes reported by practitioners, clearly marked where independent verification was not available.

3. A mapping of interventions to livelihood assets and possible impact mechanisms.

4. Comparative snapshots of cases to show typical outcomes and trade-offs.

Limitations: Practitioner-reported figures may be overly positive. Independent evaluations for some GII projects were not publicly accessible for this study. Where outcomes are reported by practitioners, they are regarded as suggestive and used to illustrate mechanisms, not as firm causal evidence.

5. The Rural Energy and Livelihoods Landscape in India

Rural livelihoods are mostly based on agriculture and change with the seasons. Many people also participate in small non-farm businesses. Energy can help address several major issues:

- Post-harvest losses for perishables happen due to poor cold storage.
- High irrigation costs and reliance on diesel are challenges.
- Institutions like schools and primary health centres often have unreliable service, which affects human development.
- Women spend a lot of time collecting water and fuel.
- Limited productive time after sunset occurs due to a lack of lights and electricity.

DRE technologies can help solve these problems by providing dependable power for pumps, mills, cold storage, refrigeration, lighting, and device charging, enabling activities that can increase income.

6. Technology and Delivery Models

6.1 Technologies

- **Solar home systems (SHS):** provide lighting, phone charging, and small DC appliances.
- **Mini/micro-grids:** AC/DC systems that support productive uses such as mills, welding, and refrigeration.
- **Solar pumps:** Include surface and submersible pumps with DC/AC drives.
- **Solar cold chains:** consist of walk-in cold rooms, refrigerated vans, and milk chillers.
- **Institutional systems:** feature rooftops with battery backup for schools and primary health centres.

6.2 Delivery models

- **Pay-as-you-go (PAYG) / Energy-as-a-Service:** users pay monthly for a service rather than just for hardware.
- **Community ownership with operations and maintenance contracts:** local councils or self-help groups own the assets, while third parties operate and maintain them.
- **Anchor-business-community (ABC):** vital loads like schools, primary health centers, and cold rooms help stabilize cash flow.
- **Product-linked finance:** financing for appliances used in productive uses through microfinance institutions or self-help groups.
- **Public-Private Partnerships (PPPs):** combined support through corporate social responsibility, grants, or viability gap funding.

7. Case Study: Green India Initiative Pvt. Ltd. & Dr. Sachin Yashwant Shigwan

7.1 Organizational overview

Green India Initiative Pvt. Ltd. (GII) is a social enterprise working in several Indian states. Its goal is to use solar energy to support rural development. The founder and director, Dr. Sachin Yashwant Shigwan, known as the Solar Man of India, has led livelihood-focused solar projects that promote productivity and social inclusion. GII's materials and project briefs highlight efforts in over 1,000 villages across 14 states, aiming to reach 10,000 villages by 2035.

7.2 Strategic pillars

GII's approach is based on several key points:

