GUIDEBOOK

Implementing Solar Irrigation Sustainably:

A guidebook for state policy-makers on implementing decentralized solar power plants through PM-KUSUM Components A and C (feeder-level solarization) with maximum social, economic, and environmental benefits

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International Institute for Sustainable Development

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FOREWORD

Solar-powered irrigation can be vital for achieving India's objectives of increasing agricultural productivity, boosting farmer incomes and reducing emissions. The Rajasthan Renewable Energy Corporation Limited (RRECL) supports efforts undertaken by a GIZ-supported research consortium to collaborate with central and state policymakers, as well as expert voices, in promoting the sustainable implementation of solar irrigation schemes in India.

Rajasthan has been the leading state in the implementation of the Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM-KUSUM) scheme. It has deployed 75 MW under component A, which helped farmers become solar entrepreneurs. It has also deployed 56,500 pumps under component B and is in the advanced tendering stage under component C (feeder-level solarization). Despite this strong progress, much more can be done to achieve the PM-KUSUM scheme's targets to overcome the slow pace of implementation in many states. There is a need to bring parity in central government incentives for component A and C, revise the benchmark capital cost of solar power plants to reflect taxation and import duty changes on solar panels, and provide targeted financial assistance to farmers through credit guarantee funds and other models. Think-tanks can play an active role in strengthening the policy's implementation.

In this regard, I am delighted to introduce the "Implementing Solar Irrigation Sustainably: A Guidebook for state policymakers on implementing decentralized solar power plants through PM-KUSUM components A and C (feeder-level solarization) with maximum social, economic and environmental benefits". This report brings together the best available evidence on component A and component C (feeder-level solarization) in India. It provides practical recommendations that can help states achieve the PM-KUSUM scheme's economic objectives, while considering both social and environmental sustainability.

This report provides context to states on the benefits and challenges of decentralized solar plants. It also provides guidance on how to reduce barriers to finance for states, developers and farmers, how states can pursue sustainable approaches of implementation and specific measures to maximize social and environmental benefits, and identifies areas that require on-ground experiments to generate evidence for policy formulation and a framework to design such pilots.

For the past year now, RRECL has provided feedback to the research consortium consisting of IISD, CUTS and TERI in their efforts to overcome hurdles faced in implementing the scheme. RRECL looks forward to building on this foundation and encourages further efforts to be directed towards providing targeted technical assistance to overcome challenges faced by state officials.

To all members of government bodies, researchers, the private sector and the general public that are interested in solar irrigation — I'm hopeful that you will find the report's findings insightful.

Anil Dhaka, IRS
MD, RREC

Anil Dhaka
Managing Director
Rajasthan Renewable Energy Corporation Limited

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Executive Summary

The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme, launched in 2019 by the Ministry of New and Renewable Energy, Government of India, aims to transform India's agriculture sector by improving crop productivity and increasing farm incomes through the solarization of the agriculture sector. This document forms the second part of a guidebook series, providing recommendations to state policy-makers on how they can implement solar irrigation models effectively and sustainably. This guidebook covers Component A and the subcomponent "Feeder-Level Solarization" under the Component C of PM-KUSUM. The previous guidebook addressed Component B and the subcomponent "Individual Pump Solarization" under Component C. An illustration of the different components is provided in Figure 1.

Component A and the subcomponent Feeder-Level Solarization under Component C (hereafter referred to as Component C(FLS)) of PM-KUSUM involve setting up small-scale solar power plants at the substation level to power rural feeders. These models are relatively new for state policy-makers. Hence the guidebook adopts a comprehensive implementation-focused approach covering four sections:

1. **Context:** The what, why, and how of decentralized solar plants, their economic impact on different stakeholders, and the need to view them through a water–energy–food nexus lens to mitigate potential externalities.
2. **Financing:** The financing challenges faced by states, farmers, and private developers that hold back the scheme's implementation and different solutions to address them.
3. **Implementation design and coordination:** Sustainable approaches of implementation and specific measures to maximize social and environmental benefits.
4. **Learning by doing:** Areas that require on-the-ground experiments to generate evidence for policy formulation and a framework to design such pilots.

Context: The why, how, and impacts of decentralized solar plants

This section deconstructs the decentralized solar plant model for solarizing rural feeders and its potential impact, including benefits to different stakeholders—farmers, distribution companies (DISCOMs), and the state government—and impact on the water–energy–food nexus.

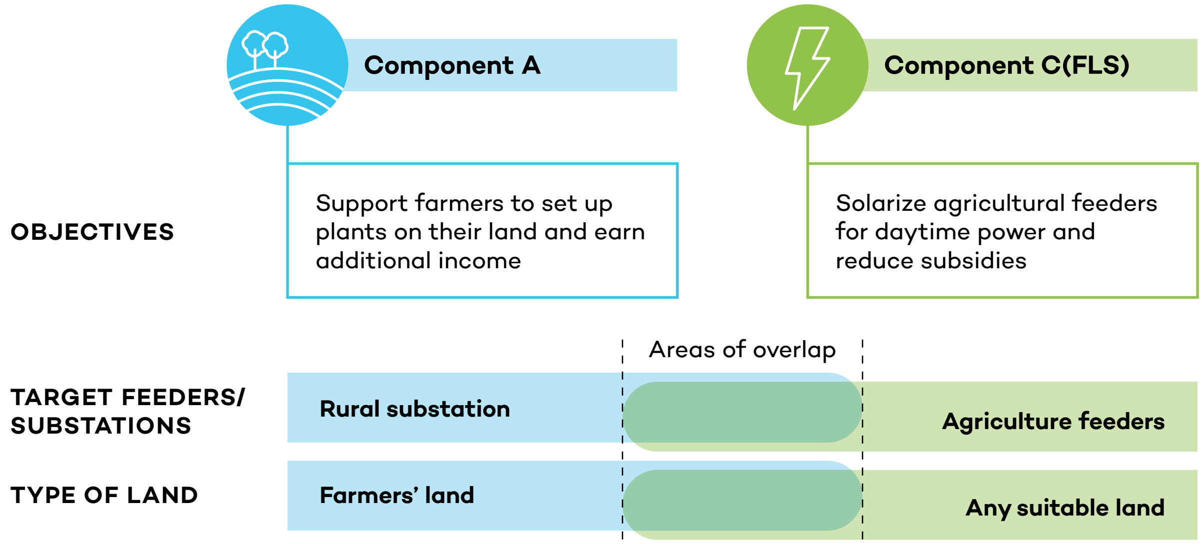
Decentralized Solar Plants

A decentralized solar plant under PM-KUSUM Components A and C (FLS) has a much smaller capacity than a grid-scale solar plant but a much larger one than a typical household rooftop solar system. It is located close to the final consumers and connected to a distribution substation.

Components

Components A and C(FLS) are designed with very different objectives. However, the two may overlap under certain circumstances (Figure ES1). A state government's primary policy objective can help determine which component of PM-KUSUM is best to pursue in a specific region.

Figure ES1. Areas of overlap between PM-KUSUM Components A and C(FLS)



Source: Authors' diagram based on MNRE, 2019, 2020.

Solarizing Agricultural Feeders

Solarizing agricultural feeders can provide multiple benefits to farmers and the state government (Figure ES2).

Figure ES2. Benefits for farmers, state, and DISCOM in solarizing agriculture feeders

Benefits for farmers

Improved quality of power supply:
Distributed power plants can improve voltage conditions and support other measures to strengthen the distribution grid.

Timing, duration, and predictability of power supply:
Farmers can get up to 10 hours of daytime power supply to reduce the difficulties and hazards of erratic nighttime power supply.

Benefits for state/DISCOM

Reduction in power purchase cost:
The cost of power from a distributed power plant is typically less than the average power purchase cost of the state.

Reduction in transmission and distribution (T&D) losses and charges:
The T&D losses and charges up to the 11 kV substation level that a future capacity addition would have incurred are avoided.

Fulfillment of renewable purchase obligations (RPOs):
If a DISCOM's renewable purchase is below RPO norms, PM-KUSUM can reduce the shortfall. The DISCOM can issue renewable energy certificates (REC) and earn income if it is in excess.

Long-term benefit of power system flexibility:
Shifting agricultural load to the daytime to coincide with solar generation is the most cost-effective strategy for grid stability in the coming years.

Social benefits, including local employment generation:
Distributed solar plants can help create new green jobs that are geographically well distributed.

However, there are some issues with the model, most of which can be addressed through better awareness and intelligent scheme design (Table ES1).

