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PM KUSUM Yojana and the Transformation of Agricultural Energy Systems in India: Policy Design, Quantitative Assessment, and Sustainability Implications

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Abstract:

India's agricultural sector relies heavily on groundwater irrigation supported by subsidized electricity and diesel pumps. This energy structure contributes to fiscal pressure on state governments, carbon emissions, and groundwater depletion. The 'Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan' (PM KUSUM), launched in 2019 by the 'Ministry of New and Renewable Energy', seeks to promote decentralised solar energy adoption in agriculture. This study examines the structural need for the programme within India's climatic and geographical conditions, explains its institutional architecture, and presents a quantitative assessment using latest official data. Findings indicate significant progress in pump installation and solarisation, though uneven regional performance and groundwater sustainability concerns remain. The paper concludes that PM KUSUM represents a structural shift in agricultural energy governance, provided it is integrated with water management and institutional reforms.

Key Words: PM KUSUM, Agricultural Energy, Groundwater Sustainability

Introduction:

Agriculture in India remains highly dependent on irrigation. Nearly half of the net sown area is irrigated, and a significant share of irrigation comes from groundwater sources. Farmers commonly use electric and diesel pumps to extract water. While electricity for agriculture is heavily subsidised, supply is often irregular and limited to specific hours. Diesel pumps increase input costs and expose farmers to fuel price volatility.

From a climate perspective, agriculture contributes to greenhouse gas emissions both directly and indirectly. Diesel pump usage increases emissions, while subsidised electricity encourages excessive groundwater extraction. Many states such as Punjab, Haryana, Rajasthan, Gujarat, and parts of Maharashtra face declining groundwater tables. In semi-arid and arid regions, irrigation energy demand is high due to low and uncertain rainfall. India also faces rising energy demand. Distribution companies experience financial stress due to agricultural power subsidies. This situation creates a need for decentralised, clean, and financially sustainable energy solutions for

agriculture. PM KUSUM was introduced in this context to promote solar energy use in farming and to transform farmers from energy consumers into energy producers.

Significance of PM KUSUM in Indian Agricultural and Geographical Context:

The significance of PM KUSUM must be understood within India's structural dependence on groundwater irrigation, uneven rural electricity supply, and high solar radiation potential across semi-arid and arid regions. Agriculture consumes a substantial share of subsidised electricity, contributing to fiscal pressure on state utilities and unsustainable water extraction in several regions. Given India's favourable solar resource base and rising climate variability, decentralised solarisation of irrigation systems presents both an energy reform and an environmental management strategy. In this context, PM KUSUM represents an institutional response to reconcile agricultural productivity, renewable energy expansion, and ecological sustainability.

• Irrigation and Groundwater Dependence:

India has more than 30 million irrigation pumps, many of which are powered by subsidised electricity. In states with flat power tariffs, farmers have little incentive to conserve water. Solar energy, if properly regulated, can reduce subsidy burdens and create opportunities for controlled and metered energy use.

• Climatic Conditions and Solar Potential:

India receives high solar radiation across most regions, particularly in western and central states. Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, and parts of Karnataka have strong solar potential due to long sunshine hours and low cloud cover. These climatic conditions make solar irrigation technically feasible and economically viable.

• Rural Energy Access and Distribution Challenges:

Agricultural feeders often experience voltage fluctuations and supply restrictions. Daytime irrigation is not always possible under conventional supply systems. Solar pumps provide decentralised power generation at the farm level, reducing pressure on rural feeders.

• Climate Change and Sustainability:

Climate change has increased rainfall variability and drought frequency in several regions. Solar irrigation systems can improve resilience by providing reliable energy for water extraction. However, they must be accompanied by water governance measures to avoid over-extraction.

Objectives of PM KUSUM Yojana:

The scheme aims to:

- Ensure energy security for farmers.
- Promote renewable energy use in agriculture.
- Reduce diesel consumption in irrigation.
- Provide additional income opportunities through sale of surplus power.

- Reduce electricity subsidy burdens on state governments.
- Support India's renewable energy capacity targets.

Components of PM KUSUM:

PM KUSUM is structured into following three interrelated components designed to address different dimensions of agricultural energy use. Together, these components create a multi-level intervention framework that combines farm-level energy access with grid-level renewable integration.

• Component A: Decentralised Solar Power Plants

Under this component, farmers, cooperatives, and local institutions can install grid-connected solar power plants of up to 2 MW capacity on barren or unused land. The electricity generated is purchased by distribution companies at predetermined tariffs. This component encourages decentralised generation and reduces transmission losses. It also enables farmers with non-productive land to generate income.