1. PUE-first orientation: Systems are created to power livelihood appliances, such as mills, cold rooms, and pumps.

2. Appliance bundling and finance: Selected appliances and financing available through SHGs and MFIs.

3. Women-led models: SHGs and women energy entrepreneurs manage services and small businesses.

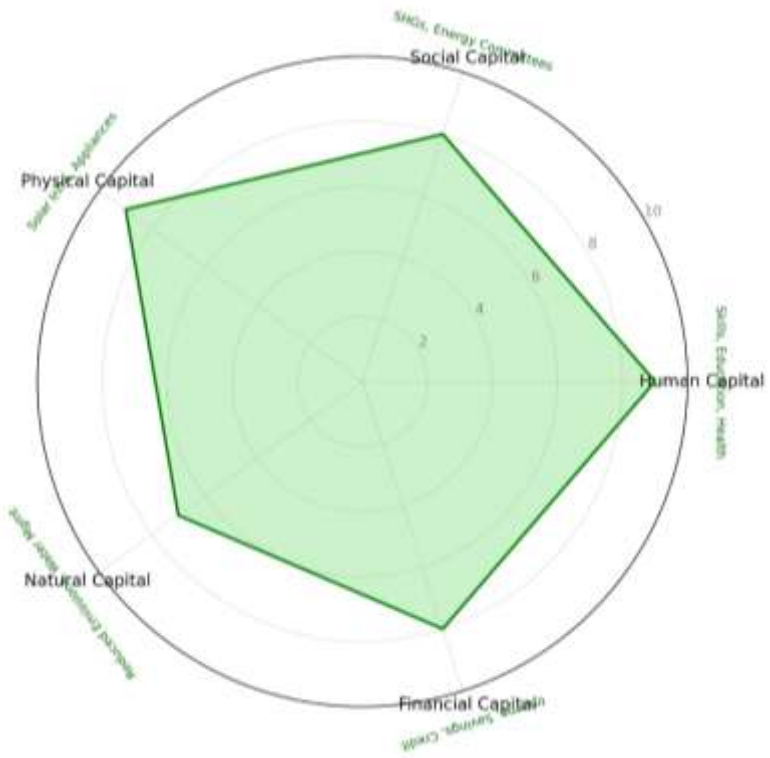
4. Anchor-load stabilisation: Schools, PHCs, and cold rooms serve as dependable customers. **5. Lifecycle service:** Remote monitoring, technician training, and service level agreements ensure uptime.

7.3 Representative interventions and reported outcomes

- **Village micro-grids with PUE:** 5-20 kW micro-grids bundled with appliance finance. GII reports 20–40 enterprises per cluster and tariff collections exceeding 70-80% after 6–12 months.
- **Solarised agriculture:** Solar pumps paired with drip irrigation. Farmers report lower irrigation costs and higher crop yields in community models.
- **Cold chains:** Walk-in cold rooms for vegetable groups. Reported spoilage reductions of 15–25% and improved prices at the farm gate of 8–15% during peak seasons.
- **Institutional electrification:** Schools and PHCs with battery-supported systems. Reported increases in study hours and steady operation of the immunisation cold chain.
- **Women's energy entrepreneurship:** SHG members trained to sell and maintain appliances. This has led to employment for thousands of women in technician and sales roles.

Evidence notes: The specific outcomes mentioned above come from practitioner reporting and typical sector magnitudes. Independent verification is suggested for formal evaluation.

8. Mapping Interventions to Livelihood Capitals



Ref. Impact of Solar Energy on Livelihood Capitals (GII Case)

Using the five-capitals lens, GII's interventions produce the following typical impacts:

- **Human capital:** Training for technicians and entrepreneurs, extended study hours for students, better health outcomes at PHCs.
- **Social capital:** Strengthened SHGs, energy committees, and FPO linkage for marketing cold-stored produce.
- **Physical capital:** Renewable energy assets such as solar arrays and batteries, PUE appliances including mills, sewing machines, and refrigerators, and improved institutional infrastructure.
- **Natural capital:** Reduced diesel emissions, potential water-use efficiency with drip irrigation, but there is a risk of groundwater over-extraction without proper governance.
- **Financial capital:** Cost savings on fuel, higher prices for perishables, and incomes from new enterprises and services.

9. Economic Viability and Financial Models

9.1 Cost considerations

While module costs have dropped, storage, inverters, balance of system (BOS), and operations and maintenance (O&M) make up a large portion of system costs. The choice of battery chemistry, depth of discharge, and system sizing significantly affects the levelized cost of energy (LCOE).

9.2 Tariff and revenue design

Successful operations often combine tiered tariffs, such as low rates for households and higher rates for productive uses, supported by reliable payments and appliance financing. Community anchors like schools and cold storage rooms help lower revenue risks. Pay-as-you-go platforms and smart meters enhance collections and support data-driven maintenance.

