



PROMOTING DISTRIBUTED SOLAR FOR AGRICULTURAL AND RURAL TRANSFORMATION





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Executive summary

Current landscape of rural electricity supply

India's agricultural sector is highly energy-intensive, consuming 17–20 per cent of national electricity, largely via heavily subsidised or zero-tariff supply through dedicated agricultural feeders operated by DISCOMs. While supporting irrigation and food security, this model creates structural inefficiencies, including DISCOM revenue gaps, distorted pricing, and weak incentives for efficient energy and water use. Key challenges include: **economic constraints**—cross-subsidisation undermines DISCOM financial viability and investment capacity; **operational challenges**—time-restricted supply misaligned with irrigation needs; and **environmental pressures**—unmetered supply drives groundwater over-extraction and diesel pump reliance, raising costs and emissions. To address these, the PM-KUSUM scheme (2019) targets:

- promoting distributed solar and other renewable energy in rural areas,
- reducing DISCOM subsidy burdens via solar generation,
- increasing farmer income by enabling sale of surplus power,
- replacing diesel pumps with solar alternatives, and
- strengthening rural energy security while supporting climate and water sustainability.

The performance of the scheme, as per recent data, has been dismal, especially in components A and C. Achievements stand at only 7.2 per cent against targets for Component A, 74 per cent for Component B, and 21.3 per cent (ILS) and 33.7 per cent (FLS) for Component C. Only Component B has achieved a higher success attributable to its modular implementation structure, simpler approval processes, higher share of total subsidy (upwards of 60 per cent).

Understanding barriers in implementation

The performance of PM-KUSUM evaluated primarily on parameters related to improving agricultural power supply positions and advancing solarisation of irrigation pumps. However, as efforts intensify to improve power supply in rural areas, significant challenges have emerged in deploying small-scale solar plants (under 2 MW capacity). These challenges are predominantly shaped by three interconnected constraint factors:

- Land-use requirements and availability.
- Viability of commercial business models at discovered tariff rates.
- Grid availability coupled with energy loss mitigation strategies.

Land-use constraints

High land costs and complex ownership structures materially constrain project development. Suitable land remains expensive, ownership among smallholders is fragmented, and agricultural-to-non-agricultural conversion is mandatory, with costs and eligibility varying widely by state (e.g., tenure limits in Madhya Pradesh versus fewer temporal constraints in Rajasthan and Karnataka). These challenges are compounded by incomplete digitisation of land records and frequent title disputes, creating uncertainty and delaying PPA execution. Land availability is further restricted by the requirement to locate projects within ~5 kilometers of substations, significantly narrowing the viable land pool. With ~85 per cent of landholdings below 1 hectare, aggregation of parcels is necessary but transaction-intensive, driving up EPC and administrative costs and limiting joint-ownership structures. Grid connectivity adds another layer of complexity, as transmission infrastructure requires extensive land approvals and Right of Way negotiations with multiple landowners, resulting in prolonged timelines and heightened cost and schedule risk for developers and financiers.

Delivering commercial success

Project commercial viability is constrained by high capital intensity, tariff inadequacy, subsidy dependence, and complex approval processes. Benchmark capital costs for PM-KUSUM projects (Rs 3.25–3.75 crore/MW) are prohibitive for farmers and small developers, while DRE financing attracts higher interest rates due to perceived risk. Limited mortgageability of agricultural land and insufficient upfront subsidies, particularly under Component A, necessitate high equity contributions, elevating LCoE. Although Component C reduces initial costs via CFA, it does not sufficiently mitigate ongoing financial risk. Tariffs (2.80–3.30/kWh) are discovered through reverse bidding and benchmarked against utility-scale solar despite smaller project sizes (1–2 MW) and higher risk profiles, often resulting in under-pricing and post-award developer exits. Additionally, projects require five to seven approvals across multiple agencies, causing delays, capital lock-in, and higher EPC costs. Technical stipulations, performance guarantees, and compliance with DCR and ALMM further increase costs and extend timelines, limiting participation and scalability.

Grid connectivity concerns

PM-KUSUM operates as a distributed solar programme layered onto structurally weak rural distribution grids that were not designed for distributed generation. Unlike utility-scale projects with integrated transmission planning, these projects are retrofitted onto existing feeders and sub-stations, making grid infrastructure a primary determinant of feasibility, costs, and timelines. Rural

grids are characterised by high losses, seasonal irrigation-driven loads, aging assets, and limited monitoring, with many substations operating near capacity and unable to manage reverse power flows. This results in voltage instability, inverter tripping, protection coordination issues, curtailment, and revenue loss. Scheme requirements for grid availability within ~5 km of substations necessitate feeder segregation and connectivity readiness, yet weak grids limit additional absorption without upgrades. Under Component C, reverse injection has stressed distribution transformers not designed for generation. Inadequate provisions for deemed generation and delayed network augmentation externalise grid-related risks to developers and farmers, creating cash-flow volatility and undermining project bankability.

Implementation of PM-KUSUM is constrained by fragmented institutional roles between DISCOMs and state implementing agencies, weak regulatory alignment, and limited execution capacity. DISCOM-led grid feasibility assessments are delayed by substation capacity constraints, inadequate load forecasting, and insufficient funding for required infrastructure upgrades, while the absence of enforcement mechanisms for decentralised RPOs weakens alignment with national targets. State nodal agencies face delays in tendering, bidding, and CFA sanctioning, coupled with inconsistent state-level net-metering, tariff, and grid-integration frameworks that create uncertainty for developers. Limited in-house capacity for tender design, evaluation, and stakeholder outreach further suppresses uptake under Components A and C. Financial viability risks persist due to high upfront capital needs, limited access to low-cost finance, tariff uncertainty, and payment delays. DISCOM liquidity constraints and availability of cheaper alternative solar procurement reduce willingness to sign PPAs, while grid-strengthening costs and delayed subsidy reimbursements further undermine project bankability.

Measures to improve schematic outcomes

To accelerate deployment and improve implementation outcomes, an integrated technical approach is required that simultaneously addresses land-use constraints, commercial and financial risks, cost of capital barriers, and grid readiness challenges. These interventions must be designed as mutually reinforcing rather than isolated measures, recognising that bottlenecks in one domain create cascading effects across the entire implementation chain. Specific interventions include;

States led participation is a key determinant

States can reduce land and participation constraints by institutionalising standardised land-use and ownership models for PM-KUSUM. Enabling long-

term (e.g., 25-year) standardised lease frameworks for public, panchayat, and revenue lands can lower acquisition risk, ensure tenure security, and contain leasing costs over PPA tenors, while resolving competing land-use claims through scheme-specific aggregation mechanisms. In parallel, states should promote productive land-use models such as agrivoltaics by incorporating incentives and dedicated tender categories that mandate dual-use designs (e.g., elevated structures compatible with crops or grazing), supported by clustered infrastructure approaches even as national standards evolve. Community-led and cooperative ownership models on village common lands can further enhance inclusion by reducing per-farmer capital burden, improving equity in energy access, and enabling participation of small and marginal farmers who are otherwise excluded from individual project ownership under Component A.

Benchmarking and standards setting for improving viability

Commercial and financial risks in PM-KUSUM can be reduced through coordinated payment security, tariff reform, and proactive infrastructure planning. Payment risk from DISCOMs should be mitigated by channelling existing subsidy flows and savings from avoided power procurement into dedicated payment security mechanisms, complemented by state-level payment security funds and instruments such as letters of credit to provide bankable guarantees. Tariff frameworks require rationalisation through indexed and two-part structures that reflect land leasing costs, higher compliance expenses from ALMM and DCR mandates, and fixed versus variable cost recovery, while also enabling compensation for outages and curtailment. In parallel, localised infrastructure planning modelled on ultra-mega solar parks—incorporating feeder mapping, land aggregation, and assured transmission—can enable bulk procurement and portfolio-based PPAs. Bundling multiple small projects lowers transaction costs, diversifies generation risk, and enhances overall bankability and implementation certainty.

Financing measures should expand for DRE sectors

Access to affordable project finance is a key bottleneck for small and marginal farmers and first-time developers under PM-KUSUM. This can be addressed through standardisation of financial documentation, including model PPAs and land-lease templates, to reduce lender due diligence costs, lower information asymmetry, and accelerate credit appraisal. In parallel, capital subsidy frameworks should be better targeted by providing higher CFA and state support for small and marginal farmers and for regions with high groundwater extraction, where water conservation benefits are greatest. To ease liquidity constraints, equity contribution requirements should be made more flexible by allowing installment-

based payments linked to project cash flows, rather than full upfront contributions, thereby improving participation and financial viability.

Grid security and connectivity to be facilitated with STU networks

Grid availability must be prioritised alongside generation assets to ensure PM-KUSUM supports, rather than stresses, rural distribution networks. This requires feeder-level planning and proactive network augmentation. PM-KUSUM plants operating within assessed hosting capacity should be accorded must-run status, with curtailment limited to grid security events and supported by dedicated feeder maintenance protocols to reduce deemed generation losses. Systematic hosting capacity assessments should precede capacity sanctioning to evaluate thermal limits, voltage impacts, and protection coordination needs, enabling rational siting and multi-year deployment planning. Targeted strengthening of 11/33 kV infrastructure—through conductor upgrades, transformer replacement, and reactive power compensation—should focus on feeders with high agricultural load density. Strategic integration of modular, short-duration battery storage can absorb surplus daytime generation, support evening loads, and defer conventional network investments, improving overall system economics.

Introduction

India's rural economy stands to gain significantly from expanded energy services, where the energy-for-development paradigm unlocks multiple co-benefits through increased per-capita consumption and demand-side growth. Distributed renewable energy (DRE) systems present a transformative opportunity for rural areas by enabling higher adoption of clean energy across productive and social activities.

As conventional electricity systems evolve, they increasingly can accommodate DRE technologies, creating pathways for integrated rural development. Grid-connected solar photovoltaic installations, for instance, can be rapidly deployed to support critical agro-farm infrastructure such as storage cold chains, agro-processing units, healthcare facilities, and service delivery centres. These interventions generate positive multiplier effects on local employment, community empowerment, and human capital development.

Within this context, the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) represents a strategic policy intervention aimed at leveraging solar energy to address agricultural power needs while catalysing broader rural economic transformation.

Scope of PM-KUSUM for rural development

Current power supply practices for the agricultural sector

India's agricultural sector represents one of the most energy-intensive segments of the national economy, ranking as the third-largest electricity consumer and accounting for approximately 17–20 per cent of total electricity demand. A substantial portion of this demand is met through highly subsidised or zero-tariff power supply, primarily delivered via dedicated agricultural feeders operated by state electricity distribution companies (DISCOMs). While this approach has supported irrigation expansion and food security objectives, it has simultaneously generated significant structural inefficiencies, including persistent financial stress on DISCOMs, distorted pricing mechanisms, and limited incentives for efficient energy and water use.

