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POLICY BRIEF

Solar-Powered Grain Milling in India

A pilot of secondary use of solar irrigation power to benefit smallholders

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Summary

Solar-powered irrigation pumps are transforming India's agricultural energy landscape, offering a clean, cost-saving alternative to diesel and grid power. Yet the potential of this technology remains underused, given that solar-powered irrigation pumps sit idle part of the day or year when irrigation is not needed. Harnessing this power for other productive secondary uses, such as milling, can extend benefits to smallholders, women, and rural entrepreneurs while advancing national goals on clean energy and inclusive development.

This evaluation of solar-powered community mills in Uttar Pradesh found that solar mills reduced milling costs, cut travel distances by over half, and encouraged need-based, diversified milling that improved food freshness and hygiene while reducing spoiling. Social impacts, though modest, were significant: women reported greater mobility, confidence, and decision-making autonomy, particularly where mills were centrally located and reliably managed. However, structural challenges—such as limited operator availability, inconsistent quality, and poor infrastructure—restricted sustained use.

Scaling secondary-use models like solar milling can make India's clean energy transition more inclusive, resilient, and economically viable—turning underused solar potential into engines of rural prosperity. Integrating such uses into the next phase of India's flagship scheme to solarize agricultural electricity use, Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM), could optimize asset use and deliver broader socio-economic gains.[1]

[1] This brief is a condensed version of *Beyond Irrigation: Harnessing the untapped potential of solar pumps:* https://www.iisd.org/publications/report/beyond-irrigation-solar-pumps-india.

Introduction

Solar-powered irrigation pumps (SIPs) are an important clean energy solution for India's agriculture, with the potential to enhance productivity, reduce fuel costs, and cut carbon emissions. As of August 2025, over 853,000 SIPs have been installed under India's major subsidy programs (Ministry of New and Renewable Energy, n.d.). However, this represents only a fraction of the country's irrigation pumps, most of which still depend on diesel or grid electricity (Chandra & Brozović, 2024).

Meanwhile, the benefits of SIP adoption have been unevenly distributed, largely favouring medium and large landowners. Many pumps are used only for cropping, leaving significant solar energy potential unutilized during non-irrigation seasons (Kulshrestha, 2023). This energy could support rural livelihoods—especially for women, youth, and smallholder farmers—through productive secondary uses, such as milling, cold storage, or food processing.

Oorja Development Solutions provides solar-powered community mills in three districts in Uttar Pradesh (Box 1). Earlier studies have examined the technical feasibility of secondary uses of solar irrigation pumps, but empirical evidence on their socio-economic and gender impacts remains limited. This evaluation of Oorja's secondary-use model for milling fills this gap. It assesses not only cost savings and use patterns but also broader effects on gender roles, inclusion, and community welfare.

Box 1. Oorja's solar-powered irrigation and community milling solutions

Oorja Development Solutions provides solar-powered irrigation and milling services to smallholder farmers on a pay-per-use basis. As of September 2025, Oorja operates 17 mills in the villages of eastern Uttar Pradesh. These mills operate while the pumps are not in use for irrigation. The primary motivations include reducing the intensity of labour and mitigating the environmental impacts of milling. Time saved by villagers can potentially be spent on other social and economic responsibilities and could have particular implications for women.

The evaluation adopted a mixed-method approach drawing on baseline, midline, and endline surveys of over 500 households across five treatment villages (with mills) and five control villages (without mills). The operational window in the quantitative study was ~10 months. Qualitative interviews were also conducted with women users in villages where mills had been operational for over a year to provide insights into longer-term impacts.

Key Results

The key takeaway messages from the mixed-method evaluation are as follows:

- Primary adoption of solar-powered mills rose between baseline and endline (from 19% to 26% of households), indicating consolidation among satisfied users.

- Oorja primary users travelled approximately 0.5–0.6 km versus approximately 1.1 km for diesel/electric users.
- Average tariffs at solar mills were generally lower than for diesel/electric, but there was a great deal of variation in per-unit prices for different milling products (e.g., grains, pulses, spices), even within villages. Tariffs need to be competitive at the local level.
- Closer, cheaper milling enables smaller, more frequent batches, reduces storage losses, and encourages the processing of diverse products.
- Short-term credit or payment deferral at the solar mill was used by a meaningful minority and eases household cash flow.
- Gender inclusion shows incremental, place-based gains. Quantitative results were not statistically significant, but qualitative results suggested greater autonomy for women where mills were centrally sited and reliably operated.
- The main barriers to wider adoption were operational, including operator unavailability, perceived flour quality issues, and delays/queues. However, qualitative results were mixed, with some respondents citing improved quality and faster milling times compared to alternative mills, suggesting mill siting and operators have a large localized effect.

Traditionally, the task of transporting grain to distant mills was managed primarily by men, given the physical effort required and the need to travel by bicycle or cart. The installation of solar mills within the village changed this dynamic.