• Component B: Standalone Solar Agriculture Pumps:

This component supports installation of off-grid solar pumps in areas without reliable grid supply. Farmers receive financial assistance from central and state governments. The pump operates during daylight hours and reduces diesel dependence.

• Component C: Solarisation of Grid-Connected Pumps:

Existing electric pumps are equipped with solar panels. Farmers use solar power for irrigation and can feed surplus electricity into the grid. This creates a dual benefit of energy self-reliance and income generation.

Financial Structure and Implementation Model:

The scheme follows a shared funding pattern between the central government, state governments, and farmers. The central assistance covers about 30% of the benchmark cost, states provide a matching share, and farmers contribute the remaining portion. Loans are available to reduce upfront burden. Implementation is carried out through state nodal agencies, distribution companies, and empanelled vendors. Both capital expenditure and service-based models are used.

Progress and Current Status of PM KUSUM:

As of January 2026, the implementation of PM KUSUM across India reflects varied progress across its components. The aggregate target for decentralised solar power plants under Component A was 10,000 MW, of which 765.33 MW has been installed, representing a 7.70% achievement, indicating early-stage deployment of larger grid-connected projects. Under Component B, the scheme has made substantial strides in rural electrification and irrigation support, with 10,05,898 standalone solar pumps installed against a target of 13,30,190, achieving 75.60% of the sanctioned target, demonstrating strong uptake among farmers. Component C comprises two parts: Individual Pump Sets (IPS) solarisation and Feeder-Level Solarisation (FLS). In IPS, 12,311 pumps have been solarised out of 55,342, marking 22.20% achievement, while FLS has reached 12,96,350

solarised pumps against 35,13,692 sanctioned, achieving 36.90%. These figures indicate that while decentralised solar plant deployment is still emerging, farmer-level solar adoption, especially under Component B has progressed rapidly, and feeder-level solarisation is advancing steadily. This mixed performance highlights both the operational momentum in solar pump programmes and the implementation challenges associated with larger grid-connected installations. The achievement are summarised in the table 1.

All India Status (As on Jan 2026)			
Component	Target / Sanctioned	Installed / Achieved	Achievement %
A: Decentralized Solar Plants	10,000 MW	765.33 MW	7.70%
B: Standalone Solar Pumps	13,30,190	10,05,898	75.60%
C1: Individual Pump Sets (IPS) Solarized	55,342	12,311	22.20%
C2: Feeder-Level Solarization (FLS)	35,13,692	12,96,350	36.90%

Table 1: PM KUSUM- All India Status

Source: <https://pmkusum.mnre.gov.in>

Top Performing States under PM KUSUM:

State-level performance under PM KUSUM reveals significant regional variation, reflecting differences in administrative capacity, solar potential, financial readiness, and institutional coordination. Maharashtra dominates in Components B and C (FLS), Rajasthan leads in Component A installations and IPS completion efficiency, and Haryana demonstrates strong performance in standalone solar pumps. The variation across states highlights the importance of administrative efficiency, grid readiness, financial mobilisation, and solar resource advantage in determining implementation success under PM KUSUM.

Under Component A (Decentralised Solar Plants), Rajasthan leads in both sanctioned and installed capacity, with 5,618 MW sanctioned and 542.62 MW installed, indicating active progress in large-scale decentralised solar deployment. The state’s high solar radiation, availability of semi-arid land, and established renewable ecosystem have supported implementation. Madhya Pradesh follows with 1,400 MW sanctioned and 75.1 MW installed, showing moderate advancement. Haryana has installed 28.61 MW out of 158 MW sanctioned, reflecting partial progress. In contrast, Telangana, despite having 1,797 MW sanctioned, has reported no installation,

highlighting possible implementation delays related to land aggregation, grid connectivity, or administrative coordination. The Table 2 suggest that while sanction levels are high in several states, actual commissioning remains a challenge under Component A.

States on Top: Component A		
State Name	Total Sanction (MW)	Total Installed (MW)
Rajasthan	5,618	542.62
Telangana	1,797	0
Madhya Pradesh	1,400	75.1
Haryana	158	28.61
Himachal Pradesh	100	100

Table 2: Top States- PM KUSUM Component A

Source: <https://pmkusum.mnre.gov.in>

Under Component B (Standalone Solar Pumps), Maharashtra emerges as the strongest performer, with 5,02,950 pumps installed against 5,75,000 sanctioned, reflecting very high execution efficiency. Haryana also demonstrates strong implementation with 1,85,066 installed out of 1,97,655 sanctioned, followed by Rajasthan with 1,24,866 installed out of 1,44,752 sanctioned. Uttar Pradesh and Jharkhand show moderate progress, while Madhya Pradesh and Karnataka display comparatively lower installation rates relative to sanction levels. Gujarat has installed 13,799 pumps out of 22,792 sanctioned, indicating steady but incomplete progress. Himachal Pradesh has achieved 100 percent implementation, with all 100 sanctioned pumps installed, though on a smaller scale. Component B shows relatively high operational success compared to other components.