The existing agricultural power supply paradigm is characterised by three critical dimensions:

- **Economic constraints:** Cross-subsidisation for agricultural and rural consumers has contributed to widening revenue gaps for DISCOMs, undermining their financial viability and capacity to invest in infrastructure upgrades.
- **Operational challenges:** Time-restricted supply—often limited to night hours—is driven by grid constraints and load management practices. This temporal restriction misaligns with optimal irrigation schedules and agricultural productivity requirements.
- **Environmental pressures:** Unmetered or flat-rate electricity supply has exacerbated groundwater over-extraction, creating long-term water security risks. Additionally, continued reliance on diesel-based irrigation pumps in off-grid or weak-grid regions results in elevated operating costs, fuel supply vulnerabilities, and increased greenhouse gas emissions.

Simultaneously, India's climate commitments under the Paris Agreement and the target of achieving 500 GW of non-fossil fuel-based installed capacity by 2030 necessitate rapid integration of renewable energy across all end-use sectors, including agriculture. Decarbonising agricultural power consumption is not merely an environmental imperative but a system-level reform requirement

for improving grid efficiency, DISCOM financial performance, and sustainable agricultural practices. This context establishes the critical need for transformative interventions like PM-KUSUM.

Premise of PM-KUSUM scheme within DRE for rural development

Within this policy and sectoral context, the PM-KUSUM, launched in 2019 by the Ministry of New and Renewable Energy (MNRE), represents a structural intervention aimed at transforming energy generation, supply, and consumption patterns in the agricultural sector. The scheme is designed to enable a transition from centralised, subsidy-driven electricity supply to a model based on decentralised solar generation, feeder-level energy balancing, with farmer participation as energy producers.

While the primary focus is on decarbonising agricultural pump-related electricity consumption, the scheme simultaneously addresses the need to rationalise tariffs for agricultural consumers by integrating subsidy reduction mechanisms within the existing regulatory framework.

PM-KUSUM explicitly targets agricultural electricity consumption by promoting a shift from grid-supplied and diesel-based energy to solar power, with a strong emphasis on daytime solar generation aligned with irrigation demand profiles. By enabling solar power generation at or near the point of consumption and injection, the scheme seeks to reduce peak load stress on distribution networks, lower aggregate technical and commercial (AT&C) losses, and improve voltage and supply reliability in rural areas.

The scheme architecture comprises three distinct components:

- **Component A** facilitates deployment of decentralised, grid-connected solar power plants (up to 2 MW) in rural and agricultural areas, allowing farmers and rural entities to monetise land assets and supply clean power directly to DISCOMs.
- **Component B** aims for solar-powered water pumps for agricultural irrigation, focusing on de-dieselisation of the agricultural sector. The target is to install 14 lakh off-grid solar pumps by target beneficiaries, such as farmers, farmer-groups, water user associations, aiming to reach individual as well as cluster beneficiaries.
- **Component C** focuses on solarisation of existing grid-connected agricultural pumps, enabling dual-source operation (solar + grid) and export of surplus solar energy through net- or gross-metering arrangements. This component

directly supports feeder-level solarisation and reduction of daytime agricultural load on the grid.

Co-benefits and strategic implications of the scheme

PM-KUSUM's impact extends beyond renewable energy generation, encompassing comprehensive human and farm-level development, with increasing evidence of income diversification and multidimensional rural transformation. The scheme addresses different dimensions of an equitable energy transition through several strategic co-benefits.

Rural income diversification emerges as farmers gain a new revenue stream by selling surplus power to the grid, thereby reducing their dependency on volatile crop income and enhancing household financial resilience. The water-energy nexus

SCHEME DETAILS AND IMPLEMENTATION STATUS

The scheme originally aimed to add solar capacity of 30,800 MW by 2022, with total central financial support of Rs 34,422 crore, including service charges to implementing agencies. The scheme would be completed by 31 March, 2026.

Component architecture and design

PM-KUSUM is structured around three distinct components, each addressing specific aspects of agricultural energy requirements and rural electrification needs.

Component A: Decentralised grid-connected solar plants

Component A targets cumulative installations of 10 GW capacity through deployment of small to medium-scale solar power plants. These installations can be executed through multiple modalities including ground-mounted systems, agrivoltaic (Ag-PV) configurations, or rooftop solar installations. The component also accommodates community-led development models that facilitate collective participation. The capacity restriction per individual installation is capped at 2 MW, designed to maintain the distributed nature of generation while ensuring technical and commercial viability.

Component A installations can support rural enterprises beyond agriculture and generate local employment opportunities in installation, operation, and maintenance activities. Solar power generated under this component is procured by DISCOMs under Power Purchase Agreements (PPAs) at tariffs determined by respective State Electricity Regulatory Commissions (SERCs), providing farmers and rural entities with a new revenue stream while contributing to DISCOM renewable purchase obligations.

Component B: Stand-alone solar agricultural pumps

Component B focuses on installation of 17.5 lakh stand-alone solar agricultural pumps for off-grid applications. Under this component, individual farmers receive support to install standalone solar pumps with capacity of up to 7.5 HP, primarily for replacement of existing diesel-based pumps and irrigation systems in off-grid areas, where grid electricity supply is unavailable or unreliable. While pumps with capacity higher than 7.5 HP can be installed, financial support from the scheme is limited to 7.5 HP capacity, ensuring subsidy targeting toward small and marginal farmers.

The financial structure for Component B provides Central Financial Assistance (CFA) of 30 per cent of the benchmark cost or tender cost, whichever is lower. State governments contribute an additional 30 per cent subsidy, with the remaining 40 per cent borne by the farmer-beneficiary. Some states have enhanced subsidy support beyond these baseline provisions, with Uttar Pradesh, Punjab, and Rajasthan offering combined subsidies approaching 70 per cent, significantly reducing farmer contribution requirements and accelerating adoption.

Component C: Solarisation of grid-connected agricultural pumps

Component C targets solarisation of 10 lakh existing grid-connected agricultural pumps, divided into two sub-components addressing individual pump solarisation (C1/IPS) and feeder-level solarisation (C2/FLS). Under this component, farmers with existing grid-connected agricultural pumps receive support to install solar PV systems. The scheme allows solar PV capacity of up to two times the pump capacity (in kW), enabling farmers to generate surplus power beyond irrigation requirements.

Farmers can utilise generated solar power to meet irrigation needs while selling excess power to DISCOMs, creating dual benefits of energy cost savings and revenue generation. The financial structure mirrors that of Component B, with 30 per cent CFA, 30 per cent state subsidy, and a 40 per cent farmer contribution based on benchmark or tender costs, whichever is lower.

Technical requirements for Components A and C

Under both Components A and C, solar plants must be located within a five-kilometre radius of rural sub-stations to ensure grid connectivity feasibility and minimise transmission infrastructure costs. State Implementing Agencies (SIAs) provide assistance with transmission connectivity arrangements, coordinating between project developers and DISCOMs to ensure technical and regulatory compliance. This proximity requirement, while ensuring grid integration feasibility, also constrains land availability and intensifies competition for suitable sites near existing electrical infrastructure.

optimisation encourages efficient water use by directly linking energy generation and consumption patterns to solar productivity, creating incentives for judicious irrigation practices and groundwater conservation. Through decentralised energy transition, the scheme enhances grid stability by distributing generation sources across the network, reducing transmission losses, and improving power quality in rural areas. Technological innovation is catalysed through encouragement of agrivoltaic models that enable dual use of land for simultaneous solar generation and cultivation, maximising land productivity.

PM-KUSUM seeks to achieve the following interlinked objectives:

- Promote distributed solar and other renewable energy sources in rural India.
- Reduce the financial burden on DISCOMs by offsetting agricultural power subsidies through solar generation.
- Enhance farmers' income by enabling them to sell surplus power to the grid.
- Replace diesel irrigation pumps with clean, solar-powered alternatives.
- Strengthen rural energy security while contributing to climate and water sustainability goals.

The deployment potential of PM-KUSUM is substantial, with opportunities to integrate energy generation with various rural services that promote energy access development. Given that rural development in India has been constrained by low per-capita income and disguised employment, anticipated growth in per-capita demand from rural areas positions clean energy-based electricity as a critical driver of economic transformation.

Implementation status and performance analysis

The scheme’s implementation trajectory, from its inception in 2019 through the current extension period until March 2026 reveals significant variations in performance across components and states. Component B has emerged as the most successful, substantially meeting its deployment objectives, while Components A and C have encountered multiple barriers limiting achievement rates.

Table: 1 PM-KUSUM implementation status across components and states

Component	State	Sanctioned	Installed	Achievement (%)
A - Grid-connected solar plants (500kW-2MW)	Total	10,000 MW	721 MW	7.2%
	Rajasthan	5,250 MW	513 MW	9.8%
	Madhya Pradesh	1,790 MW	61 MW	3.4%
	Telangana	1,650 MW	0 MW	0%
	Chhattisgarh	366 MW	7 MW	1.9%
	Gujarat	300 MW	0 MW	0%
	Maharashtra	260 MW	4 MW	1.5%
	Haryana	158 MW	29 MW	18.4%
	Himachal Pradesh	100 MW	100 MW	100%
	Odisha	90 MW	0 MW	0%
	Goa	24 MW	4 MW	16.7%
	Tripura	5 MW	0 MW	0%
	Tamil Nadu	3 MW	3 MW	100%
	Assam	2 MW	0 MW	0%
	Ladakh	1 MW	0 MW	0%
	Uttar Pradesh	1 MW	1 MW	100%
B - Off-grid solar pumps	Total	13.15 lakh Nos	9.75 lakh Nos	74.2%
	Arunachal Pradesh	5.75 lakh Nos	4.84 lakh Nos	84.1%
	Assam	1.98 lakh Nos	1.84 lakh Nos	92.9%
	Goa	1.45 lakh Nos	1.22 lakh Nos	84.2%