9.3 Financing pathways

Combining corporate social responsibility (CSR), concessional capital, and results-based financing helps reduce initial capital barriers. Connecting appliance financing to self-help group (SHG) systems and microfinance institutions (MFIs) lowers borrower risk and boosts the adoption of productive appliances.

10. Social and Gender Dimensions

Energy projects influence gender outcomes by reducing chores like collecting water and fuel, improving household safety with better lighting, and allowing home-based businesses. GII focuses on getting women involved in decision-making and energy entrepreneurship. This approach has reportedly raised women's income and leadership roles. Research shows that including women in asset ownership, training, and income streams leads to better results.

11. Environmental and Resource Considerations

Solar systems lower local air pollution and greenhouse gas emissions by replacing diesel. However, solar pumps can stress groundwater if not managed properly. Therefore, it is essential to combine energy development with hydrological monitoring, crop planning, prepaid meters, and community water-user rules. We need to plan and finance the management of e-waste and batteries at the end of their life.

12. Risks, Constraints, and Mitigation Strategies

Key risks and ways to mitigate them include:

- **Groundwater overuse:** Mitigation strategies are prepaid meters, rotational access, agronomy advice, and crop diversification.
- **Revenue shortfalls:** Mitigation strategies include anchor loads, appliance bundling, pay-as-you-go options, and results-based financing to motivate performance.
- **Operations and maintenance failures:** Mitigation strategies involve training local technicians, establishing spare-parts depots, remote monitoring, and service level agreements.
- **Exclusion of the poorest households:** Mitigation strategies are lifeline tariffs, cross-subsidies, and targeted grants through self-help groups.
- **Policy or regulatory uncertainty:** Mitigation strategies include modular designs, early engagement with state nodal agencies, and flexible interconnection plans.

13. Monitoring, Evaluation, and Learning (MEL)

Good MEL must go beyond measuring kWh to include socio-economic results like enterprise revenues, jobs created (broken down by gender), increases in yields, decreases in post-harvest loss, and service uptime. Mixed methods, including baseline and endline surveys, routine meter analysis, social audits, and qualitative stories, are essential. Results-based financing can link to verified indicators like uptime, PUE utilization, and inclusion metrics.

14. Comparative Insights:

Why Some Interventions Work Better. Interventions that produce the best livelihood outcomes share several traits:

1. Productive-use focus: Emphasising appliances and value-chain integration.

2. Stable demand: Schools, primary healthcare centres, or commercial aggregators help keep cash flow steady.

3. Inbuilt finance: Appliance loans lower upfront costs and encourage repayment discipline.

4. Community governance: Self-help groups and energy committees promote accountability and inclusion.

5. Service focus: Operation and maintenance, along with uptime guarantees, build trust and ensure continued use.

GII's model exemplifies these aspects in its field deployments.

15. Implementation Blueprint to Scale (12–36 months)

To expand livelihood-focused solar solutions to thousands of villages, the implementation plan includes:

1. Cluster-based selection: Identify areas with market connections (like dairy belts and horticulture zones).

2. Anchor engagement: Secure partnerships with institutions and commercial entities before launching.

3. Standardised modular kits: 5-25 kW modular micro-grid kits with compatible appliance sets.

4. Appliance-finance partnerships: Collaborate with microfinance institutions and self-help groups for consumer loans.

5. Technician network: Set up local training centres for technicians, prioritising women trainees.

6. Blended finance and results-based financing: Use performance-based grants to cover early-stage risks and reward uptime and livelihood results.

7. Data platform: Centralised dashboards for tracking uptime, revenue, PUE utilisation, and inclusion indicators.

8. Policy alignment: Work with state agencies on tariffs, interconnection, and groundwater regulations.

16. Discussion: Can Solar Energy Improve Rural Livelihoods?

The majority of evidence from academic studies, program evaluations, and practitioner experiences suggests a careful yes: **solar energy can improve rural livelihoods.** However, the extent and distribution of benefits depend on the design of the programs. **Electrification itself provides welfare gains, such as better lighting, health, and education.** Still, to truly transform income and employment, targeted support for productive uses is necessary. The Green India Initiative's approach includes bundling appliances, encouraging women's participation, connecting projects with institutions, and ensuring operation and maintenance. This reflects a path based on evidence to turn energy access into lasting improvements in livelihoods.