Top States : Component B		
	Total Sanction (Nos.)	Total Installed (Nos.)
Maharashtra	5,75,000	5,02,950
Haryana	1,97,655	1,85,066
Rajasthan	1,44,752	1,24,866
Uttar Pradesh	1,07,266	66,568
Jharkhand	86,985	49,790
Madhya Pradesh	59,400	7,325
Karnataka	41,365	3,130
Gujarat	22,792	13,799

Table 3: Top States- PM KUSUM Component B

Source: <https://pmkusum.mnre.gov.in>

For Component C (Feeder-Level Solarisation, FLS), Maharashtra stands out with complete achievement, having solarised 7,75,000 pumps out of 7,75,000 sanctioned, demonstrating strong feeder separation and grid integration capacity. Gujarat follows with 2,39,282 solarised out of 4,67,114 sanctioned, indicating substantial though partial implementation. Rajasthan has solarised 1,47,294 out of 4,00,000 sanctioned, and Madhya Pradesh has achieved 43,156 out of 2,52,000 sanctioned, reflecting moderate progress. Karnataka and Uttar Pradesh show slower performance relative to sanction levels, with Karnataka completing 79,314 out of 7,63,588, and Uttar Pradesh reporting only 340 solarised pumps against 3,70,000 sanctioned, suggesting significant infrastructural or administrative bottlenecks in feeder-level integration.

Under Component C (Individual Pump Sets, IPS), Uttar Pradesh has solarised 6,616 pumps out of 12,000 sanctioned, marking notable progress in individual pump conversion. Rajasthan has achieved full implementation, with 2,138 pumps solarised against the same number sanctioned, indicating strong execution at smaller scale. Kerala has solarised 2,677 out of 9,448 sanctioned, while Tripura has achieved 857 out of 3,600 sanctioned, reflecting gradual but incomplete progress. Compared to feeder-level solarisation, IPS implementation appears slower overall due to higher technical requirements, metering needs, and individual-level coordination. Top states performance for Components C (FLS and IPS) are summarised in Table 4-

Top States: Component C (FLS)		
State Name	Total Sanction - FLS (Nos.)	Total Solarised - FLS (Nos.)
Maharashtra	7,75,000	7,75,000
Karnataka	7,63,588	79,314
Gujarat	4,67,114	2,39,282
Rajasthan	4,00,000	1,47,294
Madhya Pradesh	2,52,000	43,156
Uttar Pradesh	3,70,000	340
Top States: Component C (IPS)		
	Total Sanction - IPS (Nos.)	Total Solarised - IPS (Nos.)
Uttar Pradesh	12,000	6,616
Rajasthan	2,138	2,138
Kerala	9,448	2,677
Tripura	3,600	857

Table 4: Top States- PM KUSUM Component C

Source: <https://pmkusum.mnre.gov.in>

Major Challenges in Implementation:

Although PM KUSUM has achieved notable expansion, its implementation reveals structural, financial, environmental, and institutional challenges that influence long-term sustainability.

• Financial Constraints and Farmer Affordability:

Even after central and state subsidies, farmers must contribute a share of the capital cost, typically around 30 to 40 percent depending on the state model. For small and marginal farmers, who constitute the majority of India’s farming population, this upfront contribution can be significant. Access to formal credit is uneven, particularly in rain-fed and economically weaker regions. Banks may perceive small solar pump financing as risky due to uncertain repayment capacity. Delays in subsidy disbursement further discourage participation. In some cases, farmers must initially pay

the full amount and later claim reimbursement, creating liquidity stress. This financial barrier creates unequal access, where relatively larger and financially stable farmers benefit more from the scheme compared to vulnerable groups.

• **Land Availability and Site Suitability for Component A:**

Component A requires land parcels near substations to minimize transmission losses and infrastructure costs. However, in agriculturally intensive regions, most land is actively cultivated. Farmers may hesitate to allocate productive land for solar installations unless long-term returns are guaranteed. In semi-arid regions where barren land is available, grid connectivity may be limited. Additionally, fragmented landholdings complicate the development of 1 to 2 MW plants unless cooperative or collective models are adopted. Environmental clearance, local disputes over land use, and delays in power purchase agreements can slow project development.