Component	State	Sanctioned	Installed	Achievement (%)
	Gujarat	1.07 lakh Nos	0.67 lakh Nos	62.1%
	Haryana	0.87 lakh Nos	0.47 lakh Nos	53.6%
	Himachal Pradesh	0.59 lakh Nos	0.07 lakh Nos	12.3%
	Jammu And Kashmir	0.26 lakh Nos	0.03 lakh Nos	10.3%
	Jharkhand	0.23 lakh Nos	0.13 lakh Nos	55.7%
	Karnataka	0.20 lakh Nos	0 Nos	0%
	Kerala	0.18 lakh Nos	0.12 lakh Nos	65.3%
	Ladakh	0.18 lakh Nos	0.18 lakh Nos	98.9%
	Madhya Pradesh	0.11 lakh Nos	0.07 lakh Nos	61.3%
	Maharashtra	0.05 lakh Nos	0.05 lakh Nos	97.7%
	Other States	0.23 lakh Nos	0.08 lakh Nos	27.0%
C1 (IPS) - Individual pump solarisation	Total	55,392 Nos	11,781 Nos	21.3%
	Telangana	28,000 Nos	0 Nos	0%
	Uttar Pradesh	12,000 Nos	6,246 Nos	52.1%
	Kerala	9,448 Nos	2,589 Nos	27.4%
	Tripura	3,600 Nos	788 Nos	21.9%
	Rajasthan	2,138 Nos	2,138 Nos	100%
	Punjab	186 Nos	0 Nos	0%
	West Bengal	20 Nos	20 Nos	100%
C2 (FLS) - Feeder-level solarisation	Total	35.27 lakh Nos	11.90 lakh Nos	33.7%
	Karnataka	7.79 lakh Nos	0.65 lakh Nos	8.4%
	Maharashtra	7.75 lakh Nos	7.11 lakh Nos	91.7%
	Gujarat	4.67 lakh Nos	2.25 lakh Nos	48.2%
	Rajasthan	4.00 lakh Nos	1.37 lakh Nos	34.4%
	Uttar Pradesh	3.70 lakh Nos	0 Nos	0%
	Madhya Pradesh	3.45 lakh Nos	0.39 lakh Nos	11.2%
	Andhra Pradesh	2.00 lakh Nos	0 Nos	0%
	Bihar	1.40 lakh Nos	0 Nos	0%
	Kerala	0.22 lakh Nos	0.11 lakh Nos	49.0%
	Goa	0.11 lakh Nos	0.01 lakh Nos	6.4%
	Chhattisgarh	0.10 lakh Nos	0 Nos	0%
	Odisha	0.05 lakh Nos	0 Nos	0%
Haryana	0.03 lakh Nos	0 Nos	0%	

Source: National Portal on PM-KUSUM; Achievements as of 31.12.2025

Component B's success can be attributed to its modular implementation structure, simpler approval processes, streamlined application timelines, and direct, tangible benefits for individual farmers. The combination of substantial subsidies (60–70 per cent in several states) and clear value proposition—replacement of expensive, polluting diesel pumps with clean solar energy—has driven strong adoption. Component B's relative simplicity, involving fewer stakeholders and minimal grid integration complexities, has enabled faster deployment compared to Components A and C.

Conversely, Component A demonstrates the slowest implementation progress, with only 7.2 per cent of sanctioned capacity commissioned. This underperformance stems from the component's inherent complexity involving multiple stakeholders, numerous approval requirements spanning land-use permissions, funding arrangements, technical clearances, and lack of technical expertise among farmer groups, Farmer Producer Organisations (FPOs), and small developers regarding implementation procedures. Additionally, ceiling tariffs set by regulatory commissions have proven unattractive, as factors including design specifications, location constraints, and sizing requirements disproportionately affect smaller installations compared to large utility-scale projects, undermining commercial viability.

State-wise analysis reveals that despite substantial sanctioned capacities, actual installations remain minimal across most jurisdictions. Rajasthan leads in absolute installed capacity (466.75 MW) but has achieved only 8.9 per cent of its 5,250 MW sanctioned allocation. Notable exceptions include Himachal Pradesh, Tamil Nadu, and Uttar Pradesh, which have fully achieved their modest sanctioned capacities; however, these represent very small absolute quantities. Several states including Telangana, Gujarat, and Odisha have achieved zero installations despite significant sanctioned capacities, indicating severe implementation bottlenecks or lack of prioritisation at state level.

Individual pump solarisation performance demonstrates wide variation. Rajasthan and West Bengal have achieved full implementation of sanctioned targets, albeit from relatively modest baselines. Uttar Pradesh shows reasonable progress at 48.8 per cent achievement. However, Telangana, despite sanctioning 28,000 installations, has achieved zero implementation, representing the largest absolute gap in this component.

Feeder-level solarisation shows the most dramatic performance variation. Maharashtra stands out with 84.5 per cent achievement (654,695 installations),

demonstrating successful large-scale implementation. Gujarat and Kerala show moderate progress at 46.3 per cent and 49.0 per cent respectively. However, several states with substantial sanctioned capacities including Uttar Pradesh (370,000), Andhra Pradesh (200,000), and Bihar (140,300) have achieved zero installations, indicating fundamental implementation barriers or lack of state-level prioritisation.

Regional patterns and state performance analysis

Performance across Components A and C has been highly varied, despite large sanctioned capacity allocations. States such as Rajasthan, Maharashtra, and Madhya Pradesh are leading in absolute deployment scales, yet even these frontrunners exhibit wide gaps between sanctioned and installed capacity.

An interesting observation is that northern states heavily reliant on irrigation—through surface water (Punjab, Haryana) or groundwater extraction (Uttar Pradesh, Madhya Pradesh, Bihar)—should theoretically be rapid adopters, given their agricultural energy requirements and water stress conditions. However, the failure of scheme proliferation across these states indicates that policy transmission has not effectively reached intended beneficiaries across all jurisdictions.

The scheme's success depends extensively on state-level proactiveness. States performing well have implemented supportive measures including creation of dedicated administrative desks and online application platforms under State Nodal Agency supervision (exemplified by Rajasthan, Haryana, and Madhya Pradesh), extensive publicity campaigns highlighting scheme benefits (Maharashtra and Gujarat), and streamlined approval processes.

As MNRE directives establish PM-KUSUM as a state-driven scheme, states must first furnish their preferred solarisation modalities—through standalone pumps or feeder-level approaches—and submit capacity requirement projections. Only upon acceptance of such demand parameters does MNRE clear sanctioned capacity allocations. This demand-driven structure places implementation responsibility squarely on state governments, explaining substantial inter-state variation in outcomes.

Current tender activity and future pipeline

Currently, with implementation extended through March 2026, several state nodal agencies have released new tenders under Components A and C. Tender auctions are being conducted more frequently for Component C compared to Component A, reflecting perceived lower implementation complexity and clearer

value propositions. States including Madhya Pradesh, Rajasthan, Maharashtra, and Andhra Pradesh are leading with new tender releases. Notably, these same states also demonstrate proactive engagement with utility-scale solar procurement tenders, suggesting that states with established renewable energy procurement infrastructure and expertise are better positioned to implement PM-KUSUM effectively.

Direct evidence indicates the role of states in facilitating solar power procurement through development of dedicated digital portals for PM-KUSUM applications and tendering processes, available on both national and state-level platforms. This digital infrastructure development correlates with higher implementation rates, suggesting that administrative capacity and digital enablement constitute critical success factors.

Tariff structures for Components A and C

To incentivise power procurement from PM-KUSUM installations, MNRE provides financial incentives of Rs 0.4/kWh or Rs 6.6 lakh/MW annually to encourage procurement viability. Discovered tariffs for projects range between Rs 2.9/kWh to Rs 3.4/kWh across states, with the majority of accepted tariffs falling within Rs 3.00/kWh to Rs 3.15/kWh. These tariffs reflect land leasing or ownership costs, operational expenses, and provisions for annual escalations.

Available data indicates average variable power costs for DISCOMs supplying rural consumers range from Rs 4.03/kWh to Rs 5.30/kWh. Hence, current PM-KUSUM tariffs are theoretically beneficial for DISCOMs in terms of displacing higher-cost conventional power procurement. However, field insights reveal that actual operational costs borne by farmer-developers frequently exceed assumptions underlying tariff structures. Limited annual tariff escalation provisions mean current costs are based on project capital cost estimations that may not adequately reflect ground realities, contributing to tariff viability concerns among developers.

Tariff structures show modest variation across states, with Chhattisgarh offering highest tariffs (Rs 4.07-4.24/kWh for Component A), while Gujarat and Uttar Pradesh offer lowest rates. These tariff differentials reflect varying state contexts, including land costs, grid infrastructure conditions, DISCOM financial health, and competitive intensity in procurement auctions. States offering relatively higher tariffs (Chhattisgarh, Rajasthan, Assam) may be attempting to incentivise participation in challenging implementation environments, although tariff levels alone have proven insufficient to overcome other systemic barriers limiting deployment.

Table: 2 State-wise tariff comparison

State	Tariff for Component A (Rs/kWh)	Tariff for Component C (Rs/kWh)
Gujarat	2.95	2.35–3.04
Maharashtra	2.97	3.10
Rajasthan	3.14	2.70–3.04
Uttar Pradesh	2.79–3.05	2.99
Madhya Pradesh	3.07	2.94–3.30
Chhattisgarh	4.07–4.24	3.70
Assam	3.30	3.30
Tamil Nadu	3.10	3.10

Source: Authors' compilation from tariff-orders

Synthesis of implementation performance

The implementation analysis reveals that PM-KUSUM's success is highly contingent on state-level prioritisation, administrative capacity, and targeted policy support beyond baseline scheme provisions. Component B's relative success demonstrates that simplified processes, clear value propositions, and adequate subsidies can drive adoption. Conversely, Components A and C face systemic challenges spanning land acquisition, tariff viability, grid integration, financing access, and procedural complexity that require coordinated interventions beyond incremental adjustments to existing frameworks.

Insights from stakeholder consultations

The author undertook extensive consultations with diverse stakeholders across the PM-KUSUM implementation ecosystem to understand ground-level challenges and operational realities. The engagement process began with secondary research on recurring challenges within Components A and C, drawing from available studies and field reports. Based on this preliminary analysis, a comprehensive primary survey was designed covering critical themes preventing higher installations within states.

The consultations and virtual meetings were undertaken with key stakeholders, such as farmer beneficiaries who have availed installations under PM-KUSUM, project developers/EPC within the distributed solar markets, state renewable energy agencies (SNAs) who have implemented PM-KUSUM projects, renewable energy associations/industry groups involved in policy advocacy, and power procurers, DISCOMS involved in purchasing power from PM-KUSUM plants. The detailed questionnaire is provided in the Annexure.

The methodology employed questionnaires and semi-structured interviews organised around four common thematic areas:

- Project execution and management within the current regulatory framework.
- Current scheme design, relevance, and governance mechanisms.
- Ease of implementation based on technical performance and reliability.
- Cost of capital and financing for projects including power procurement arrangements.