Table ES1. Challenges faced by DISCOMs in solarizing agricultural feeders and potential solutions

Concerns	Solutions
Seasonal fluctuation in agricultural load	The key to avoiding upstream power flow during the non-irrigation season is optimal targeting and sizing of the power plant. Sizing should consider the base load requirement of the substation.
Higher cost than utility-scale solar plants	Although utility-scale solar plants offer cheaper power, their growth has inherent limitations, and decentralized power plants can play a complementary role. Further, some cost advantages of utility-solar plants are due to temporary incentives, such as the interstate transmission system waiver.
Impact on daily load management	Shifting agriculture load to the daytime is the most cost-effective means of load management as the share of solar power increases in the grid. States can use PM-KUSUM to plan the long-term transition of agricultural power.
Excess contracted capacity	Cost-benefit studies show that even if it takes a few years for the demand to exceed contracted capacity, there is a benefit to states from PM-KUSUM.

Source: Authors.

Impact on Water

The impact of solarizing agriculture feeders on groundwater sustainability and water markets is not well studied. However, past experiments on improving electricity access show that when the local hydrogeology is suitable, and water is the primary constraint to increasing crop production, then there is a strong possibility of increasing groundwater use, reiterating the need for careful scheme design.

Preventing Groundwater Depletion

Cost-reflective electricity pricing is the long-term solution to address groundwater concerns. However, if states cannot implement it due to political sensitivities, they should consider other strategies to address groundwater concerns. PM-KUSUM guidelines offer a framework for states to consider demand-side management by providing direct incentives for farmers to stay within a stipulated benchmark electricity consumption limit, potentially preventing groundwater depletion. There are advantages and challenges to this model (Table ES2).

Table ES2. Pros and cons of direct water incentives mechanism

Advantages	Challenges
• It is voluntary and based on incentives that make it more politically feasible. • It does not require the participation of all farmers in the feeder. However, the higher the participation, the better the potential outcomes.	• Identifying the appropriate benchmark consumption limit or quota. • Participation of tenant farmers due to their lack of electricity connection. • Financial and capacity burden on the DISCOM to implement direct incentives.

Source: Authors

Case Studies

Two case studies—one on Mukhya Mantri Saur Krishi Vahini Yojana (MSKVY) of Maharashtra and the other on the Paani Bachao Paisa Kamao (PBPK) scheme of Punjab—are provided in the Appendix. MSKVY is the most successful scheme for feeder solarization and provides valuable learnings for the PM-KUSUM. The PBPK scheme is the largest direct incentives scheme for water conservation.

Financing

Financing is linked with different aspects of the scheme, and any risks and opportunities affecting the scheme are reflected in ease of financing. Hence, this section uses financing as an anchor to investigate challenges facing investment in the scheme and recommends measures to overcome them.

Financing remains the biggest challenge to the scheme's success. **There are two ways to boost investment:**

- By reducing the risk perception of the scheme
- By increasing tariffs to make returns more attractive to the farmer/developer.

Three key concerns lead to a higher risk perception of the scheme among developers. Some proposed solutions that states can adopt to address these concerns are as follows:

Table ES3. Key concerns on distributed solar power plants and proposed solutions to mitigate them

<table>
<tr><th>Concerns</th><th>Solutions</th></tr>
<tr><td colspan="2">Concerns about poor grid infrastructure</td></tr>
<tr><td>Developers suggest that the safeguards recommended in the PM-KUSUM guidelines for grid availability do not fully allay their concerns about the likelihood of outages due to the poor state of rural feeder infrastructure.</td><td>Incorporating “deemed generation clauses” into the power purchase agreements.
Undertaking grid upgrading at the distribution level, potentially through convergence with the Revamped Reforms-based and Results-linked Distribution Sector Scheme.
Although Component C (FLS) mainly targets segregated feeders, states can opt for virtual feeder segregation in places where physical segregation doesn’t make economic sense.</td></tr>
<tr><td colspan="2">Concerns arising due to operational and regulatory costs</td></tr>
<tr><td>Developers face a challenge in identifying and leasing affordable land for setting up a solar plant and the transmission and evacuation infrastructure.

Another key challenge is related to land revenue regulations, including the timely application of land-use regulations restricting land transfer in certain conditions.</td><td>Facilitating interactions between potential developers and landowners. This facilitation can happen at three levels:
Identifying interested farmers by initiating a registry of landowners interested in the scheme—a so-called “land bank”—and connecting them with developers.
Supporting developers to assess the suitability of different lands using the DISCOMs’ field staff and data-based facilitation.
Supporting negotiations with landowners, especially for the right of way of transmission lines and evacuation bay.
Enabling close coordination with the land revenue department to address land-regulation concerns.
Promoting alternative ownership models like special purpose vehicles wherever land leasing is restricted.</td></tr>
<tr><td colspan="2">Concerns arising due to payment risks and poor creditworthiness of developers</td></tr>
<tr><td>Two key challenges concerning financing are the timely payment of dues and access to finance. DISCOMs’ poor track record in making timely payments necessitates the creation of safeguards by states for timely payment. Access to credit from financial institutions is a challenge due to the low capacity of farmers to provide upfront capital and the poor creditworthiness.</td><td>Issuing letters of credit or state guarantees to allay payment concerns.
Exploring the possibility of bringing in central public sector units as intermediaries, which has been a successful model in the utility-scale solar segment.
Exploring alternative financing channels in partnership with development finance institutions.
Allowing joint ventures can also help interested parties with complementary strengths come together.
Enabling close coordination with banking officials, state-level banking committees, and developers to raise awareness, support bankers’ training, and simplify procedures in accessing finance.
Explore convergence opportunities in financing with other schemes, including micro-, small-, and medium-sized enterprises schemes and the Agriculture Infrastructure Fund.</td></tr>
</table>

Setting a tariff commensurate to the risks and efforts undertaken by developers is critical for the viability of the decentralized solar plant model. An analysis of the tariff adopted in different states indicates that there are a few critical issues in the process of setting a tariff. Three key aspects emerged as the reason for an unviable tariff set in many states, which led to limited developer interest:

1. A small-scale power plant's operation and maintenance cost is much higher per megawatt than a grid-scale plant.
2. The actual capital cost reported during our interviews and other sources is higher than the assumptions used by most state electricity regulatory commissions.
3. The logistical overheads of establishing a solar plant, such as land identification and negotiation, add to the cost but aren't properly integrated into the tariff.

States can either refine their tariff calculations or make them more responsive to market variations. States can also look for alternative tariff-setting options, including comparison with the present landed cost of power.

Implementation Design and Coordination

Decentralized solar power plants impact multiple sectors like power, agriculture, and land revenue. Hence, a well-thought-out implementation design plan is needed for states to maximize the scheme's outcomes, with input and participation from all relevant departments.

Allocating Responsibilities

The participation of all concerned departments is desirable, but sharing responsibilities equally between multiple departments can slow implementation. Hence, there needs to be a proper balance in allocating responsibilities for optimal coordination. The state implementing agency (SIA) is responsible for implementation and must ensure coordination with other departments.

1. **Facilitating information exchange**

   Our consultations suggest that many non-implementing state departments are unaware of the scheme due to its newness. In facilitating information exchange with these departments, the SIA will also gain important information on land-use change regulations, the local groundwater situation, and geographical areas for other schemes. It is recommended that SIAs organize an inception workshop and subsequent coordination meetings with agriculture and land revenue departments, groundwater agencies, and SLBCs. An indicative list of key information to be shared and collected is provided in Table 7 of Section 4.

2. **Undertaking infrastructure planning**

   To maximize the scheme's outcomes, the SIA should:

   - Identify the most suitable feeders for the scheme
   - Decide the optimum capacity of the plants
   - Support the scheme with complementary activities to strengthen the grid.

To maximize the economic outcomes, the SIA should select substations with a high agriculture load and a significant non-agriculture load to minimize the upstream flow of power in the non-irrigation season. Targeting substations with poor-quality power may increase the scheme's social outcomes through improved power quality for farmers. MNRE has issued sizing guidelines for the upper limit of solar plants eligible for CFA. SIAs are recommended to conduct a base load analysis at a substation level and optimize plant size to reduce upstream flow in the non-irrigation season.

3. **Promoting linkages to energy and water efficiency**

   Linking PM-KUSUM with water and energy efficiency policies is highly desirable. But states need to consider the impact of a policy on three stakeholders—the DISCOM, farmers with electricity connections, and farmers depending on water markets.

Promoting Energy and Water Efficiency

States need to select and identify the right set of measures. The impacts of some of these measures are well established, and others require pilot testing before scaling up. In locations where direct cash incentives can work and are desirable, states can use them as a tool to incentivize energy and water efficiency.

Figure ES3. Measures to increase efficiency and suitability in specific contexts

Proven measures for increasing efficiency

Energy-efficient pump replacement: Studies show potential savings of 30%–40% energy through pump replacement. However, a lack of incentives to maintain the pump effiency quickly leads to deterioration in a few years.