• **Risk of Groundwater Over-Extraction:**

Solar pumps drastically reduce the marginal cost of irrigation. Once installed, the operating cost of pumping water is almost zero. This can create incentives for excessive groundwater extraction, especially in water-stressed states such as Punjab, Haryana, Rajasthan, and parts of Gujarat. In regions where groundwater tables are already declining, unrestricted solar pumping can intensify ecological stress. Without regulatory measures such as metering, water quotas, or incentives for efficient irrigation, solarisation may unintentionally worsen resource depletion. Therefore, the energy transition must be aligned with groundwater governance frameworks to prevent environmental imbalance.

• **Grid Integration and Infrastructure Constraints:**

Feeding surplus electricity into the grid under Component C requires smart meters, net metering or gross metering systems, feeder separation, strengthened distribution infrastructure. Many rural feeders are old and overloaded. Voltage instability and limited transformer capacity can affect grid reliability. In some states, distribution companies delay grid connectivity approvals due to technical and financial concerns. Delayed payments for surplus power supplied by farmers can also reduce trust in the scheme. Efficient grid integration requires coordinated planning between renewable energy agencies and distribution utilities.

• **Institutional Coordination Issues:**

Implementation involves multiple stakeholders including MNRE, state nodal agencies, distribution companies, financial institutions, private vendors and other local administrative bodies. Coordination gaps can lead to delays in tendering, approval processes, vendor empanelment, and subsidy release. Variations in state-level execution capacity create uneven progress across India. States with strong administrative systems and prior renewable experience show faster adoption, while others lag due to procedural inefficiencies.

• **Maintenance, Quality Control, and After-Sales Service:**

Solar pump systems require periodic cleaning of panels, inverter maintenance, and occasional part replacement. In remote villages, technical service networks are often weak. Inadequate after-sales support may lead to system malfunction and underutilisation. Quality control during procurement

and installation is critical to avoid premature equipment failure. Without proper maintenance structures, long-term performance may decline, reducing confidence among farmers.

• **Regional Disparities and Uneven Adoption:**

Implementation data show concentration of installations in certain states such as Maharashtra, Rajasthan, and Gujarat. States with lower fiscal capacity or weaker renewable ecosystems show slower adoption. Climatic suitability, administrative efficiency, and farmer awareness influence adoption rates. Eastern and northeastern regions, despite having irrigation needs, show relatively lower participation due to institutional and financial constraints. This uneven spread limits the nationwide transformative potential of the scheme.

Policy and Sustainability Considerations:

While PM KUSUM has expanded renewable energy adoption in agriculture, its long-term effectiveness depends on policy coherence across energy, water, financial, and institutional domains. Sustainability concerns arise not only from technical deployment but also from groundwater governance, tariff structures, fiscal implications, and maintenance ecosystems. Therefore, policy refinement must move beyond installation targets and focus on integrated resource management and economic viability.

- Solar pump deployment should be linked with groundwater monitoring and efficient irrigation practices to prevent excessive water extraction in stressed aquifers.
- Well-designed feed-in tariffs can encourage farmers to sell excess electricity to the grid rather than increase irrigation beyond crop requirements.
- Collective ownership through farmer producer organisations or cooperatives can reduce capital burden and improve maintenance efficiency.
- Low-interest loans, credit guarantees, and timely subsidy disbursement can expand participation among small and marginal farmers.
- Developing local technical service networks ensures long-term system reliability and reduces downtime in rural areas.
- Real-time monitoring systems improve accountability, track performance, and support evidence-based policy adjustments.
- The scheme contributes to national renewable energy commitments and emission reduction goals, strengthening its strategic policy relevance.
- Balanced tariff structures and gradual rationalisation of electricity subsidies are essential to maintain fiscal sustainability for both states and distribution companies.

Conclusion:

PM KUSUM represents a significant institutional effort to restructure the relationship between agriculture and energy in India. The scheme addresses long-standing concerns associated with subsidised electricity, diesel dependence, and declining groundwater resources, while simultaneously supporting renewable energy expansion. The component-wise performance reveals that decentralised solar adoption at the farmer level has gained momentum, although grid-connected and feeder-level interventions require stronger institutional coordination and infrastructural readiness. State-level variations further demonstrate that administrative capacity, solar resource advantage, financial preparedness, and grid infrastructure play decisive roles in implementation outcomes.

The long-term impact of the scheme, however, will depend on its integration with groundwater regulation, tariff rationalisation, and improved financial access for small and marginal farmers. Without complementary water governance measures, the reduction in energy costs could intensify resource stress in vulnerable regions. Strengthening maintenance ecosystems, digital monitoring systems, and cooperative participation models will be essential to ensure durability and equity. If implemented with sustained policy alignment and institutional reform, PM KUSUM has the potential to transform agricultural energy systems by enhancing farmer income security, reducing fiscal burdens, and contributing to climate mitigation objectives within India's diverse geographical landscape.

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