The following insights are compiled based on discussions held with the stakeholder groups. While the questionnaires and interview protocols varied across stakeholder categories, common themes have been synthesised to understand ease of access and enrolment, financial and technical design considerations, implementation and operational experiences, institutional coordination challenges, and governance mechanisms. The consultations also captured stakeholder perspectives on performance outcomes, economic risk factors, and overall satisfaction with the scheme. The objective was to generate evidence on how PM-KUSUM is functioning across different contexts and stakeholder groups, identify implementation bottlenecks and good practices, and draw actionable insights to strengthen and scale the scheme effectively.

Beneficiary consumers: Farmers and project developers

Discussions with farmers and project developers revealed several operational realities and implementation challenges that shape their participation in the scheme.

Project scale and business potential: The bulk of capacity being added under Components A and C falls between 1–1.5 MW project sizes, with almost all installations being ground-mounted systems. Respondents acknowledged significant business opportunities due to ongoing tender auctions, upcoming capacity allocations, scale and diversity of installations, and emerging demand from rural consumers. However, the realisation of these opportunities remains constrained by multiple factors discussed below.

Tariff viability concerns: A recurring theme across developer consultations was that auctioned tariff rates are being determined as uncompetitive and often marginal or too low to cover investment and interconnection costs. This has resulted in fewer bids and slower uptake across several states. Developers documented instances of project cancellations even after winning letters of award (LoA), as actual commissioning costs exceeded projected internal rates of return (IRR). The competitive bidding process, while ensuring price discovery, has pushed tariffs to levels that compromise project bankability, particularly for smaller developers with limited capacity to absorb risks.

Land identification and transaction costs: Identification of suitable land and adherence to land-use principles emerged as one of the biggest implementation drawbacks. The overall transaction costs from additional expenses incurred from various procedural and regulatory factors continue to remain prohibitively high, effectively excluding small and middle-sized farmers from participation. Leasing rates vary substantially based on regional contexts and include annual escalation clauses, often quoted higher than sanctioned benchmarks, leading to increased capital costs for project owners over the project duration. The requirement that sites must be located within a five-kilometre radius of existing sub-stations further constrains the available land pool, intensifying competition and driving up costs.

Subsidy adequacy and technology uncertainty: Despite substantial subsidies under Component C (up to 40 per cent of project costs), participation remains lower than anticipated due to uncertainty regarding technology performance and long-term benefits. This has particularly impacted Component C2 (feeder-level solarisation) and Component A, where individual farmer end-users are not directly present and high upfront costs have discouraged farmers from opting for

larger installations. Affordability remains a significant concern for majority of farmers, even with subsidy support, highlighting the need for innovative financing mechanisms.

Integration with farming practices: On a positive note, there is a strong perception among farmers of increased income opportunities from integrating solar projects with existing farm practices. Many respondents reported successfully configuring crop production with solar installations, hinting at an emerging interest in Solar PV for purposes that co-benefit an integrated farm operation. This suggests growing awareness of agrovoltaic models and dual-use land optimisation strategies.

Competition with subsidised grid electricity: In areas where grid electricity remains cheap or free, farmers expressed limited incentive to shift to solar-based systems. Respondents mentioned contentment with current supply hours and patterns, noting that grid-based electricity continues to be provided with no additional financial burden, creating no compelling economic incentive to invest in solar-based irrigation or power systems. This highlights the challenge of competing with heavily subsidised conventional electricity supply.

Approval process complexity: Project developers consistently mentioned that the overall design and administrative process of the scheme requires multiple sequential approvals rather than parallel processing. This approval and documentation process is cumbersome and not consumer-friendly, particularly for small agencies, including farmers and EPC contractors. The prevalence of stringent technical specifications, financial guarantee requirements, and lack of robust payment security mechanisms creates navigation challenges that disproportionately affect smaller stakeholders with limited administrative capacity.

State nodal agencies, implementation agencies, and DISCOMs

Consultations with state-level institutions revealed their critical role in scheme implementation, along with significant institutional and operational challenges.

State prioritisation as success determinant: The success or failure of the scheme has often depended on priorities identified by state implementation agencies for solarising irrigation infrastructure. Since the scheme mechanism requires states to inform MNRE about proposed capacity additions, their role in promoting and facilitating the scheme is pivotal. States performing well on PM-KUSUM—such as Rajasthan and Haryana for Component A, and Maharashtra and Gujarat for Component C—have prioritised deployment based on regional and local factors

including groundwater stress, agricultural load profiles, and fiscal considerations. Given that state roles extend to tender design, tariff auctioning, approval processing, and monitoring, their proactive engagement has proven critical for faster implementation.

Coordination and capacity constraints: State nodal agencies face significant barriers in terms of coordination bottlenecks, including identification of suitable land parcels and detailing sub-station geographic and technical specifications. These challenges are compounded by limited availability of suitable technical and administrative manpower. SNAs highlighted insufficient staffing to undertake parallel activities across different scheme components simultaneously. Components A and C are substantially more complex than Component B in terms of regulatory compliance, grid integration, and contractual arrangements. Fragmented state regulations governing land leasing, metering infrastructure requirements, and monitoring protocols vary considerably across jurisdictions, creating additional administrative burden for SNAs attempting to maintain consistency and compliance.

Grid feasibility and integration challenges: There is a strong consensus on the requirement for comprehensive grid feasibility assessments for distributed renewable energy resources. DISCOMs and SNAs reported that current distribution systems lack the technical flexibility and robustness to integrate variable renewable energy on local distribution networks without significant upgrades. Some respondents mentioned undertaking in-house studies toward network expansion and exploring cheaper power procurement from distributed resources. However, they repeatedly emphasised the absence of detailed studies on localised impacts from DRE sources, including voltage fluctuations, protection coordination, and feeder loading patterns. This knowledge gap has contributed to connectivity failures and instances of deemed generation that could have been avoided with proper technical assessment and planning.

Localised consumption versus grid export: Respondents noted that the landed costs for power procurement from PM-KUSUM plants are currently not localised, with bulk power purchase and injection occurring at 11/33 kV voltage levels. However, the real economic and technical benefits materialise when there is increased localised consumption rather than exported to the broader grid, reducing transmission losses and improving voltage profiles. The emergence of utility-scale storage tenders presents opportunities to integrate battery storage with PM-KUSUM plants, offering more robust and stable power generation profiles while creating additional revenue streams through peak power supply and grid services.

Project finance and lending agencies

Discussions with financial institutions revealed significant risk perception issues and structural barriers to credit flow, as mentioned below:

Risk perception and collateral challenges: Lenders reported that risk perceptions for loan defaults in small-scale solar projects are legally and socially complex, representing unfamiliar territory for traditional agricultural and infrastructure lenders. Small-scale solar projects carry higher perceived default risks compared to utility-scale projects. Suitable alternative collateral options beyond land are largely absent, and the lack of reliable credit ratings for farmer-borrowers limits higher credit disbursal. Agricultural land, while valuable, often faces restrictions on mortgage and foreclosure, creating legal uncertainties for lenders in default scenarios.

Due diligence and project assessment barriers: While financial institutions are receiving applications for PM-KUSUM projects, extensive due diligence requirements—regarding financial viability, weighted cost of capital calculations, and PPA structure analysis—restrict their ability to lend extensively to the sector. Lenders suggested that availability of standardised credit rating frameworks for developers and farmer-borrowers could help more accurately assess the appropriate extent and quantum of financial assistance, potentially unlocking greater credit flow.

Priority sector lending framework gaps: Although provisions exist for PM-KUSUM projects under priority sector lending (PSL) norms, the absence of clearly defined or officially recognised frameworks restricts financiers from extending credit with confidence. Lenders cited multiple risks including payment defaults from DISCOMs, non-compliance issues such as delayed project timelines, deemed generation disputes, and unclear land records as factors that raise their overall cost of lending and reduce appetite for this segment. Respondents highlighted the presence of several cross-cutting financing mechanisms available for solar and rural development projects—including climate funds, livelihood support mechanisms, and agricultural investment funds—that could potentially be leveraged in complementary fashion to support solarisation initiatives in rural areas. However, coordination mechanisms to integrate these diverse funding sources remain underdeveloped.

Synthesis of stakeholder perspectives

The stakeholder consultations reveal that PM-KUSUM's implementation challenges are systemic rather than isolated, spanning regulatory design, institutional

capacity, financial architecture, and technical infrastructure. Successful scaling of the scheme requires coordinated interventions addressing these interconnected barriers, with particular attention to streamlining approval processes, enhancing tariff viability, strengthening grid infrastructure, and developing innovative financing mechanisms that distribute risks more equitably across stakeholders. The varying success rates across states underscore the importance of state-level prioritisation, capacity building, and adaptive implementation strategies tailored to local contexts.

AGRI-PHOTOVOLTAICS: AN ALTERNATIVE BUSINESS MODEL FOR PM-KUSUM

Opportunity in shifting towards alternative business models

The implementation of PM-KUSUM has revealed several persistent challenges that conventional solar deployment models struggle to address effectively. Among these, land availability, farmer acceptance, and project financing remain the most critical barriers. As the scheme progresses, it has become increasingly clear that innovative approaches are needed to unlock the full potential of decentralised solar energy in rural India.

One such promising alternative is Agri-Photovoltaics, or Agri-PV, a technology that fundamentally reimagines how we use agricultural land. Rather than choosing between farming and energy generation, Agri-PV enables both activities to coexist on the same plot. This dual-use approach represents more than just a technical innovation; it offers a pathway to resolve the fundamental tension between India's growing energy needs and the imperative to preserve productive agricultural land.

Agri-PV systems employ solar photovoltaic panels installed on elevated structures above agricultural fields, allowing crops to continue growing beneath them. The panels are typically mounted at heights ranging from two to five metres, creating sufficient clearance for farm machinery, irrigation equipment, and workers to operate normally. This configuration ensures that farming activities can proceed without significant disruption while simultaneously generating clean electricity.

The partial shading created by these elevated panels brings additional agronomic benefits. In India's increasingly hot agricultural zones, the shade helps mitigate crop heat stress, reduces water evaporation from soil, and moderates local microclimatic conditions. These effects can actually improve crop yields for certain varieties, particularly leafy vegetables and some horticultural crops that are sensitive to extreme heat.

However, despite its promise, Agri-PV currently occupies an uncertain position within PM-KUSUM's framework. The scheme does acknowledge that cultivable land may be utilised where solar plants are installed on elevated structures, allowing crop cultivation beneath while power is sold to DISCOMs. Yet, there are no dedicated incentives or specific standards to actively promote agrivoltaic deployment. This gap is significant because Agri-PV systems face considerably higher capital costs compared to conventional ground-mounted installations.

The economics present a clear challenge. Agri-PV installations cost approximately Rs 3.5 crore per MW, which is 40 to 60 per cent higher than ground-mounted systems. This cost differential stems from the more complex structural requirements, elevated mounting systems, and the need for careful design optimisation to balance energy generation with agricultural productivity. The existing performance-based incentives offered to DISCOMs for procuring power from PM-KUSUM-sanctioned plants do not differentiate between ground-mounted and agrivoltaic systems, leaving no mechanism to offset these higher costs.