Capacitor bank installation: Installation of capacitor banks at the load end (i.e., with the motor) significantly improves the power factor. However, a key challenge is that it is effective only when most farmers in a feeder adopt it and hence need a coordinated approach from the DISCOM.

Water-efficient practices: Water-efficient irrigation technologies and techniques can significantly save water and energy. However, the absence of incentives and need for capacity building make it challenging to implement at a wider scale.

Measures suitable in certain contexts

Direct incentive mechanism: The direct incentive mechanism under PM-KUSUM may help reduce electricity and water consumption in specific contexts but may also increase the water market rates and disadvantage water buyers. The net financial benefit or cost of implementing direct incentives for states requires further analysis. A decision tree on whether to explore the direct incentive mechanism or not is provided in Figure 12.

Support from other departments can significantly enhance the scheme implementation. The functions of different agencies are provided in Table 8 of Section 4.

Learning by Doing

PM-KUSUM Components A and C (FLS) are not yet widely deployed. New challenges for implementation and sustainable scheme outcomes may arise in the future. Furthermore, policy innovations recommended in the PM-KUSUM scheme guidelines, such as water incentives and agrivoltaics, can offer sustainable solutions for states. However, they require evidence-based strategies to suit different contexts. Hence it is critical to learn by doing—gather data on implementation and constantly refine deployment approaches based on the data.

Strategy for Monitoring and Evaluation

Figure ES4. Strategy for monitoring and evaluation

Tools for gathering data

The Solar Energy Data Management Portal
Consists of functioning data from the distributed power plant and the pumps in the target feeder

Feeder meter data from the target feeder
For baseline data on energy consumption. If RMS is not installed with pumps, it can also act as a proxy for consumption data after the scheme implementation

Criteria and parameters for evaluation

Economic impact on the state

- Total energy generation from solar power plant
- The coincidence of solar power generation and consumption within the substation

Impact on farmers' energy access

- Energy consumption by farmer
- Voltage variations
- Farmers' crop choices
- Intangible impacts due to the shift in power supply to daytime

Social impact of the scheme

- Land size category of farmers benefiting from the scheme
- Water prices in the local water market

Impact on groundwater

- Water consumption
- Groundwater level (long term)

Source: Authors'.

Piloting Innovative Models

States can allocate a small share of new projects for piloting innovative models, including water incentives and agrivoltaics. This approach would generate evidence for subsequent scaling up of these models without hampering current deployment. We explored two key innovative models: i) direct incentives for water conservation and ii) agrivoltaics.

Efficiency Incentives

The PBPK scheme is the first large-scale initiative piloting the direct cash incentives proposed in the PM-KUSUM guidelines. Initial studies by research organizations found that the combination of daytime electricity provision and cash incentives for unused electricity led to farmers reducing their self-reported irrigation hours under the PBPK scheme. However, more data and impact evaluation studies are needed before any definitive conclusions can be drawn. The PBPK scheme offers some unique learnings in addressing implementation challenges (See the PBPK case study in the Appendix for further reading):

1. **Direct benefit transfer scheme for agriculture:** PBPK's design is based on one of three direct benefit transfer models, where farmers are allocated a seasonally adjusted predetermined amount of electricity based on their connected load and paid a monetary incentive directly into their bank accounts if they use less than their allocated consumption. Initial trials showed that with adequate communication activities, a sizable share of farmers was interested in enrolling in the scheme.
2. **Context-specific approach to fixing quota:** Although calculating the electricity quota based on the size of a farmer's land holding is more desirable, PBPK used the prevailing electricity use-based quota for practical reasons.
3. **Water-saving techniques in demonstration farms:** Popularizing water-efficient practices is critical to ensuring sustained reduction in groundwater usage. Punjab created demonstration farms on scheme feeders to highlight the benefits of water-saving techniques and resource-conservation technologies.
4. **Coordination structures and incentives for implementing agencies:** Aside from water conservation, the PBPK design also focused on creating institutional structures that promote effective interagency coordination and better implementation. The scheme was based on extensive consultation with all stakeholders; there was high-level political and administrative commitment; and there was a clearly defined multilayered administrative structure in place (elaborated in Box 15).
5. **Measures to include tenant farmers:** The state introduced amendments to its electricity policies to enable joint electricity connections in the name of legal heirs and enabled cash transfer directly to tenant farmers after the enrolment of the landowner.

Learnings from the Punjab PBPK scheme may not apply to other parts of the country given the diversity of agroeconomic contexts in different states. Indeed, a pilot study conducted in Gujarat that trialled electricity-linked incentives for farmers found a high enrolment for metering but no impact on water consumption.

Agrivoltaics

Agrivoltaics refers to the simultaneous use of land for agriculture and photovoltaic power generation. This is achieved by designing a solar power plant to enable cultivation between or below the photovoltaic panels. There have been only a handful of pilots on agrivoltaics in India. Mainstreaming them requires the development of new business models, regulations, standards, and promotional measures and creating evaluation frameworks for continuous learning (Table ES4).

Table ES4. Key lessons from agrivoltaics pilot projects in India

Business models	There are three broad business models that we have explored in agrivoltaics: 1. Partnership between farmer and developer 2. System wholly owned and operated by one entity 3. Developer as a primary promoter, farmer as a partner The suitability of the models varies with the agroeconomic situation—the first two are suitable where high-value crops are cultivated, and land rent is high; the third model is suitable for arid and semi-arid regions.
Promotional measures	The state can facilitate the uptake of agrivoltaics through awareness and financial incentives. Organizing state-level workshops for developers and farmers could generate awareness. Creating a mechanism to fund special projects based on proposals from stakeholders can help innovate new models.
Evaluation	States should evaluate the first set of future projects along five criteria: i) techno-commercial evaluation to understand the viability and technical characteristics of different technology models, ii) effective land area of agriculture and crop yield, which can form the basis of standards in the future, iii) impact on water resources, iv) shading characteristics of different models to create guidelines for crop selection, and v) other operational challenges.

Source: Authors.

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Abbreviations and Acronyms

CAPEX	capital expenditure
CESL	Convergence Energy Services Limited
CTU	Central Transmission Utility
CUF	capacity utilization factor
DFI	development finance institutions
DISCOM	distribution company
EESL	Energy Efficiency Services Limited
ESCO	Energy Service Company
FLS	feeder-level solarization
FY	financial year
INR	Indian rupee
ISTS	interstate transmission system
KVK	Krishi Vigyan Kendra
LCOE	levelized cost of electricity
MERC	Maharashtra Electricity Regulatory Commission
MGSIPA	Mahatma Gandhi State Institute of Public Administration
MNRE	Ministry of New and Renewable Energy
MSEDCL	Maharashtra State Electricity Distribution Company Limited
MSKVY	Mukhymantri Saur Krishi Vahini Yojana
MW	megawatts
MWp	megawatt peak
PFC	Power Finance Corporation
PM-KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahaabhiyan
PPP	public–private partnership
PSPCL	Punjab State Power Corporation Limited
PV	photovoltaic
RDSS	Revamped Reforms-based and Results-linked Distribution Sector Scheme
RE	renewable energy

REC	renewable energy certificates
RESCO	Renewable Energy Service Company
RMS	remote monitoring system
RPO	Renewable Purchase Obligation
SEDM	Solar Energy Data Management
SERC	State Electricity Regulatory Commission
SIA	State Implementing Agency
SECI	Solar Energy Corporation of India
SLBC	State-Level Banking Committee
SME	small and medium-sized enterprises
SPV	special purpose vehicle
WEF	water–energy–food

