TECHNICAL BRIEF

Scaling Solar Irrigation through Grassroot Institutions in India

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About Solar Energy for Agricultural Resilience (SoLAR)

International Water Management Institute (IWMI) has launched the second phase of the Solar Energy for Agricultural Resilience (SoLAR) project, supported by the Swiss Agency for Development and Cooperation (SDC). Running from July 2025 to December 2029, this new phase expands both the geographical and thematic scope of the initiative to strengthen climate resilience and drive agricultural transformation through solar energy. Building on the achievements and lessons of Phase 1 (December 2019 – May 2024) across Bangladesh, India, Nepal, and Pakistan, Phase 2 extends the project's reach to Ethiopia and Kenya, while scaling up interventions in Bangladesh and India. Through South–South collaboration, SoLAR aims to establish solar-powered agricultural systems as a replicable and scalable model for sustainable, socially inclusive, and climate-resilient agriculture across the Global South.

About CGIAR Scaling for Impact (S4I) Program

Scaling for Impact (S4I) is a CGIAR program (2025–2030) that tests, refines, and scales innovations in food, land, and water systems. It works to align those innovations with stakeholder needs to achieve transformative impact.

Website: https://www.cgiar.org/cgiar-research-porfolio-2025-2030/scaling-for-impact/

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List of Abbreviations

CSC – Citizen Service Centre

DISCOM – Distribution Company

EEA – Energy Extension Agent

FAO – Food and Agriculture Organization of the United Nations

FPO – Farmer Producer Organisation

GDP – Gross Domestic Product

KVK – Krishi Vigyan Kendra

MNRE – Ministry of New and Renewable Energy

NABARD – National Bank for Agriculture and Rural Development

NRLM – National Rural Livelihoods Mission

PM KUSUM – Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan

SHG – Self-Help Group

SIP – Solar Irrigation Pump

SNA – State Nodal Agency

Key Highlights

- This technical brief lays emphasis on the role **grassroot institutions** could play in overcoming the technical and financial challenges faced by farmers in adopting solar irrigation.
- Solar irrigation is central to India's climate and energy transition: adoption has risen from ~10,000 pumps in 2012-13 to nearly 2 million by 2025-26 under Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM KUSUM).
- Institutions drive adoption: a meta-analysis of 83 studies shows that extension support increases Solar Irrigation pump (SIP) uptake by 14 p.p. , collective institutions improve access to formal 8.7 p.p.
- Three institutional pathways can accelerate inclusive scaling under PM KUSUM ecosystem: renewable energy extension through Krishi Vigyan Kendra (KVKs), Self-Help Group (SHG)-based financing via National Bank for Agriculture and Rural Development (NABARD) and National Rural Livelihoods Mission(NRLM), and end-to-end PM KUSUM facilitation through Citizen Service Centre (CSCs).
- Early pilot evidence from Uttar Pradesh demonstrates that CSC integration can convert awareness into uptake, reaching over 6,555 farmers, engaging 844 farmers, and enabling 34 on-the-spot SIP applications.

Introduction

Agriculture accounts for nearly one-fifth of global greenhouse gas emissions, with diesel- and coal-based groundwater irrigation among the largest contributors (FAO, 2020). For countries in the Global South, reducing these emissions is essential not only to meet climate commitments but also to secure rural livelihoods that depend on affordable and reliable irrigation (Mani et al., 2018). India, the world's largest user of groundwater, has committed to reducing the emissions intensity of its Gross Domestic Product (GDP) by 45 %by 2030 and achieving net-zero emissions by 2070 (MNRE, 2024). Solar irrigation pumps (SIPs) are central to this transition. Adoption has expanded rapidly-from around 10,000 pumps in 2012-13 to nearly 2 million by 2025-26-driven largely by the *Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan* (PM KUSUM) scheme launched in 2019. The scheme aims to solarise approximately 5 million irrigation pumps through capital subsidies, covering at least 60% of upfront costs for individual SIPs and around 30% for feeder-level solarisation. To date, over 950,000 standalone solar pumps have been installed, and more than 1 million agricultural grid connections have been solarised through feeder-level projects. Solar irrigation delivers a clear triple policy dividend. It reduces emissions-avoiding roughly 4 tonnes of CO_2 annually per 5-hp off-grid pump-while enhancing climate resilience through reliable, on-demand irrigation and improving farm incomes by lowering irrigation costs and expanding access to clean energy in areas with unreliable grid supply. Nearly 30 million diesel and electric pumps remain in operation, underscoring that scale-up cannot rely on subsidies alone. Farmers with low literacy, limited digital skills, and poor awareness are often excluded because accessing subsidies for SIPs requires navigating complex application processes. These barriers disproportionately affect smallholders and women farmers, who also face greater constraints in accessing information and credit.

This brief argues that grassroot institutions are critical to overcoming these access barriers and ensuring that solar irrigation scaling is inclusive, efficient, and sustainable. Strengthening the role of agricultural extension systems, self-help groups (SHGs), and citizen service centres (CSCs) therefore offers a pragmatic policy pathway to simplify access, reduce transaction costs, and accelerate equitable adoption.