For prospective developers—whether individual farmers, farmer collectives, cooperatives, panchayats, farmer producer organisations, or independent power producers—this creates a strong disincentive. Without tariff structures that adequately reflect the higher capital requirements and additional benefits of Agri-PV, these systems struggle to compete economically with conventional solar installations. The result is that despite India's enormous Agri-PV potential, deployment remains limited to a handful of demonstration projects and forward-thinking early adopters.

According to the Solar Technology and Application Atlas of India, the country's Agri-PV potential stands at an impressive 3,156 GW across various states. The maximum potential lies in Punjab, Rajasthan, Haryana, Madhya Pradesh, and Telangana—states that also happen to have the highest agricultural intensity. This overlap is not coincidental; it represents the fundamental value proposition of Agri-PV, transforming the very regions where agricultural land is most precious into locations where land can serve dual purposes without compromise.

The question facing policymakers is how to unlock this potential. In principle, if ceiling tariffs under competitive bidding are set at levels that adequately reflect the higher costs of Agri-PV, DISCOMs could derive value from these investments under PM-KUSUM Component A. Farmers, meanwhile, could benefit through enhanced land-leasing revenues, particularly when their land is located near substations where grid connectivity is readily available. Creating a supportive policy environment requires recognising that Agri-PV is not merely an alternative technology but a fundamentally different development model that deserves tailored support mechanisms.

How Agri-PV addresses key barriers in PM-KUSUM implementation

The challenges facing PM-KUSUM are well-documented. These include land acquisition difficulties, farmers' reluctance to commit agricultural land for extended periods, financing constraints, and concerns about the social acceptance of solar projects in rural communities. Agri-PV offers concrete solutions to each of these barriers, transforming obstacles into opportunities for more inclusive and sustainable development.

Addressing land constraints

Land availability has emerged as one of the most significant bottlenecks in Component A implementation. Farmers are understandably hesitant to dedicate productive agricultural land exclusively to solar installations, particularly when they face uncertainty about long-term returns and the opportunity cost of removing land from cultivation. This hesitation is most acute among small and marginal farmers whose entire livelihood depends on their limited landholdings.

Agri-PV directly resolves this tension by enabling dual land use. Agricultural land can simultaneously support solar power generation and crop cultivation, fundamentally altering the calculation for farmers. There is no longer a binary choice between farming and energy; both can proceed together on the same plot. This dramatically reduces the opportunity cost that has deterred many farmers from participating in PM-KUSUM Component A.

Moreover, the partial shading provided by solar modules can actually enhance agricultural outcomes in several ways. In regions experiencing rising temperatures and increased heat stress—conditions that are becoming more common across India's agricultural belt—the shade from panels helps protect crops from extreme heat. Water evaporation from soil is reduced, improving irrigation efficiency and helping crops maintain productivity even during hot periods. For certain crop varieties, yields may actually improve under the moderated microclimate created by the panels.

This means farmers are not sacrificing agricultural productivity for energy generation. Instead, they are optimising their land for both purposes, potentially even enhancing crop performance while adding an entirely new revenue stream. The land remains productive, continues generating agricultural income, and farmers retain

the flexibility to adjust their farming practices as conditions change. This addresses the deep-seated concern about locking land away for the 25-year lifecycle of solar installations.

Overcoming financial barriers

Access to finance remains a critical constraint for PM-KUSUM implementation, particularly for small and marginal farmers who lack the capital to invest in solar installations or the collateral to secure conventional loans. Even when subsidies are available, the upfront financial commitment required can be prohibitive. This has limited participation in Component A primarily to larger landholders and outside developers, reducing the scheme's inclusivity.

Agri-PV transforms the financial equation by creating dual revenue streams. Farmers can earn income both from solar power generation and from agricultural crop yields. This diversification is valuable not just for farmers themselves but for the entire financing ecosystem. Projects with multiple income sources are inherently less risky and more bankable. Financial institutions can offer loans with greater confidence when repayment depends on both electricity sales and agricultural production rather than a single revenue source.

The combination of short-term operational returns from seasonal crops and long-term predictable revenue from electricity sales under power purchase agreements creates a balanced income profile. This makes Agri-PV projects more attractive to both developers and lenders, improving access to capital and reducing the cost of financing. Better project economics also allow farmers to participate with lower subsidy requirements, improving the overall financial sustainability of PM-KUSUM Component A.

Beyond farmer-level benefits, Agri-PV also addresses financial challenges for DISCOMs. By enabling distributed generation close to demand centres, these systems reduce the need for extensive feeder upgrades and long-distance transmission infrastructure. Capital expenditure requirements decrease, and distribution losses are minimised. DISCOMs can procure locally generated power at competitive rates while avoiding the substantial infrastructure investments that would otherwise be needed to meet growing rural electricity demand.

This localised generation model aligns with the broader objectives of Components A and C, supporting grid stability and rural electrification while reducing the financial burden on distribution companies. The result is a more financially sustainable model for implementing decentralised solar projects across rural India.

Building social acceptance and farmer agency

Perhaps the most powerful advantage of Agri-PV lies in its ability to address social and cultural barriers to solar adoption. Traditional solar installations require farmers to transform their identity from cultivators to power producers, a shift that many find uncomfortable. Agricultural land holds deep cultural and social significance in rural India; it represents not just an economic asset but family heritage, social standing, and a way of life passed down through generations.

Agri-PV allows farmers to retain their identity as cultivators while adding a complementary role as clean energy producers. They maintain control and ownership of their land, continue their farming operations, and benefit from increased incomes without fundamentally changing their occupation or social role. This continuity is crucial for building acceptance in farming communities.

The technology also creates opportunities for community-led initiatives and scaling through collective action. Farmer producer organisations, cooperatives, and community groups can establish Agri-PV installations that benefit multiple members, building social cohesion while achieving economies of scale. This model is particularly important for small and marginal farmers who individually lack the resources to participate but can join together to create viable projects.

By preserving agricultural production while adding energy generation, Agri-PV directly addresses the core objectives of PM-KUSUM—improving farmer incomes, promoting renewable energy, and supporting rural development. The scheme was designed not merely to deploy solar capacity but to do so in a way that empowers farmers and strengthens rural economies. Agri-PV fulfils this vision more completely than conventional solar installations, making it easier to build the broad social acceptance needed for large-scale implementation.

Supporting climate resilience and national goals

India faces the dual challenges of meeting growing energy demand and ensuring food security for a rising population, both while adapting to climate change. Agri-PV offers a pathway to address these intertwined challenges simultaneously rather than forcing difficult trade-offs between them.

The climate benefits extend beyond clean energy generation. By reducing crop exposure to extreme temperatures, Agri-PV enhances agricultural resilience in food production. This aligns with national decarbonisation goals while helping farmers adapt to changing climatic conditions. The systems can power irrigation, processing, and storage infrastructure with clean energy, reducing dependency on diesel and improving post-harvest management.

In essence, Agri-PV represents a comprehensive solution that strengthens environmental sustainability, enhances rural incomes, supports national renewable energy targets, and builds agricultural resilience—all from the same infrastructure investment. This integrated approach makes it a powerful tool for implementing PM-KUSUM in a way that creates lasting value for farmers, communities, and the nation.

Learning from the field: Case studies in Agri-PV implementation

While policy frameworks for Agri-PV are still evolving, several pioneering projects across India demonstrate the technology's practical viability and its diverse applications. These case studies reveal how different configurations and business models can be adapted to local conditions, crop choices, and farmer needs.

Case study A: Krishi Vigyan Kendra (KVK) Ujwa, Najafgarh, New Delhi

At the Krishi Vigyan Kendra (KVK) in Ujwa, a 110-kW demonstration project showcases how Agri-PV can benefit small farmers through innovative integration of horticultural production and solar energy generation. This project serves an important educational purpose, demonstrating the dual benefits of the Agri-PV model to farmers who might otherwise be sceptical of the technology.

The panel configuration at KVK Ujwa was carefully designed to maximise the usable space beneath the elevated structures. The site grows a variety of horticultural products including green leafy vegetables, cauliflower, onions, turmeric, and radish. The choice of these crops is deliberate; they benefit particularly well from the partial shading provided by the panels, which reduces heat stress and water loss during the hot summers in Delhi.

The installation employs efficient sprinkler irrigation systems that work in harmony with the shading from the panels above. Together, these elements create an optimised microclimate that has demonstrated improved yields for the crops grown beneath the panels. Water-use efficiency increases because reduced evaporation means lessens the amount of irrigation required to maintain soil moisture levels.

Power procurement from this site is managed by BSES Rajdhani, the distribution company serving New Delhi. Beyond electricity generation, the project's greatest value may be as a demonstration and training facility. Farmers visiting KVK Ujwa can observe firsthand how the system operates, understand the agricultural practices that work best beneath the panels, and evaluate whether similar

installations could work on their own land. This hands-on learning opportunity helps build confidence and knowledge, potentially catalysing wider adoption.



ALL PHOTOGRAPHS: ARVIND POSWAL / CSE

110 kW installation at KVK Ujwa, New Delhi

Case study B: Bhaloji village, Kotputli district, Rajasthan

Near Kotputli in Rajasthan, a 1 MW installation completed in 2021 demonstrates the flexibility of Agri-PV systems and their potential for multiple utility purposes. This site employs a mixed-use approach, combining ground-mounted solar panels with elevated Agri-PV sections, creating different zones optimised for different functions.

The project's evolution tells an interesting story about adaptation and optimisation. Initially, the site featured an extensive fish farming operation beneath the panels, with ponds dug out under the solar structures. This aquavoltaic approach



Case study B 1 MW mix land-use solar plant at Bhaloji, Rajasthan

represented one form of dual-use land management, combining aquaculture with solar energy generation. Later, the configuration was modified and converted to a different system, reflecting the owner's ongoing efforts to optimise land use and revenue generation based on practical experience.

The tariff discovered for this site is Rs 3.14 per kilowatt-hour for a period of 25 years, with operational costs estimated at under Rs 7 lakh per MW annually. These figures demonstrate that, even with the higher capital costs of elevated structures, Agri-PV installations can achieve competitive tariffs under the right conditions. Power procurement is handled by JVVNL, the Jaipur DISCOM, providing a stable long-term revenue stream for the project.

The Bhaloji case illustrates an important point—Agri-PV systems can be adapted and reconfigured over time as operators learn what works best for their specific circumstances. This flexibility is valuable in a technology that is still relatively new in India, where best practices are still being established through real-world experimentation.