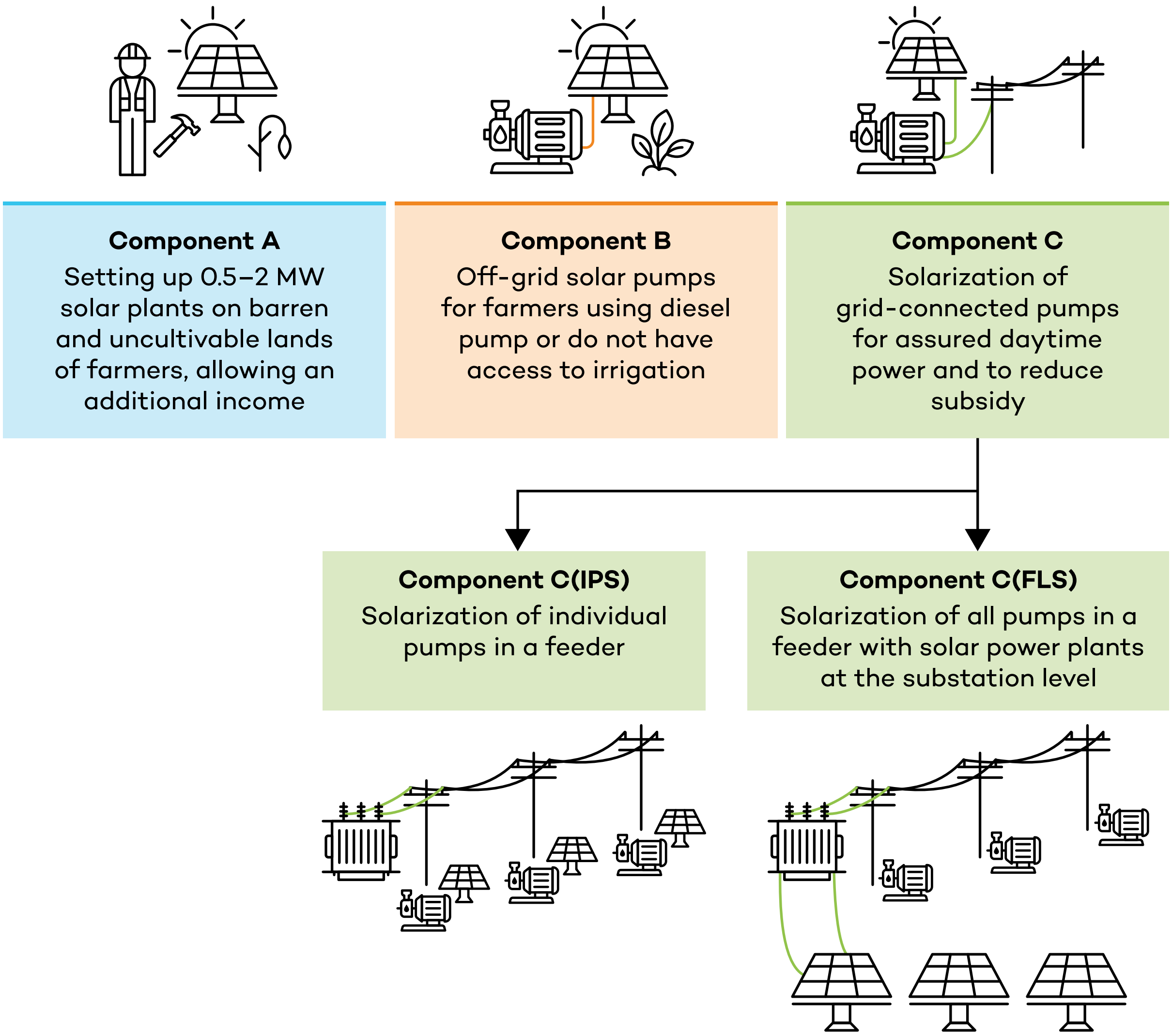
1.0 Introduction

In 2019, the Government of India launched a major scheme to promote solar-powered irrigation: the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahaabhiyan (PM-KUSUM). The scheme consists of three components promoting different deployment approaches:

- A – 10 gigawatts of decentralized ground-mounted, grid-connected renewable power plants on farmers' land
- B – 2 million stand-alone solar-powered agriculture pumps
- C – Solarization of 1.5 million grid-connected pumps under either of two models—individual pump solarization or feeder-level solarization (FLS) (See Figure 1 for details)

Solarizing irrigation has huge potential. Cost-effective and reliable irrigation can significantly improve farmer incomes and well-being. Shifting away from highly subsidized grid electricity can relieve financial pressure on electricity distribution companies (DISCOMs)—a review of tariff orders in 17 states and Union Territories found that 75% of all such subsidies go to agriculture (Aggarwal et al., 2020). Furthermore, solar irrigation can help India

Figure 1. PM-KUSUM components



shift to clean energy, reducing air pollution and greenhouse gas emissions. At the same time, care must be taken to implement it sustainably. There are complicated interconnections between water, energy, and food—often called the "water–energy–food nexus" or WEF nexus—where interventions in one area can cause unexpected impacts in another.

This guidebook has been developed in cooperation with the Ministry of New and Renewable Energy (MNRE). It is dedicated to supporting state policy-makers and agencies in sustainably implementing grid-connected solar power at a substation level, thereby "solarizing" the supply used by farmers connected to the substation. We refer to this as "decentralized solar power plants for irrigation," which includes components A and C(FLS) of PM-KUSUM. Given the relative lack of experience with these models in India, we aim to bring together essential guidance on implementing them effectively. We also examine sustainability, identifying best practices for maximizing social outcomes and groundwater resources. Based on an initial needs assessment, this guidebook covers the following:

1. **Context:** What are these models, and what are their potential impacts?
2. **Financing:** What can states do to reduce the costs of financing?
3. **Implementation design and coordination:** How can specific inter- and intra-departmental coordination mechanisms improve outcomes?
4. **Learning by doing:** While states prioritize immediate deployment, how can they integrate pilots of innovative approaches for maximizing sustainability to inform ongoing improvements?

As a guidebook, this publication is based on the best available evidence, but it is not a research paper. We focus on practical suggestions for state policy-makers and implementing agencies with illustrative examples, drawing on a combination of secondary and primary research, including:

- Reviews of existing policy research literature
- 32 in-depth interviews with state and central officials, financiers, and policy experts
- Case studies on state schemes in Maharashtra and Punjab (see Appendix)
- A background paper on agrivoltaics based on literature review and stakeholder consultations (provided as a supplementary to this guidebook)
- Various multistakeholder roundtables with policy-makers and experts on solar irrigation

This guidance is focused only on components related to decentralized solar power plants for irrigation. It is intended to directly assist state policy-makers with implementing PM-KUSUM and be relevant for any solar irrigation scheme, including future policies once PM-KUSUM is completed. For guidance on other forms of solar irrigation—stand-alone and grid-connected pumps—see our separate guidebook *Implementing Solar Irrigation Sustainably: A Guidebook for State Policy-Makers on Maximizing the Social and Environmental Benefits From Solar Pump Schemes*, published in 2021.

2.0
Context: The Why, How, and Impacts of Decentralized Solar Plants

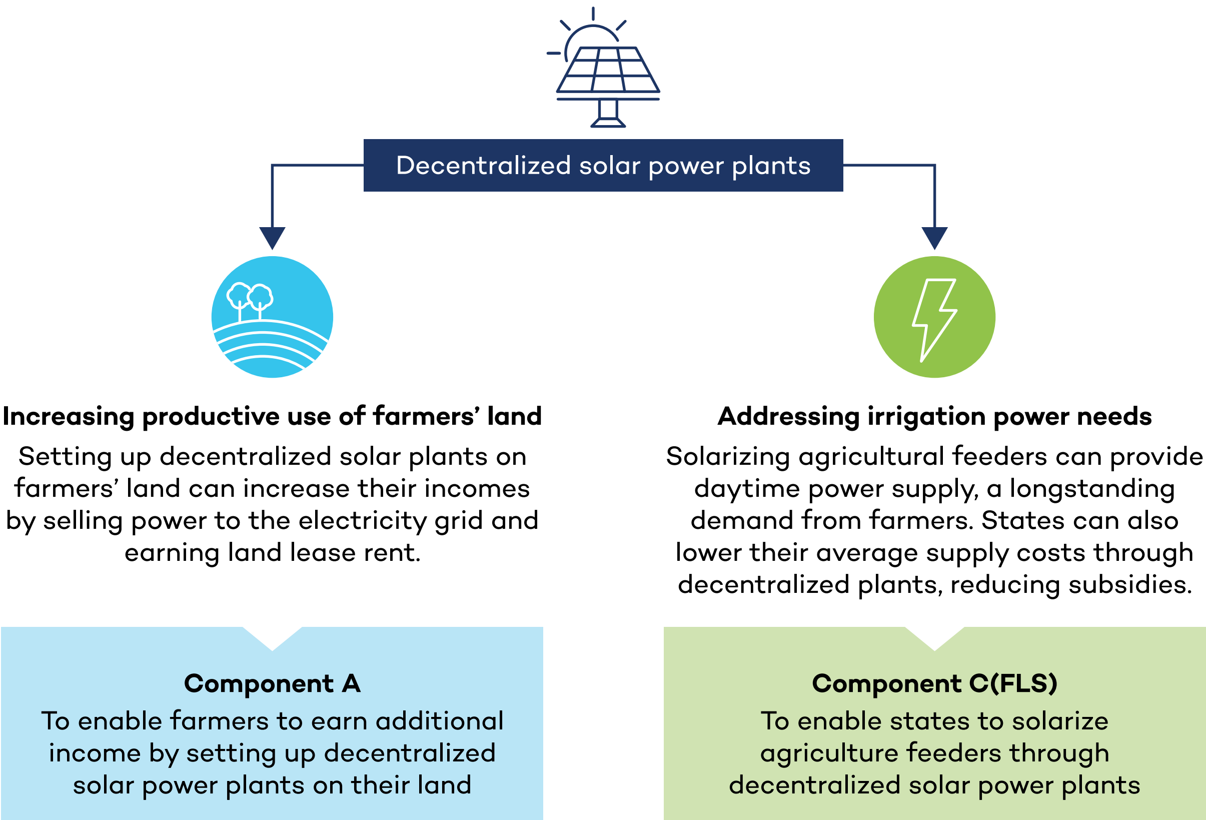
2.1 Why Does the Context Matter?