> "I go whenever I feel the need. There is no need to ask anyone."
> —Female interviewee

The study revealed that secondary use of SIP power is feasible and can provide an innovative solution for rural households with positive impacts on economic savings, food-related practices, autonomy, and decision making. As with any intervention, the impact was dependent on enabling conditions to overcome structural challenges.

Several patterns emerged from an analysis of the evaluation findings.

Lower Milling Costs and Household Savings

Solar-powered mills delivered measurable cost savings, with users paying INR 1.94/kg compared to INR 2.33/kg for diesel or electric mills—a savings of around INR 100 per household per milling cycle. However, benefits varied across locations, emphasizing the need for context-specific tariff-setting and community participation in pricing.

Greater Accessibility and Proximity

Users of Oorja's mills travelled approximately 0.5 km, compared to more than 1 km for alternative options (such as diesel/electric mills), reducing travel time, improving safety, and enhancing women's mobility.

Shifts in Milling and Food Practices

Solar mills encouraged a move from bulk to need-based milling, improving food freshness and hygiene and reducing spoilage. Some households began milling maize, coriander, and turmeric—indicating greater diversity and alignment with nutrition-focused programs.

Gender and Social Inclusion

Early evidence points to growing mobility, confidence, and autonomy among women, especially among younger and older women. Proximity and inclusion in operations increased women's participation.

Village-Level Variations

Retention rates for the use of solar mills varied widely: up to 65% in well-managed villages with competitive pricing and consistent operator presence compared to below 30% in others.

Continued Attrition

At the endline, 41% of households continued using Oorja as their primary mill. Attrition was driven by technical constraints, operator priorities, and poor road access.

Solar mills can cut milling costs and travel time, making energy access more affordable and convenient. They also support livelihood diversification and small but meaningful gains in women's decision making and mobility.

Policy Recommendations

When solar assets are designed for multi-use rather than single-purpose applications, they can deliver stronger economic returns, higher utilization rates, and broader benefits to the wider community, including women and marginalized groups. India's PM-KUSUM scheme currently supports solar irrigation but not secondary uses or gender-responsive design. IISD's engagement with the Ministry of New and Renewable Energy has prompted discussions on expanding subsidies to include productive applications like milling.

Alignment with emerging clean energy initiatives could further embed gender equality and social inclusion principles and cross-ministerial coordination—spanning renewable energy, small business, agriculture, and rural development—to unlock broader economic and social benefits from solar infrastructure.

The following recommendations primarily relate to India, but most also apply to other governments considering policies to promote secondary use of SIP power. Further details are available in the full report.

1. Promote secondary uses of solar energy, while addressing the challenges highlighted in this evaluation, through higher-capacity systems incorporating battery storage, operator incentives, and service-level benchmarks to sustain adoption.
2. Foster collaboration through cross-sectoral platforms and joint pilots.
3. Recognize and support both for-profit and social enterprise models.
4. Strengthen local ownership and operations, using performance-linked incentives for operators who manage both irrigation and processing effectively.
5. Embed gender equality and social inclusion measures—such as training women operators and supporting co-ownership models—to strengthen early gains made in this area.
6. Align solar policy with post-harvest and microenterprise needs.
7. Ensure solar-powered infrastructure is accessible and inclusive.
8. Tailor interventions to village-level dynamics. Localized business models need to be responsive to community demand and competition.
9. Invest in research and development to support more efficient solar milling and other solar-compatible appliances for secondary productive use.

Overall, governments, technology developers, and businesses could further develop secondary use to improve the economic viability of SIP systems, boost the financial use case for consumers, and address the energy needs of energy-poor agricultural communities and households. Effective safeguards, such as ensuring sustainable groundwater extraction and complementarity with grid-based supply, will be essential to prevent unintended environmental and system-level risks.

Conclusions

This evaluation revealed that milling is a viable secondary use of solar irrigation power and has delivered benefits to treatment households. The findings show that solar mills can cut milling costs and travel time, making energy access more affordable and convenient. They also support livelihood diversification and small but meaningful gains in women's decision making and mobility. Long-term success depends on tackling challenges like maintenance, operator availability, and user retention, which ultimately shape the sustainability of solar-powered milling.

Solar mills complemented diesel or electric mills rather than replacing them. Building multi-service solar hubs—combining irrigation, milling, and cooling—could improve system utilization and community resilience, as seen in Kenya's diversified rural energy ecosystems (Efficiency for Access, 2024).

India's rapid expansion of decentralized solar irrigation—through programs like PM-KUSUM and state-level policies such as the Uttar Pradesh Solar Energy Policy 2022—has significantly improved agricultural energy access. Integrating secondary uses, such as milling, into PM-KUSUM's subsidy and tariff framework could maximize the economic returns from solar assets to make maximum use of solar power to reduce energy poverty.

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