Case study C: Bhoopsera village, Kotputli District Rajasthan

A larger 4 MW installation near Neemrana demonstrates how solar installations can support rural development even in semi-arid landscapes with challenging agricultural conditions. This site, located on land bordering the Aravalli hills, operates on mixed shrub and arid terrain that limits opportunities for conventional agriculture or typical Agri-PV crop cultivation.

The project owner has innovatively adapted the elevated panel concept to create livestock infrastructure in some sections. Sheds and structures housing milch animals have been constructed beneath the solar panels, creating a dual-use system where the elevated structures serve both as solar mounting infrastructure and as protective roofing for animal husbandry operations.

The tariff structure for this site reflects its phased development, with 2.5 MW commissioned at Rs 3.07 per kWh and an additional 1.5 MW at Rs 3.14 per kWh, accounting for different project timelines. JVVNL serves as the power procurer, and the site plays an important role in supplying decentralised renewable energy in an area characterised by high transmission and distribution losses.

The Bhoopsera case demonstrates that the Agri-PV model need not be limited to conventional crop cultivation. In regions where agricultural limitations exist, the

elevated panel infrastructure can still enable productive dual use of land through livestock management or other compatible activities. This flexibility broadens the potential application of the technology across diverse agro-climatic zones.



Case study C 4 MW Bhoopsera, Rajasthan

Case study D: Khargapur, Tikamgarh district, Madhya Pradesh

The most technically ambitious of these case studies is a 4.5 MW installation near Khargapur in Madhya Pradesh, developed by Khare Energy Pvt. Ltd. This project represents a serious scientific effort to test the feasibility of Agri-PV for traditional food crops, particularly wheat—a staple that forms the backbone of India's food security.

While Agri-PV has demonstrated success with horticultural crops and vegetables, its viability for dominant food crops like wheat, rice, and pulses has remained uncertain. These crops have different light requirements, growth patterns, and agricultural management practices compared to the vegetables and fruits that have worked well in earlier Agri-PV installations. Proving that food crops can thrive beneath solar panels is essential for Agri-PV to scale significantly across India's vast agricultural landscape.

The Khargapur site employs five different configuration settings, each designed to test specific variables and their impact on wheat yield and nutritional quality. These configurations vary in vertical distance between panels and ground, spacing between panel rows, structural dimensions, irrigation methods, light incidence patterns, and shading intensity. By systematically comparing crop performance across these different setups, the project generates valuable data about optimal design parameters for wheat cultivation under Agri-PV systems.

The research extends beyond wheat. Khare Energy is conducting similar trials for banana, various pulses, sugarcane, and other crops important to Indian agriculture. This comprehensive research approach reflects an understanding that different crops will require different Agri-PV configurations, and commercially viable systems must be tailored to the specific requirements of the crops farmers actually cultivate.

The tariff discovered for this project is Rs 3.17 per kWh, with power procured by MPPKVVCL, the Madhya Pradesh distribution company. While the tariff is slightly higher than some conventional ground-mounted installations, it remains within competitive range, especially considering the dual value generated through both electricity and crop production.

What makes the Khargapur project particularly valuable is its contribution to building the knowledge base needed for widespread Agri-PV adoption. By rigorously testing different configurations and documenting their effects

on crop yields, nutritional content, and farming practices, this installation is helping establish the technical standards and best practices that will be essential for scaling Agri-PV across India. The data generated here can inform design guidelines, help farmers make informed decisions about system configurations, and provide evidence to support policy frameworks that recognise the distinct value of agrivoltaic installations.



Case study D 4.5 MW Agri-voltaic solar plant at Tikamgarh, Madhya Pradesh

Major challenges identified in the scheme implementation for Component A and C

The performance of PM-KUSUM has been evaluated primarily on parameters related to improving agricultural power supply positions and advancing solarisation of irrigation pumps. However, as efforts intensify to improve power supply in rural areas, significant challenges have emerged in deploying small-scale solar plants (under 2 MW capacity). These challenges are predominantly shaped by three interconnected constraint factors:

- Land-use requirements and availability.
- Viability of commercial business models at discovered tariff rates.
- Grid availability coupled with energy loss mitigation strategies.

Unlike large-scale utility solar power plants—where challenges of land acquisition, grid connection, and infrastructure availability are somewhat mitigated through mechanisms like the solar parks scheme and economies of scale—project developers under PM-KUSUM must accommodate their operations within significantly tighter constraint parameters. The complexities are further compounded by the demand-driven nature of the scheme, which places the onus of implementation exclusively on state governments. States determine overall annual targets for implementation of scheme components based on their assessment of power supply requirements and solar adoption potential, creating significant variations in implementation outcomes across jurisdictions.

Land-use constraints and acquisition challenges

Land-use requirements emerging from solar project deployment present multifaceted constraints spanning land availability, leasing processes, conversion procedures, and regulatory compliance requirements that collectively impact project land acquisition timelines and costs.

High land costs and ownership complexities: Land costs in suitable locations remain high while ownership rates among small farmers are relatively low, raising overall acquisition costs for projects. Land conversion from agricultural to non-agricultural categories is typically required, with additional costs varying substantially across states. For instance, Madhya Pradesh restricts conversions

for tenures beyond six years, while Rajasthan and Karnataka impose no such temporal limits but maintain restrictions on land type and size eligibility. The absence of clear, digitised land records and prevalence of ownership disputes further compound acquisition challenges, ultimately disrupting PPA execution timelines and creating uncertainty for developers and financiers.

Limited availability and competing uses: The requirement that projects be located within five kilometres of applicable sub-stations significantly constrains the pool of technically suitable land, reducing geographic spread of potential projects. The fragmented nature of land holdings creates additional complications with high transaction costs for aggregating sufficiently large land parcels. Traditionally, land parcels in India have been less than 1 hectare (approximately 85 per cent of holdings), making individual plots unviable for solar installation unless aggregated together. Fragmented holdings substantially increase engineering, procurement, and construction (EPC) overheads for project execution. Negotiating agreements between numerous landowners or lessors is administratively cumbersome and practically restricts joint-ownership arrangements that could otherwise facilitate project development.

Grid connectivity and transmission infrastructure: Connectivity challenges are further exacerbated by land approval processes required for laying grid connectivity infrastructure and transmission lines. Legal complexities associated with Right of Way (RoW) permissions require protracted negotiations with multiple landowners along transmission corridors, adding significant delays to project deployment timelines and introducing additional cost uncertainties.

Commercial and procedural viability challenges

The commercial and procedural viability of projects is substantially impacted by high capital investment requirements, tariff adequacy relative to project costs, the extent and effectiveness of subsidy support, and procedural costs associated with obtaining multiple approvals while navigating technical constraints. Project stakeholders remain highly dependent on public subsidies, DISCOM offtake contracts, and bank financing. Consequently, cost of capital, approval timelines, and overall project viability are disproportionately impacted by tariff levels and procurement uptake.

High capital costs and financing barriers: Benchmark capital costs for PM-KUSUM projects range from Rs 3.25–3.75 crore per MW, representing prohibitive investment levels for individual farmers, farmer groups, and small-sized project developers. The cost of financing through bank loans for DRE

projects is substantially higher compared to large utility-scale projects, with lenders charging higher interest rates reflecting perceived elevated risks. Beyond capital costs, projects face high operational costs stemming from multiple approval requirements involving five to seven different administrative bodies. In the absence of substantial upfront subsidy under Component A, projects require significant equity contribution from developers or owners, with limited mortgage financing available against agricultural land. These compounding costs result in higher levelised cost of energy (LCoE), rendering current tariff levels unviable for many potential participants. While Component C provides subsidy and CFA that reduce upfront capital costs, these measures do not adequately address ongoing financial risks of projects, thereby limiting their effectiveness in catalysing broader participation.

Tariff viability concerns: Tariffs for Components A and C across various states predominantly range between Rs 2.80/kWh to Rs 3.30/kWh. Tariff determination processes employ reverse-bidding formats, despite relatively small project ticket sizes (typically 1–2 MW each, compared to utility-scale projects exceeding 10 MW). Distributed solar tariffs are frequently benchmarked against utility-scale solar rates despite fundamentally different cost structures, risk profiles, and operational characteristics. Tariffs serve as critical price signals influencing farmer inclusion, developer participation, and long-term project viability. Current competitive bidding models drive tariffs down aggressively, often below levels necessary to ensure adequate returns. This misalignment has resulted in project developer exits even after securing winning bids, as documented in Rajasthan and Maharashtra where developers found actual implementation costs exceeded financial viability thresholds assumed during bidding.

Table 3: Structural misalignment of tariffs for PM-KUSUM

Aspect	Utility-scale Solar	PM-KUSUM/DRE
Project size	50–500 MW large-scale installations	500 kW–2 MW smaller distributed scale
Financing	Low-cost institutional financing from multiple agencies	High-cost financing for rural segments with limited lender participation
Approval risks	Centralised and typically pre-approved processes	Fragmented with significant state-wise variations
Tariff determination logic	Scale-driven model with assured connectivity infrastructure	Risk-driven model with unrealistic assumptions on financing costs

Source: Authors' construct

Multiple approval processes: Project development involves numerous entities in approval and design processes. Typically, five to seven distinct approvals are required, including, land-related clearances from revenue departments, tender

design and PPA execution with DISCOMs/SIAs, subsidy sanction from MNRE/SIA, grid connectivity approvals from DISCOMs/state transmission utilities, and various other regulatory clearances. Multiple parallel approval systems prove cumbersome for farmers and small developers while locking up costly capital during extended timeline uncertainties. Strict requirements regarding plant sizing, location parameters, and system generation profiles within tender designs, coupled with technical considerations such as performance bank guarantees, substantially increase EPC costs. These additional costs render projects unviable for small farmers and project developers, effectively restricting meaningful participation. Application of Domestic Content Requirement (DCR) rules and Approved List of Models and Manufacturers (ALMM) mandates for PM-KUSUM projects have further impacted commercial viability and extended implementation timelines.

Grid connectivity constraints

Fundamentally, PM-KUSUM represents a distributed solar energy generation programme embedded within India's weak rural distribution grid infrastructure. Unlike large-scale solar installations where transmission planning is integrated with new generation capacity from the outset, PM-KUSUM projects are retrofitted onto existing rural grids and feeder sub-stations that were not originally designed to accommodate distributed generation. This structural reality has created substantial barriers related to connectivity, capacity constraints, and grid connection costs, making grid infrastructure a core determinant of operational feasibility, project economics, and implementation timelines.

Capacity constraints: Rural distribution grids in India are characteristically burdened by high technical losses, seasonal and irrigation-dominated load profiles, aging infrastructure components, and limited real-time monitoring capabilities. Notified sub-stations are frequently operating at or near capacity limits and were not designed to accommodate reverse power flows from distributed generation. Integration of solar generation raises technical considerations including voltage surges, inverter tripping events, and protection coordination challenges, ultimately resulting in curtailment of exported power and revenue losses for generators.