In preparing this guidebook, consultations found that many stakeholders are unfamiliar with decentralized solar plants for irrigation. Recurring questions included: What is the difference between the two main PM-KUSUM components that can support this technology? What are the benefits for farmers, states, and DISCOMs? And what are the implications for sustainability? Understanding these questions is critical to ensure that schemes align with state objectives and maximize social and environmental benefits.

2.2 What Are the Main Differences Between PM-KUSUM Components A and C(FLS)?

A decentralized solar plant is much smaller than typical grid-scale plants but much larger than a typical household rooftop solar or a solar pump and is located close to final consumers, near the distribution substation. The exact size depends on demand in the substation but is typically in the range of a few hundred kilowatts to a few megawatts. Being close to consumers, it offers them more reliable power while reducing costs by minimizing distribution losses. If the generation is ever too low to meet demand fully, the substation can draw power from the

Figure 2. Objectives of decentralized solar power and how they link to PM-KUSUM



Source: Authors' diagram based on MNRE, 2019, 2020.

Note: Agriculture feeders refers to electricity distribution feeders exclusively supplying to agricultural consumers.

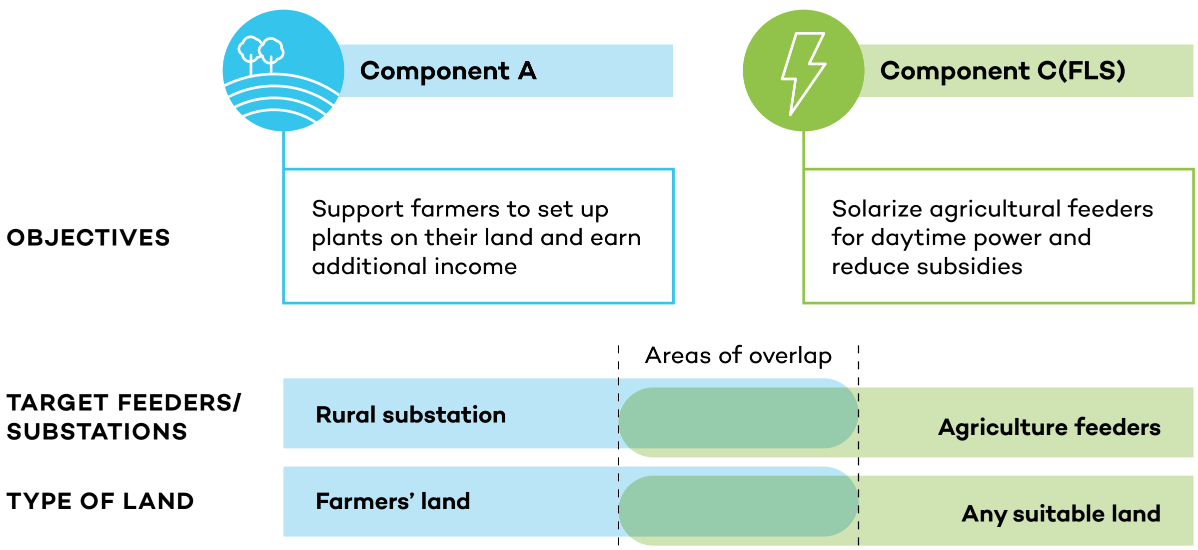
grid. If the generation is too high, power can be fed back into the grid.

The PM-KUSUM scheme can support solar irrigation in several ways, each with a corresponding scheme component. Decentralized solar plants can be supported under component A and the feeder-level subcomponent of C, which we refer to throughout this guidebook as "C(FLS)." The most up-to-date PM-KUSUM guidelines can always be found on the [MNRE website](). The two components are conceptualized with two different objectives. Figure 2 summarizes the two major objectives and how each one lines up with different components of PM-KUSUM.

Despite this difference in the two components' objectives, a common outcome from both components involves setting up a decentralized solar power plant near distribution substations. Hence, there is an overlap between the two components, as illustrated in Figure 3. To make it clearer for the reader, Table 1 compares and contrasts the design differences between A and C(FLS).

A state government's primary policy objective can help determine which component of PM-KUSUM is best to pursue. It should be noted that these objectives are not mutually exclusive—in many instances, PM-KUSUM will deliver upon both of them. But in most cases, prioritizing one can help drive decision making. In areas where they overlap, it makes financial sense for states to opt for Component C(FLS), as it offers more central financial assistance.[1] States can also decide to prioritize both objectives, in which case it would be appropriate to set targets under both components.

Figure 3. Areas of overlap between PM-KUSUM Components A and C(FLS)



Source: Authors diagram based on MNRE, 2019, 2020.

[1] MNRE's guidance concerning situations where both components overlap can be accessed here.

Table 1. Design differences between PM-KUSUM Components A and C(FLS)

Design feature	Component – A	Component – C (FLS)
Target feeders	Feeders in rural substations	Agriculture feeders or feeders having major agriculture load.
Size of the power plant	0.5 – 2 megawatts (MW)	Depends on the total load of target feeders (with restrictions on pump size eligible for central financial assistance as detailed in Box 12).
Ownership of the land	Private land (farmer-owned)[2]	Private or public lands (owned by DISCOM or state governments)
Central gov. incentives	Performance-based incentive of INR 0.40 per kWh for the first 5 years	30% capital subsidy of the power plant cost to be provided over 10 years.

Source: MNRE, 2019, 2020.

Box 1. Agrivoltaics – Extending solar plants to cultivable lands under PM-KUSUM A and C(FLS)

Solar power plants require a relatively large amount of land surface area to generate significant quantities of electricity. This fact raises concerns about competition between land for solar power generation and land for food production (Nonhebel, 2005). Agrivoltaics represents an innovative solution to this problem. With this practice, a solar power plant shares land with crops, increasing the net value of output from the land. Crops are cultivated below the panels or between them.

Agrivoltaics is a relatively new practice. PM-KUSUM Component A is the first national scheme to support it. The scheme guidelines stipulate that farmers can set up a power plant on cultivable land as long as the photovoltaic (PV) panels are installed on a raised platform supported by stilts with adequate spacing between panel rows (MNRE, 2019). Component C(FLS) on feeder-level solarization also enables the construction of decentralized solar power plants. It does not explicitly refer to agrivoltaics, but there is no restriction for implementing agencies to explore agrivoltaics under this component as well. A detailed background paper on the prospects and challenges of agrivoltaics is included as a supplement to this guidebook.

[2] The scheme primarily targets uncultivable barren lands. But cultivable land can be used with solar plants installed on stilts allowing agrivoltaics (see Box 1).

Due to the overlaps between the two components, much of the advice in this guidebook can apply to both components. In the subsequent sections, we will refer to "PM-KUSUM" for both components. Only when learnings are exclusive to one component will A or C(FLS) be explicitly mentioned.

2.3 How Do Farmers Benefit From Solarizing Agricultural Feeders Under PM-KUSUM?

Under Component A of KUSUM, the main benefit for farmers is clear: they either develop and own the decentralized solar power plant and earn an additional revenue stream from its operations, or they lease out their land to a developer and receive income as a share of that developer's profits.

Under Component C(FLS) of KUSUM, the main benefit for farmers is an improved power supply for irrigation. Under Component A, an improved power supply is also likely to be created in addition to revenue benefits. The full advantages of an improved power supply are not as self-evident as a new income stream and deserve further explanation.

There have been great strides in recent years to improve energy access, with around 59% of India's landholdings in 2021 now using grid electricity for irrigation (Ministry of Agriculture and Farmers Welfare, 2021). Nonetheless, many farmers still experience a low-quality, erratic power supply with problematic timing.

Figure 4. Impact on quality of power supply

PROBLEM

Voltage levels in agriculture feeders are often below the stipulated grid code. This causes frequent pump burnouts that can cost the farmer more than the electricity bill (World Bank, 2001).

→

SOLUTION

A decentralized solar power plant provides voltage support to the target feeders. Simulations based on real-world feeder parameters show that an appropriately-sized solar plant connected to feeders can bring the voltage to standard limits (Bharadwaj & Tongia, 2003; Sri & Narasimham, 2012).

However, it is important to note that the quality of the power supply is predominantly determined by the robustness of the distribution infrastructure. A decentralized power plant can, at best, play a supporting role in improving the quality.