17. Policy Recommendations

For Central and State Governments

- Shift subsidies toward results-based incentives that reward uptime, PUE uptake, and gender inclusion.
- Include PUE in agricultural, MSME, and social sector programs; allow appliance finance through SHGs or MFIs.
- Clarify mini-grid regulations, such as interconnection and tariff changes when the grid arrives, to lessen investor risk.
- Set up groundwater governance measures alongside solar pump installations.

For Financiers and CSR

- Offer first-loss and blended capital for early-stage development of PUE models.
- Back appliance rental or leasing pilots and provide guarantees to lower default risk.
- Invest in energy entrepreneurship programs led by women.

For Implementers

- Use service-first models rather than hardware-first approaches: sell cooling, milling hours, or pumping services.
- Use anchor loads to stabilise revenue and expand household connections.
- Carry out thorough monitoring, evaluation, and learning; publish anonymised performance and social impact dashboards.

18. Operational Recommendations for Practitioners (like GII)

1. Design for local value chains. Tailor appliance packages to meet the specific needs of clusters like dairy, horticulture, and food processing.

2. Prioritise inclusion. Set quotas for women-run businesses and ensure marginalised households have access to essential services.

3. Use data for operations and maintenance. Utilise remote monitoring and predictive maintenance to increase uptime.

4. Plan for sustainable end-of-life management. Create pathways for battery recycling and e-waste management.

5. Document and publish independent evaluations. This will strengthen credibility and help attract larger financing.

19. Conclusion

Solar energy has become an affordable and flexible technology that can power rural livelihoods in India. The key to turning technical potential into real social and economic benefits is to connect energy deployment with appliances, finance, markets, governance, and ongoing service. The Green India Initiative, led by Dr. Sachin Yashwant Shigwan, offers a tested plan that focuses on productive use of energy, women's leadership, and customer service. These elements are crucial for achieving real benefits for livelihoods. Expanding this model to tens of thousands of villages needs policy changes that reward results, mixed financing to cover risks, and careful monitoring and evaluation to improve methods. When integrated into such a system, solar energy does more than just provide electricity. It supports businesses, frees up time, empowers women, and fosters climate-resilient rural economies.

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Note: The references below offer foundational background and sector perspective. The practitioner project data mentioned in this paper comes from Green India Initiative. It is advised to verify this data independently in future academic publications.

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Annex A: Suggested MEL Indicators (Brief)

- **Energy service:** Average hours of supply per day, uptime percentage, response time for faults.
- **Livelihoods/PUE:** Number of businesses using PUE appliances, additional enterprise revenue, jobs created (male/female).
- **Agriculture:** Irrigated area per farm, yield per acre, water use per kilogram of output.
- **Cold chain:** Post-harvest loss percentage, storage utilisation, price premium achieved.
- **Social services:** School evening study hours, PHC hours of operation, vaccine cold-chain failures.
- **Inclusion:** Share of women-headed businesses, percentage of households below the poverty line with lifeline access.
- **Environment:** Diesel displacement (litres per year), CO2 emissions avoided, battery recycling rate.

Annexe B: Sample Risk Register (Brief)

- **Technical:** Component failure, mitigated by remote monitoring, warranties, and spare part depots.
- **Financial:** Payment default, mitigated by PAYG, appliance finance, and SHG guarantees.
- **Environmental:** Groundwater depletion, mitigated by prepaid water metering, cropping advisories.
- **Social:** Elite capture, mitigated by transparent governance, and reserved quotas for marginalised groups.
- **Policy:** Changes in subsidy regimes, mitigated by diversified revenue streams and modular designs.

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