Grid connection costs and feeder requirements: Per scheme guidelines, grid availability must be maintained for solar plants located within a five-kilometre radius of rural sub-stations. This necessitates feeder segregation and connectivity readiness during solar generation hours. The inherently weak rural grid connectivity and stability constraints limit the quantum of additional solar power that can be absorbed without infrastructure upgrades. Under Component C, reverse power injection back to local transformers has created transformer loading issues, as

equipment was designed exclusively to address peak consumption rather than accommodate generation, potentially leading to under-sizing of installed plant capacity relative to technical potential.

Deemed generation and revenue uncertainty: Accounting for deemed generation during periods when grid availability has been curtailed or infrastructure proves inadequate leads to revenue reduction for developers. Delays in network augmentation and net-metering infrastructure deployment create cash-flow cycle disruptions that undermine project financial viability. In the absence of a cohesive framework to account for these hidden costs related to grid access constraints, such costs are externalised to farmers and developers, who bear the financial consequences of infrastructure inadequacies beyond their control.

Barriers to scaling for DISCOMs and state nodal agencies

The functional responsibilities of DISCOMs and state implementing agencies (SIAs) regarding scheme implementation create barriers in project approvals, sanctioning processes, and tendering and bidding procedures. Inadequate regulatory alignment and limited in-house capacity to synchronise scheme implementation between state and national policy frameworks generates multiple challenges.

Inadequate infrastructure upgrades: DISCOMs undertaking grid feasibility assessments to ensure technical compatibility for PM-KUSUM projects face challenges, including limited substation capacity and inadequate forecasting of future load requirements, which delay approval processes. For SNAs, delays in tendering and bidding processes result in diminished developer interest. Limited outreach capacity and insufficient in-house capacity building efforts fail to engage local stakeholders adequately. Infrastructure development and upgrades necessary to accommodate new projects depend on prior funding availability and investment prioritisation by DISCOMs for DRE integration. Absence of enforcement mechanisms such as mandatory Renewable Purchase Obligation (RPO) contributions from decentralised resources lead to poor alignment with national renewable energy deployment trajectories.

Fragmented regulations and state-level bottlenecks: Different states have adopted varying net-metering frameworks, grid integration protocols, and tariff policies that ostensibly reflect local conditions. However, significant variations exist even within individual states, creating inconsistent implementation

environments. Procedural delays in CFA sanctioning and coordination challenges between MNRE and SNAs result in disjointed implementation, creating timeline delays and uncertainty for farmers and developers attempting to navigate the system.

In-house capacity and stakeholder engagement: Limited resources available for tender design, bidder evaluation, and contract finalisation create administrative bottlenecks and timeline challenges. This capacity constraint leads to lower adoption rates, as meaningful outreach and engagement remain limited for Components A and C, contrasting sharply with Component B where maximum implementation progress has been achieved due to its more modular and simplified implementation structure.

Challenges pertaining to financial viability and de-risking

Financial viability challenges extend beyond simple capital availability to encompass comprehensive de-risking requirements that affect all stakeholder categories.

Access to capital and high cost of finance: Farmers and developers encounter high upfront capital requirements, limited access to low-interest credit compared to utility-scale projects, inadequate scope of subsidy/CFA to cover financial risks, and uncertainty regarding long-term tariff stability. Payment delays from offtakers and late subsidy transfer further compound financial risks, creating liquidity pressures that discourage participation.

DISCOM and constraints from power procurement: DISCOMs and power procurers frequently struggle with liquidity constraints that limit investment capacity in new resources, particularly when conventional solar power is available at competitive rates through alternative procurement mechanisms. This dynamic creates reluctance to sign PPAs for PM-KUSUM projects due to perceived higher costs, concerns about additional grid-strengthening expenses including feeder augmentation requirements, and delays in subsidy reimbursements from MNRE or state governments for power procurement. State nodal agencies face insufficient budget allocations, administrative burden from multiple concurrent processes, and lack of effective monitoring systems for tracking performance of existing projects.

Table 4: Summary of factors and their impacts

Factor/Challenge	Impact	Stakeholders involved
Land-use related: Acquisition/leasing/siting	Delays in site selection, acquisition, construction and commissioning. Difficulty establishing viable business models for allocated land. Inability to use land as secure collateral for financing.	Farmers, developers, SNAs
Commercial and financial viability of projects	High capital investments and elevated borrowing costs. Requirement for tariffs reflective of DRE cost structures. Multiple and layered approval processes raising overall transaction costs.	Farmers, developers, financial institutions, offtakers, SNAs
Grid connectivity constraints	Network capacity augmentation requirements. Limited availability of suitable power infrastructure. Delays in commissioning and revenue losses from deemed generation.	DISCOMs, offtakers, STUs, farmer-developers
Programme implementation and alignment	Multiple process requirements stretching working capacity of DISCOMs and SNAs. Infrastructure upgrade requirements prior to tender release.	DISCOMs, offtakers, SNAs, farmer-developers
Financial viability	Limited access to finance and high borrowing costs for all stakeholders. Liquidity constraints and payment delay risks.	Farmer-developers, DISCOMs

Source: Authors' construct

These interconnected challenges demonstrate that successful scaling of PM-KUSUM requires integrated interventions addressing land, finance, tariff, grid, and institutional capacity simultaneously rather than isolated sector-specific reforms.

Mechanisms to strengthen components A and C

Based on sectoral consultations, expert opinions, and primary and secondary research insights, this section establishes mechanisms and strategies that provide supplementary support to strengthen the PM-KUSUM operational guidelines. The recurring challenges identified through stakeholder engagement centred on five critical domains—land-use principles and acquisition processes, approval procedures and risk mitigation frameworks, grid connectivity and network augmentation requirements, availability and accessibility of project finance, and creation of robust governance and monitoring mechanisms involving centre-state coordination.

To accelerate deployment and improve implementation outcomes, an integrated technical approach is required that simultaneously addresses land-use constraints, commercial and financial risks, cost of capital barriers, and grid readiness challenges. These interventions must be designed as mutually reinforcing rather than isolated measures, recognising that bottlenecks in one domain create cascading effects across the entire implementation chain.

Specific land-use interventions include

Utilisation of public and community lands: States should facilitate use of public, panchayat, and revenue lands through standardised 25-year lease mechanisms with predetermined terms. Standardised lease agreements provide assurance on leasing dimensions and protect developers and farmers from arbitrary escalations in leasing costs over the project lifecycle. State governments should address tenure security, resolve competing land-use claims, and ensure cost containment during PPA periods through standardised aggregation models developed exclusively for PM-KUSUM projects.

Promotion of productive land-use models: States should actively encourage productive land-use models, including agrivoltaic systems and their various business configurations, by providing incentives for dual-use of land. State tendering authorities can invite specialized bids requiring elevated structures and designs that enable partial shading compatible with crop cultivation or livestock grazing, even as national definitions and technical standards for agrivoltaics continue to be developed. The clustered infrastructure approach can be leveraged to create

specialised tender categories that mandate a certain capacity share (expressed as a percentage of total allocation) to be delivered as agrivoltaic installations, thereby mainstreaming this approach.

Community-led ownership models: As a subset of productive land-use strategies, states should facilitate community-led models on village common lands for solar energy generation that serves shared pumping and electricity consumption needs. Cooperative ownership structures reduce per-farmer financial burden, improve energy access equity, and strengthen community engagement with the scheme. These models are particularly relevant for small and marginal farmers who cannot individually afford Component A installations but can participate collectively.

Reducing commercial and financial risks

Commercial and financial risks should be mitigated through robust payment security mechanisms, tariff rationalisation, and infrastructure planning that reduces project-level uncertainties. Key interventions include:

Payment security architecture: Address payment risk from DISCOMs to generator-developers by leveraging central and state funds through utilisation of savings from avoided power purchase costs and existing subsidy allocations for agricultural consumers. This can be accomplished without creating entirely new fund structures but by redirecting existing subsidy flows and procurement savings into dedicated payment security funds. Beyond the central Payment Security Fund (PSF), states should establish state-led PSFs similar to those provisioned in Madhya Pradesh and Maharashtra, utilising instruments such as letters of credit that provide bankable payment guarantees to project developers.

Tariff alignment and adequacy: State Electricity Regulatory Commissions (SERCs) must adopt indexed tariff structures that account for land leasing costs, higher implementation expenses resulting from Approved List of Models and Manufacturers (ALMM) and Domestic Content Requirement (DCR) mandates. Tariffs should be structured as two-part (split) tariffs comprising a capacity charge (compensating for plant availability and fixed costs) and an energy charge (compensating for actual kWh delivered). This variable mechanism also provides a framework for compensation during grid outages and establishes clear terms for curtailment compensation, addressing one of the major revenue uncertainties facing developers.

Localised infrastructure development: States should replicate the principles of the ultra-mega solar park scheme by provisioning dedicated line infrastructure,

systematic land identification, detailed feeder mapping, and assured transmission connectivity in areas with high penetration of agricultural loads and pump usage. This approach enables states to pursue aggregated bulk procurement for solar projects, including those incorporating storage solutions. Portfolio-based PPAs that bundle multiple smaller solar plants together reduce site-specific underperformance risks, lower transaction costs, and improve overall project bankability by diversifying generation risk across multiple locations and developers.

Ensuring access to project finance

Access to affordable project finance remains a critical constraint, particularly for small and marginal farmers and first-time developers. Interventions to improve financial access include:

Standardisation of financial documentation: Develop and mandate standardised financial documentation frameworks based on model PPAs and land-lease templates. The current lack of standardised PPAs increases due diligence burdens on lenders, contributing to lending reluctance. Standardisation reduces information asymmetry, enables faster credit appraisal, and lowers transaction costs for both lenders and borrowers.

Enhanced and targeted capital subsidies: Enhance capital subsidy targeting by provisioning higher CFA and state subsidies for small and marginal farmers, and for areas experiencing higher groundwater utilisation and extraction rates where the scheme's water conservation co-benefits are most critical. To enhance participation, states should introduce provisions allowing farmers to defer their equity contribution through structured instalment payments aligned with project revenue generation, rather than requiring full upfront payment that creates liquidity barriers.

Improving grid availability and network augmentation

Grid availability must be treated as a co-equal investment priority alongside solar generation assets. This requires systematic feeder-level assessments and proactive network augmentation planning to transform PM-KUSUM from a potential grid stress factor into a long-term distribution system strengthening intervention. Critical measures include:

Must-run status within hosting capacity: Provide must-run status for PM-KUSUM plants operating within assessed feeder hosting capacity, with curtailment permitted only for legitimate grid security reasons. This requires creation of dedicated PM-KUSUM feeder maintenance protocols specifying

higher inspection frequencies, preventive maintenance schedules, and priority fault restoration procedures to minimise deemed generation losses that erode project economics.