Figure 5. Impact on timing, duration, and predictability of the power supply

PROBLEM

Most states schedule agricultural power supply for off-peak hours, including nighttime, either permanently or through rostering, which helps balance demand. Some states restrict their power supply to 4–5 hours daily. Often, the supply is not predictable.

Many farmers use auto-switch-on mechanisms due to the intermittency of power, leading to water wastage. Furthermore, irrigating at nighttime is often hazardous. One survey shows that 19% of agriculture consumers faced electricity-related accidents (Bali et al., 2020). Power supply at night also disproportionately impacts women due to safety concerns.

→

SOLUTION

With PM-KUSUM, farmers will get up to 10 hours of daytime power supply—a longstanding demand from farmers. The coincidence of solar power generation with irrigation requirements makes agriculture suitable for solarizing.

Improved predictability of power availability might lead to better irrigation management, improved agricultural productivity, and fewer accidents. However, the over-exploitation of groundwater is also a key risk with increased energy access. We discuss this in detail in Section 4.2.3.

? But … won't shifting the power supply to the daytime affect load management?

Many states supply power to agriculture feeders at night to balance the peak load. Studies show that this benefits DISCOMs by reducing around 5% of the total cost (Khanna, 2021). However, this strategy is only optimal for the current energy mix, in which thermal power plants dominate. As India achieves a higher renewable energy (RE) share, as per its stated energy policy targets, shifting the agriculture supply to daytime will, in fact, improve load management. According to the International Energy Agency (IEA) (2021), the agriculture demand shift is the most cost-effective way of achieving higher power system flexibility for RE integration (IEA, 2021). It will also help reduce future RE curtailments in high-RE-share scenarios (Khanna, 2021). By kickstarting this shift, PM- KUSUM can give states a great head start in achieving their RE targets. Karnataka, the state with the highest renewables in its energy mix, has decided to shift much of the agricultural peak load to daytime to coincide with solar generation ("Bescom Maps Out," 2019).

2.4 How Do the States and DISCOMs Benefit From PM-KUSUM?

In addition to fulfilling social obligations to farmers and contributing to clean energy targets, PM-KUSUM also saves financial costs for states and DISCOMs by reducing direct subsidies and cross-subsidies. The savings for states primarily arise from the following factors:

Reduction in Power Purchase Cost

The average power purchase cost from non-RE sources across the country is INR 3.85 per unit, and agriculture-intensive states are even higher (Central Electricity Regulatory Commission, 2021). In comparison, the ceiling tariff in Maharashtra's solar irrigation scheme, the Mukhyamantri Saur Krishi Vahini Yojana (MSKVY), which had the most success in the decentralized solar power plant model, is INR 3.30 per unit. This is only a superficial comparison, as the actual power purchase cost from non-RE sources for agriculture feeders is likely somewhat lower than INR 3.85 per unit since part of the supply happens during off-peak demand hours. However, the significant difference between the average cost of supply and the ceiling tariff from decentralized solar schemes shows a clear case for states to explore PM-KUSUM.

But … my state already has excess contracted capacity. Will we end up paying a fixed cost for the surplus capacity if we start PM-KUSUM?

States can save the variable cost (energy cost) component of their power purchase from Day 1. For the savings on fixed cost (capacity cost) to kick in, the states must include the PM-KUSUM in their power purchase planning. Cost-benefit analysis shows that even if states consider some years of waiting period for demand to exceed contracted capacity, there is a benefit from PM-KUSUM (Rahman et al., 2021).

Reduction in Transmission and Distribution Losses

PM-KUSUM can help states to reduce transmission and distribution (T&D) losses. Power utilities incur T&D losses when power is sent from generation stations to the distribution substation. This includes losses at the Central Transmission Utility level, State Transmission Utility level, and the 33 kV level within the distribution. In FY 2019, average T&D losses in India were 20% of the total power generated (Central Electricity Authority, 2022). It should be noted that most of the losses occur at voltages below 11 kV and are not avoided through the PM-KUSUM power plant. They are primarily due to a lack of proper maintenance and can only be addressed through sustained investment in infrastructure. Nonetheless, due to better voltage support, PM-KUSUM power plants can reduce some losses at the 11 kV level (Bharadwaj & Tongia, 2003).

But … we get power at a low cost from a utility-scale solar plant at the state periphery. Why go for distributed plants under PM-KUSUM?

There are two reasons to consider decentralized solar plants. First, utility-scale plants have growth limits due to land requirements and environmental and social impact concerns. As demand increases, decentralized plants have a role to play. Second, some cost advantages arise from temporary policies supporting clean energy. For example, the interstate transmission system (ISTS) waiver, which exempts renewables from ISTS charges and losses, discounts the cost of carrying power from utility-scale power plants to the consumer.

Reduction in Transmission Capacity Requirements

As electricity demand increases, utilities must constantly upgrade the T&D capacity, including replacing transformers and load-tap-changer maintenance. DISCOMs usually incur these costs as transmission charges and maintenance costs. Utilities can save by deferring transmission requirements and capacity upgrades if agriculture consumers move away from conventional power sources. A study on a 500-kW power plant in California connected to a 12 kV rural feeder showed a reduction in substation transformer temperature, an increase in capacity, and an extension of load-tap-changer maintenance interval by 10 years (Farmer et al., 1995).

Reduction in Cost of Creating Power System Flexibility

Power system flexibility is vital for integrating RE due to its variable nature. As the share of renewables in the grid increases, the grid becomes unstable. India and many states have set ambitious renewable targets. To achieve these targets, DISCOMs will have to invest in system flexibility solutions like battery energy storage service, pumped hydro systems, and so on. However, studies show that shifting agricultural load to coincide with solar generation is the most cost-effective solution for achieving power system flexibility (IEA, 2021). PM-KUSUM paves the way for achieving this coordination effectively.

? But … agricultural load fluctuates a lot within a year. Outside irrigation periods, most power will need to flow upstream. Won't it cause congestion and losses?

This is a valid concern for many states, especially irrigation-intensive states. At high penetration levels of decentralized solar power plants, the losses increase, which can lead to transmission congestion (Jadhav et al., 2020). The key is in targeting and the optimal sizing of power plants. Not all feeders can be solarized under the scheme. The sizing of the power plant in any substation should consider the base load throughout the year (see Section 3 for more details).

Fulfilling a Renewable Purchase Obligation

The Electricity Act (2003) mandates State Electricity Regulatory Commissions (SERCs) to specify a minimum percentage of the DISCOM's total power purchase to be from renewable sources. This is called a renewable purchase obligation (RPO). Accordingly, SERCs have prescribed RPOs for respective DISCOMs. If a DISCOM cannot fulfill the obligation, it needs to buy Renewable Energy Certificates (RECs) to cover the shortfall. The power purchased from the PM-KUSUM power plant can count toward the DISCOM's RPO obligation. If a DISCOM exceeds RPO targets, it can issue REC certificates corresponding to the excess generation and sell them in the REC market. Thus in both scenarios, PM-KUSUM solar plants benefit the DISCOM.

Employment Impacts

Apart from these direct impacts, there is also the benefit of generating jobs in rural areas. Smaller solar plants generate more jobs per MW. Studies show that rooftop solar creates 24.72 full-time equivalent jobs per MW, while a sizable utility-scale power plant creates 3.45 full-time equivalent jobs per MW (Kuldeep et al., 2017). The significantly higher number of jobs for rooftop solar come from business development, design, and construction phases due to the small size of individual projects. PM-KUSUM's job creation potential would likely lie closer to that of a utility-scale power plant. However, unlike the utility-scale power plants, the job potential is well distributed geographically. There is also the added advantage of diffusion of technical capacity to remote areas.

? So … does this mean purchasing power from a decentralized solar plant is always more beneficial than from a conventional power plant?

Not necessarily. Although decentralized solar plants provide the benefits mentioned above, it is important to note that solar power is variable and infirm. This poses grid-integration costs. DISCOMs can only capture the costs and benefits accurately by undertaking a detailed substation study. This is further elaborated in Section 3.3.

2.5 How Do Solarized Agriculture Feeders Impact the WEF Nexus?

Solarizing a feeder is an energy-access intervention. However, energy has complex interlinkages with water and food—a concept called the water–food–energy nexus. This means that an intervention in one area that can impact others in multiple ways, affecting the PM-KUSUM scheme's sustainability. Since feeder solarization is a relatively novel approach with very few real-world pilot studies, these interlinkages are poorly understood. But it certainly helps to set the context based on the experiences and studies so far so that the state policy-makers can take appropriate mitigation and monitoring measures.