Why Grassroot Institutions Matter for Solar Irrigation Adoption

The adoption of renewable energy technologies in agriculture is shaped not only by technical feasibility but also by institutional and social factors (Makata, 2020; Durga et al., 2024). These factors influence how farmers learn about SIPs, how rural markets function, and who ultimately gains access to public support mechanisms.

Technology adoption as a social process.
SIP uptake depends on farmers' awareness, perceived benefits, compatibility with existing practices, and peer influence, rather than availability alone. Women and marginalised farmers often lack access to reliable information, limiting informed decision-making (Murray et al., 2016). Energy Extension Agents (EEAs) can address these gaps by acting as trusted intermediaries-demonstrating SIP technologies, providing hands-on training, and offering post-installation guidance. Through sustained engagement, EEAs help embed SIP adoption within local learning and social networks, particularly for farmers excluded from conventional technology diffusion channels.

Institutions and market coordination.
Rural solar markets are characterised by high transaction costs, information asymmetries, and coordination failures (Kydd and Dorward, 2004). Institutions such as EEAs and CSCs help reduce these frictions by simplifying application procedures, facilitating digital documentation, and lowering search and compliance costs, thereby improving trust in public programmes (Kafle et al., 2022).

Institutions and energy justice.
Persistent inequalities related to gender, landholding, and socio-economic status continue to constrain farmers' access to subsidies and clean energy technologies. SHGs help address these inequities by enabling collective applications, reducing credit risk, amplifying women's participation, and strengthening procedural justice and equitable access to public programmes (Feder et al., 2010).

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What Evidence Shows: Institution Engagement Accelerate Solar Irrigation Adoption

A meta-analysis drawing on 83 peer-reviewed studies demonstrates that institutional support is a decisive driver of solar irrigation adoption (Varshney et al., 2026). The analysis shows that structured extension support including demonstrations, farmer training, and sustained engagement, increases the likelihood of SIP adoption by approximately 14 p.p. In practical terms, in low-uptake settings where baseline adoption is below 10 p.p., this translates into around 140 additional adopters per 1,000 eligible farmers.

The meta-analysis further indicates that collective institutions-such as SHGs, farmer producer organisations (FPOs), and cooperatives-play a critical role in easing financial constraints. Participation in these institutions improves farmers' access to formal credit by 8.7%, addressing one of the most persistent barriers to technology adoption.

These findings underscore that institutional enablers are not merely complementary to technology deployment; rather, they play a causal role in enabling both scale and participation among smallholder and women farmers, who typically face low awareness and credit constraints in the transition to solar irrigation-particularly in programmes that struggle to move farmers from awareness to installation

Institutional Pathways for Scaling Solar Irrigation Adoption

PM KUSUM implementation is currently led by State Nodal Agencies (SNAs), Distribution Companies (DISCOMs), and empanelled vendors (MNRE, 2024). While this architecture has enabled rapid deployment, it pays limited attention to grassroot institutions that are critical for overcoming information asymmetries, trust deficits, and last-mile service delivery constraints that continue to limit equitable adoption. Recent evidence highlights that integrating such institutions into the implementation framework can reduce transaction costs, increase uptake, and improve inclusion (Varshney et al., 2026).

Three complementary institutional pathways offer practical options for strengthening PM KUSUM delivery.

- First, the Krishi Vigyan Kendra (KVK) network, India's frontline agricultural extension system, can play a central role by incorporating renewable energy expertise. Although KVKs host subject matter specialists across agricultural disciplines, they currently lack dedicated capacity on clean energy technologies. Embedding renewable energy extension within KVKs would institutionalise farmer awareness, technical guidance, and operational support for SIPs, in coordination with the Ministry of New and Renewable Energy (MNRE) and state agencies.

- Second, SHGs supported through the National Bank for Agriculture and Rural Development (NABARD-SHG) Bank Linkage Programme provide a viable pathway for addressing financing constraints. Evidence from community-managed solar irrigation initiatives points to the potential for earmarked provisions under NRLM to enable SHGs to finance upfront investments for SIP adoption under PM KUSUM. Group-based adoption can ease collateral constraints, promote group ownership, and expand access especially for women and small and marginal farmers.

- Third, integrating CSCs into the PM KUSUM delivery ecosystem can address persistent digital access barriers. With CSCs operating in nearly every gram panchayat, these centres are well positioned to support application submission, document verification, grievance redressal, and scheme tracking. Enabling CSCs to provide structured, end-to-end facilitation would improve accessibility for farmers with limited digital literacy while streamlining administrative processes across the scheme.

As the scheme evolves with the MNRE considering guideline revisions, these institutional pathways offer a timely opportunity to redesign delivery for greater inclusion and efficiency. When SIP delivery is channelled through local intermediaries such as EEAs, SHGs, and CSCs, adoption improves and public investments tend to translate more effectively into farmer-level benefits. Embedding these actors within the programme architecture can expand access, especially for small and marginal farmers through reduced transaction costs, and improve gender inclusion. Thus, scaling solar irrigation fundamentally depends more on strengthening grassroot institutions than on technological or financial interventions alone.

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