Comprehensive hosting capacity assessment: Conduct systematic hosting capacity assessments for all eligible feeders before sanctioning new capacity. These technical studies assess thermal limits of equipment including conductors and transformers, quantify the scope of voltage fluctuations (both rise and drop), and evaluate protection coordination requirements. Detailed hosting capacity assessments provide states with multi-year roadmaps for deploying higher shares of distributed generation resources, enable rational project siting decisions, and proactively avoid issues such as frequent curtailment and disputed deemed generation that undermine developer confidence.

Targeted infrastructure strengthening: Undertake targeted strengthening of 11/33 kV distribution infrastructure, including capacity enhancement through conductor upgrades and transformer replacements, and deployment of reactive power compensation devices (using STATCOM or inverter-based solutions). Priority should be given to feeders with high agricultural connection density, substantial daytime agricultural loads, and currently low renewable energy penetration where PM-KUSUM integration offers maximum system benefit.

Strategic storage integration: Optimise deployment of storage assets for flexibility operations by installing smaller-scale modular battery storage systems (typically under two-hour duration) to absorb excessive daytime generation and support evening agricultural loads when solar generation is unavailable. Strategic storage deployment also assists DISCOMs in deferring or avoiding capital expenditures for conventional network augmentation, improving the overall economic case for distributed solar integration.

Conclusion

Effective scaling of PM-KUSUM Components A and C requires a fundamental shift from subsidy-driven, project-by-project implementation to an integrated distribution-system-centric design that simultaneously addresses land availability, financial bankability, and grid readiness. The analysis demonstrates that PM-KUSUM's challenges are not rooted in solar technology maturity but in institutional design, risk allocation frameworks, and distribution network constraints that require coordinated policy interventions.

Prioritising feeder-proximate degraded land and dual-use agrivoltaic models through standardised long-term leasing and aggregation mechanisms can significantly reduce land-related delays and cost volatility. Equally critical is treating PM-KUSUM assets as grid-supporting distribution infrastructure rather than standalone generation sources. This requires feeder-level hosting capacity assessments, proactive network augmentation, standardised interconnection protocols, and strategic deployment of storage and voltage regulation technologies.

When implemented comprehensively, these measures improve grid availability, minimise curtailment losses, and align DISCOM incentives with long-term system performance objectives. The proposed recommendations position PM-KUSUM not merely as a renewable energy deployment programme but as a structural reform instrument that enhances distribution network resilience, reduces agricultural subsidy burdens, strengthens farmer income security, and delivers sustainable energy access outcomes for India's rural economy.

Annexure

Questionnaire towards understanding status of PM-KUSUM and opportunities for using DRE framework for supporting rural development.

Stakeholders: Beneficiary consumers, state nodal agencies, DISCOMS, project developers, and consultants.

Beneficiary consumers

1. Technical information
 - a. Capacity of installation
 - b. Tariff realised
 - c. Region
 - d. Size
2. Implementation information
 - a. Duration of the project and time since application and commissioning
 - b. Benefits and monthly expenditures
 - c. Challenges being faced directly (on-site related) and indirectly (from reasons such as grid availability, energy accounting mechanisms, etc.)
3. Other information related to project
 - a. Option to enhance capacity and future plans of extension
 - b. Financing for the plants, own contribution and ease of process in lending from financial institutions
 - c. Viability for the project in addition of further value-added services, such as crop production, water conservation practices, etc.
4. Perspectives on adding Agro-PV on their site (whether open to the idea)
 - a. Have you heard about Agro-PV, what is your opinion on integrating it?

State nodal agencies and related government stakeholders

1. Technical information
 - a. Performance of recent tenders in the scheme
 - b. Future outlook and scope in terms of additional power procurement
 - c. Related to tender designing and tariff processes
 - d. Implementation of schemes with cross-cutting avenues such as ALMM, and use of domestic modules
2. Project related information
 - a. Financing challenges being identified and role of SNA in assisting the consumers towards securing finance

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- b. Enforcement of contracts and penalties
 - c. Participation profile of consumers and response for various sectors
3. Additional information
- a. How do you see rural development being supported under PM-KUSUM, especially in respect of increased energy access?
 - b. How is the feasibility of Agro-PV in the state and any dedicated avenues created for promoting Ag-PV in your state?
 - c. What are your recommendations towards scaling PM-KUSUM and what changes are you expecting towards improving adoption of scheme?
 - d. How has the power supply position improved in your area after the implementation of the scheme?

DISCOM and power procurers

1. Technical information
- a. What is the capacity you have contracted under this scheme and what is the pipeline capacity anticipated?
 - b. What benefits have you observed from implementation and power procurement within the state?
 - c. Are there projects which have also been promoted under the open access routes in your region/circle?
 - d. How has the power supply position improved in the area where the scheme was implemented? Has it created an impact in your revenues?
 - e. Have you conducted feasibility studies/roadmap for integrating higher share of DRE plants in your circle?
2. General information
- a. What are the reasons for the delays in the implementation of the projects in your circle?
 - b. How has the issue of grid availability been recognised and how do you see its impact on the implementation of the scheme?
 - c. What are your views on increased power procurement from within state RE plants, especially under PM-KUSUM?
 - d. How has this scheme assisted in terms of compliance for RPO/RCO in your procurement-portfolio?

Project developers/cooperatives, other agencies which have installed projects under PM-KUSUM

1. Technical information
- a. What are the typical sizes of the projects you are installing?
 - b. Is the tariff viable towards supporting PM-KUSUM in your region?
 - c. How has the overall response been for the projects in terms of project

- conversions within states?
- d. How has the issues of domestic content requirements (DCR), ALMM and related have impacted you project viabilities?
2. General information
 - a. What is the typical profile of your customers who are installing these plants?
 - b. What activities are being undertaken by you for enhancing penetration of the scheme?
 - c. What alternative business models can be integrated within PM-KUSUM for power procurement?
 - d. Have you installed any Agro-PV solar plant within your business, how do you see business viability of agro-pv within your business operations?

Survey respondents: Consultations were conducted through extended in-person meetings and virtual interactions spanning multiple states. Participating stakeholders included farmer-beneficiaries who have installed under PM-KUSUM (Mr. Amit Yadav, Mr. B.S. Saini, Mr. Lakhendra Ram, Mr. Luvkush Bhadoria, and Mr. Om Prakash Bishnoi), project developers and EPC contractors within the distributed solar installations markets (Khare Energy, Dharma Solar, Rajasthan Electronics and Instruments, Megamax Solar, and Sun Beam Energy), solar energy industry associations from Kerala (KREEPA), Telangana (Solar Power Developers Association), and Rajasthan (Renewable Energy Association of Rajasthan), state nodal agencies (UPNEDA, MPUVNL, PEDA, HAREDA, and TSGREDA), and DISCOMs (TSSPDCL, BSES, and KSEB).

Bibliography

Anon, 2024. Conference Paper - Distributed Renewable Energy for Sustainable Development. Climate Policy Initiative. Available at <https://www.climatepolicyinitiative.org/wp-content/uploads/2024/02/DRE-Conference-Paper-24052024.pdf>, as accessed on 11 December, 2025

National Portal on PM KUSUM, Scheme related details. Available at <https://pmkusum.mnre.gov.in/#/landing#achievement>, as accessed 13 December, 2025

National Portal on PM KUSUM. Available at <https://pmkusum.mnre.gov.in/#/landing#achievement>, as accessed on 26 December, 2025

Rajasthan Renewable Energy Corporation Limited (RRECL), KUSUM A. Available at <https://energy.rajasthan.gov.in/rrecl/#/pages/sm/department-page/55296/1577>, as accessed on 12 December, 2025

Chattisgarh State Electricity Regulatory Commission (CSERC), Tariff Orders. Available at https://cserc.gov.in/Welcome/show_tariff_orders, as accessed on 12 December, 2025

Nikita B More, et al., 2024. *Constraints faced and suggestions given by beneficiary of PM KUSUM scheme*, International Journal of Research in Agronomy. Available at <https://www.agronomyjournals.com/archives/2024/vol7issue10S/PartK/S-7-10-94-653.pdf>, as accessed on 13 December, 2025

Kaushlendra Srivastava, et al., 2025. *Farmer Awareness and Socio Economic Determinants of PM KUSUM Adoption in Uttar Pradesh, India*, Archives of Current Research International 25 (7):507-16. Available at <https://www.journalacri.com/index.php/ACRI/article/view/1354>, as accessed 13 December 2025

Himanshu Chawla, et al., 2025. *Tapping the potential of Agriphotovoltaics in India*, Power Foundation of India. Available at <https://www.powerfoundation.org.in/assets/downloads/pfi-report-agriphotovoltaics.pdf>, as accessed on 13 December, 2025

Shawn Rumery, 2024. *Understanding Barriers to Agrivoltaics: A Survey Approach*, Solar and Storage Industries Institute. Available at <https://www.>

ssii.org/wp-content/uploads/2025/04/SI2_FARMS-Survey-Report_Final.pdf, as accessed on 14 December, 2025

Martin Scherfler and Frano D'Silva, 2025. *Feasibility of Agri-Photovoltaics in Indian Agriculture*, GIZ and Auroville Consulting. Available at https://snrd-asia.org/wp-content/uploads/2025/05/Feasibility-of-Agri-Photovoltaics-in-Indian-Agriculture_GIC-Project.pdf, as accessed on 15 December, 2025

Parul Kulshrestha and Kundan Pandey, 2023. *Off-grid, standalone solar pumps under government scheme remain underutilised*, Mongabay. Available at <https://india.mongabay.com/2023/09/under-utilisation-of-off-grid-standalone-solar-pumps-remains-a-challenge/>, as accessed 12 December, 2025

India's rural electricity supply is shaped by an energy-intensive agricultural sector that consumes nearly one-fifth of national electricity through heavily subsidised or zero-tariff power. While this supports irrigation and food security, it has generated structural inefficiencies, including DISCOM financial stress, distorted price signals, inefficient water and energy use, and environmental degradation. The PM-KUSUM scheme, launched in 2019, aimed to address these challenges by promoting decentralised solar energy, reducing subsidies, replacing diesel pumps, and enhancing farmer incomes. However, implementation has been uneven, with weak performance under Components A and C due to land constraints, poor commercial viability, complex approvals, and weak rural grids. Addressing these gaps requires integrated land, financial, tariff, and grid reforms led by proactive state participation.



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