2.5.1 How Do Decentralized Solar Plants Affect Water Markets?

Many farmers, especially small and marginal farmers, depend on informal water markets to fulfill their irrigation needs. They buy water from farmers with electric connections. The basis for these transactions is quite diverse—some are based purely on kinship, some on hourly rent or rent for area irrigated, and others on sharing the harvest. Any change in the cost and supply of power can indirectly affect such markets. It can create benefits: it can help water sellers to potentially increase revenues from the sale of water and benefit water buyers due to more reliable and timely electricity supply. It can also lead to costs: for example, a disruption in the existing water market and the depletion of groundwater tables.

Currently, no reliable national data lets us generalize how solar irrigation affects local water markets. As part of larger monitoring and evaluation mechanisms, policy-makers are encouraged to interview farmers in geographic areas where solar irrigation is being targeted before and after the introduction of decentralized plants.

2.5.2 How Will Solarizing Feeders Impact Groundwater Sustainability?

Groundwater depletion is a major challenge for sustainable irrigation in many parts of India. The highly subsidized power to agriculture connections provides little incentive for farmers to adopt water-efficient practices. Low groundwater levels increase energy demand for irrigation and deprive economically disadvantaged farmers of accessing irrigation, as they won't be able to increase pump size regularly.

Among the experts interviewed to prepare this guidebook, we found no consensus on how decentralized solar power plants will affect groundwater levels. The limited number of pilot studies also means that there is relatively little evidence to rely upon.

Based on interviews, however, we have identified some guiding questions that can help states assess the risk of groundwater impacts:

1. Does the duration of the power supply increase as a result of the decentralized solar power plant?
2. Is power supply the main constraint for growing more lucrative but water-intensive crops?
3. Does the hydrogeology in the feeder area support more water extraction?

The question about hydrogeology deserves attention because it is the least understood. Aquifers can be understood using the "bathtub" vs. "egg carton" analogy (Beattie, 1981). The "bathtub" analogy refers to a well-connected aquifer system spread over a large area, acting like a giant bathtub. In

such aquifers, a change in water levels is very gradual, and the impact of pumping and rainfall is only visible over several years. In contrast, an "egg carton" analogy is an aquifer that is small, unconnected, and much more sensitive to changes in pumping and rainfall. In the case of bathtub-type aquifers, farmers are likely to see water as an unlimited resource and extract as much as possible, with no incentive to conserve. With egg carton-type aquifers, there is a clear and quicker feedback link between water reserves and pumping activity, so an increase in energy access is unlikely to trigger a significant increase in groundwater consumption.

In reality, the type of aquifer is somewhere between these two analogies. In general, however, large parts of the Indo-Gangetic plains and coastal river valleys behave more like bathtub aquifers, while the peninsular hard rocks of western India behave more like egg-carton-type aquifers (Srinivasan, 2022). Many parts of the peninsular plateau already face seasonal water depletion. In such cases, energy is not the constraint to expanding irrigation.

If the answer is "yes" to all of the above questions, then there is a reasonable chance that water consumption will increase. One clear indication is the outcome of the Surya Raita project in Karnataka, which showed an increase in water abstraction after scheme implementation in the absence of any incentive mechanism to conserve water (see Box 2). In such cases, policy-makers are encouraged to ensure that water impacts are well covered by larger monitoring and evaluation mechanisms, particularly in the first waves of deployment, both before and after the introduction of decentralized plants. The feedback from such assessments should guide future deployments in the state or region. States can also explore convergence opportunities with measures for improving the energy efficiency of pump sets and efforts to popularize water-efficient practices, which are detailed in Section 4.2.3.

Box 2. Improved electricity access leading to increased water consumption: The Surya Raita scheme

Under the Surya Raita scheme, Karnataka state solarized about 300 pumps in one feeder on a pilot basis. The scheme was similar to PM-KUSUM Component C (FLS). However, the state could not pay the feed-in tariff as planned. The only benefit for farmers was the increased hours of power supply, without any incentive to conserve water. A study of the scheme estimated a 1.77 times increase in farmers' water consumption due to increased electricity access. Many farmers shifted to mulberry cultivation, a water-consuming but much more remunerative crop. Although this was a general trend in the area, this shift in crop choice was much higher among beneficiary farmers, indicating that the increased electricity access catalyzed the transition (Durga et al., 2021).

2.5.3 Should States Introduce Incentive Mechanisms to Address Groundwater Concerns?

The sustainable long-term solution to address groundwater depletion concerns is introducing cost-reflective pricing for electricity use. However, farm energy is highly politicized, and farmers in several states have resisted any attempts to introduce metering. Interviewees highlighted the political sensitivity of the issue. They suggested that states should explore other mechanisms to address the challenge given the prevailing groundwater crisis in many parts of the country.

PM-KUSUM guidelines propose a cash transfer mechanism for incentivizing farmers to conserve groundwater. Under this mechanism, the DISCOM sets electricity usage quotas for all farmers as Minimum Energy Support. Farmers who consume fewer units than their quota are eligible for a cash transfer for the saved units at a predetermined rate (MNRE, 2020). There is no penalty, however, for consuming above the quota.

This type of mechanism has two-fold advantages for implementation.

1. It is purely based on incentives and does not penalize farmers for overconsumption.
2. It does not require the participation of all farmers in a feeder. Interested farmers can opt in voluntarily; the higher the participation, the better the likelihood of improved outcomes.

These factors make it easier to mitigate the political challenges of metering. Only interested farmers need to be metered on a voluntary basis.

This mechanism is, however, not yet widely tested. The only large-scale implementation was in Punjab under the state government's Pani Bachao Paisa Kamao (PBPK) scheme (see Box 3). There are multiple challenges in the implementation of this design. We have elaborated on them in the subsequent sections and the case study of PBPK in the Appendix. However, three key design challenges are worth highlighting upfront:

- **Fixing the quota for farmers:** In theory, the quota set for farmers should depend on the natural recharge rates of the local aquifers to ensure water withdrawal is sustainable. However, this is impractical to implement, as farmers will likely opt out of the scheme if the quota is set much lower than their prevailing consumption. A more practical approach is to fix a quota nearer to farmers' current levels of consumption. However, assessing the baseline consumption is challenging since the targeted connections are unmetered. An Energy Sector Management Assistance Program study proposes setting the quota based on the connected load (size of the pump) or the size of the land holding (Gulati & Pahuja, 2015). Under the PBPK, an average monthly electricity quota based on the pump motor capacity was fixed for each agriculture feeder (See Section 5.3.1).
- **Participation from tenant farmers:** In areas where a significant number of farmers cultivate on leased land, states will have to adopt innovative solutions to ensure tenant farmers' participation. Under PBPK, the government enabled cash transfer directly to the tenant farmers after the enrolment of the landowner (See Section 5.3.1).

- **Financial and capacity burden on DISCOM:** The success of a direct incentive mechanism relies on several initiatives to be undertaken by DISCOMs, including feeder separation, grid upgrading to ensure daytime power supply to farmers, outreach and awareness campaigns, monitoring and vigilance to prevent farmers from using multiple pumps or to bypass meters, the purchase and use of innovative IT tools, and timely payments of water incentives to farmers. Given the precarious financial situation of many DISCOMs in India, dedicated budgetary funding from states and the support of external knowledge partners will be essential for the initiative's success. Under the PBPK scheme, the state allocated INR 40 crore (~USD 5 million) from the agriculture subsidy budget, of which INR 5 crore was reimbursed to the DISCOM, Punjab State Power Corporation Limited (PSPCL), for the scheme implementation (Mahatma Gandhi State Institute of Public Administration [MGSIPA], n.d.). In addition, knowledge partners like the World Bank, Abdul Latif Jameel Poverty Action Lab–South Asia (J-PAL SA), and The Energy and Resources Institute supported the scheme's implementation.

It is worth noting that learnings from Punjab may not be applicable to other parts of the country. Indeed, a pilot study conducted in Gujarat that trialled electricity-linked incentives for farmers resulted in high enrolment for metering but no impact on water consumption (Fishman et al., 2016). Hence it is critical to contextualize the learnings. Section 3 explores in more detail how to pilot such mechanisms and summarizes some findings in this regard. It

? But ... in our state, farmers get electricity almost for free. Wouldn't providing an additional incentive increase the financial burden on the state government?

Not necessarily. Although the state is incentivizing the farmer, its subsidy burden can be reduced with the right scheme design. For example, suppose a farmer consumes about 4,000 kWh annually, and the state announces an incentive of INR 3 per kWh saved. If the farmer reduces their consumption to 3,500 kWh a year, the state government will incur a cost of INR 1,500 for the incentive. But it also saves the cost of buying and servicing 500 kWh of power to the farmer. Considering the average cost of supply of about INR 6.5 per kWh, the savings amount to INR 3,250. The state thus saves about INR 1,750 per farmer annually by providing the incentive, which could overcome the capital and operational cost of implementing the scheme over a specific time period.

The above example is just for illustrative purposes. The actual benefit will vary based on the prevailing tariff for agricultural connections, subsidy amount, and the actual cost of service for the DISCOM. In addition, the utility will need to establish the right baseline for individual farmers, which is challenging given the absence of farm-level metering. States also need to consider the scheme's cost and analyze its economic impact for each DISCOM.

is also worth reiterating that even if proven successful, a direct incentive mechanism may not be a substitute for cost-reflective electricity pricing in the long run. Further, there are other mechanisms for achieving energy efficiency and load reduction. Some of these are outlined in Section 3.

Box 3. The Pani Bachao Paisa Kamao pilot experience in Punjab

The Punjab government, in consultation with the World Bank and J-PAL SA, implemented an innovative pilot scheme in 2018 to address the challenge of the over-withdrawal of groundwater in the agriculture sector. The PBPK or “Save water, earn money” scheme provides a direct incentive to participating farmers to conserve electricity within a stipulated limit and thereby conserve groundwater. The scheme aims to solve the interlinked challenges of rapidly depleting groundwater tables and the growing financial debt of electricity utilities. The scheme was voluntary and did not include a penalty for consumption over the stipulated quota. It relied on the installation of smart meters to monitor farmers’ electricity consumption. Power supply to the consumers was shifted to the daytime for 8 hours duration during the paddy season and 3–4 hours for the rest of the year (Asian Development Bank, 2020).

The first phase of the pilot scheme achieved a 33% enrolment among the targeted farmers in six feeders (MGSIPA, n.d.). t The second phase of the PBPK pilot was disrupted by the COVID-19 pandemic, which led to only 4% of the targeted enrolment in 250 feeders. A study carried out by the International Water Management Institute (IWMI) found that the combination of daytime electricity provision and cash incentives for unused electricity has the potential to incentivize farmers to reduce electricity consumption and irrigation hours by at least 7.5% and up to 30%, without affecting paddy yields (Mitra et al., 2022). Interviews with implementing officials, however, suggest that more data is required before any definitive conclusions are drawn regarding the scheme’s impact on electricity and groundwater consumption.

Although crop diversification was highlighted as an objective in the scheme guidelines, consultations with agricultural experts revealed that it was not a priority given the assured income that farmers receive from paddy cultivation (PSPCL, 2022).

Section Summary

This section deconstructs the decentralized solar plant model for solarizing rural feeders and its potential impact, including benefits to different stakeholders—farmers, DISCOM, and the state government—and impact on the water–energy–food nexus.

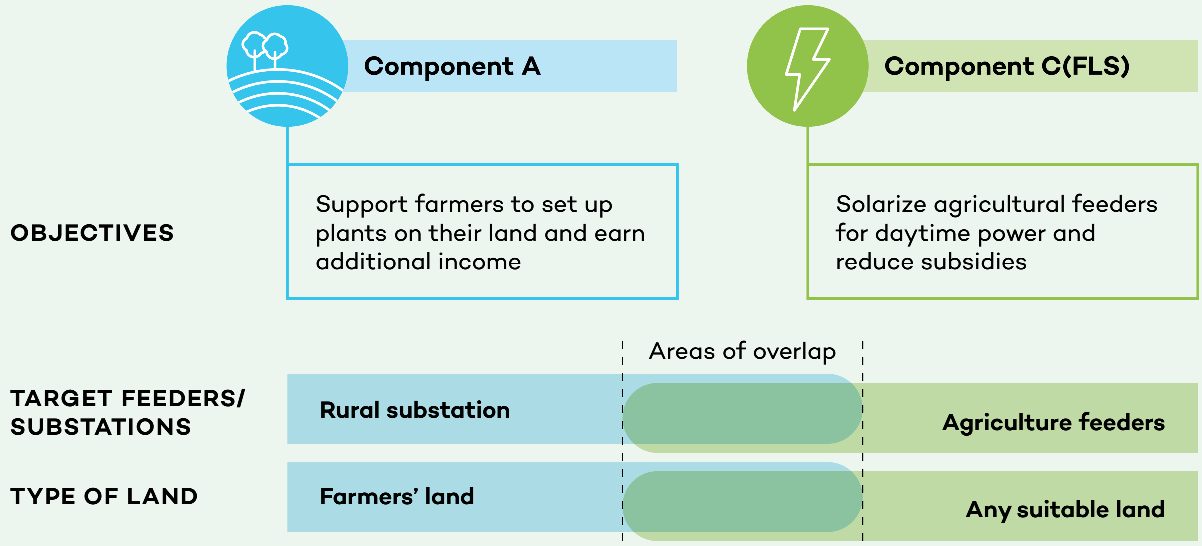
Decentralized Solar Plants

A decentralized solar plant, under PM-KUSUM Components A and C (FLS), has a much smaller capacity than a grid-scale solar plant but much larger than a typical household rooftop solar system, is located close to the final consumers, and is connected to a distribution substation.

Components

Components A and C(FLS) are designed with very different objectives, but the two may overlap under certain circumstances. A state government's primary policy objective can help determine which Component of PM-KUSUM is best to pursue in a specific region.

Figure 3 (duplicate). Areas of overlap between PM-KUSUM Components A and C(FLS)



Solarizing Agricultural Feeders

Solarizing agricultural feeders can provide multiple benefits to farmers and the state government.

Figure 6. Benefits for farmers, state, and DISCOM in solarizing agriculture feeders

Benefits for farmers

Improved quality of power supply:
Distributed power plants can improve voltage conditions and support other measures to strengthen the distribution grid.

Timing, duration, and predictability of power supply:
Farmers can get up to 10 hours of daytime power supply to reduce the difficulties and hazards of erratic nighttime power supply.

Benefits for state/DISCOM

Reduction in power purchase cost:
The cost of power from a distributed power plant is typically less than the average power purchase cost of the state.

Reduction in transmission and distribution (T&D) losses and charges:
The T&D losses and charges up to the 11 kV substation level that a future capacity addition would have incurred are avoided.

Fulfillment of renewable purchase obligations (RPOs):
If a DISCOM's renewable purchase is below RPO norms, PM-KUSUM can reduce the shortfall. The DISCOM can issue renewable energy certificates (REC) and earn income if it is in excess.

Long-term benefit of power system flexibility:
Shifting agricultural load to the daytime to coincide with solar generation is the most cost-effective strategy for grid stability in the coming years.

Social benefits, including local employment generation:
Distributed solar plants can help create new green jobs that are geographically well distributed.

However, the model is not without issues. Most of these can be addressed through better awareness and intelligent scheme design.

Table 2. Challenges faced by DISCOMs in solarizing agricultural feeders and potential solutions

Concerns	Solutions
Seasonal fluctuation in agricultural load	The key to avoiding upstream power flow during the non-irrigation season is optimal targeting and sizing of the power plant. Sizing should consider the base load requirement of the substation.
Higher cost than utility-scale solar plants	Although utility-scale solar plants offer cheaper power, their growth has inherent limitations, and decentralized power plants can play a complementary role. Further, some cost advantages of utility-solar plants are due to temporary incentives, such as the interstate transmission system waiver.
Impact on daily load management	Shifting agriculture load to the daytime is the most cost-effective means of load management as the share of solar power increases in the grid. States can use PM-KUSUM to plan the long-term transition of agricultural power
Excess contracted capacity	Cost-benefit studies show that even if it takes a few years for the demand to exceed contracted capacity, there is a benefit to states from PM-KUSUM.

The impact of solarizing agriculture feeders on groundwater sustainability and water markets is not well studied. However, past experiments on improving electricity access show that when the local hydrogeology is suitable, and water is the primary constraint to increasing crop production, then there is a strong possibility of increasing groundwater use, reiterating the need for careful scheme design.

Cost-reflective electricity pricing is the long-term solution to address groundwater concerns. However, if states cannot implement it due to political sensitivities, they should consider other strategies to address groundwater concerns. PM-KUSUM guidelines offer a framework for states to consider demand-side management by providing direct incentives for farmers to stay within a stipulated benchmark electricity consumption limit, potentially preventing groundwater depletion. There are advantages and challenges to this model.

Table 3. Pros and cons of direct water incentives mechanism

Advantages	Challenges
• It is voluntary and based on incentives that make it more politically feasible. • It does not require the participation of all farmers in the feeder. However, The higher the participation, the better the potential outcomes.	• Identifying the appropriate benchmark consumption limit or quota. • Participation of tenant farmers due to their lack of electricity connection. • Financial and capacity burden on the DISCOM to implement direct incentives.

Further guidance and resources

Center for Study of Science, Technology and Policy. (2019). *Dedicated feeders for Ips using solar based generation.* https://kmea.karnataka.gov.in/storage/pdf-files/Reports%20and%20other%20docs/GoK_Dedicated_Feeders_Final.pdf

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3.0
Financing

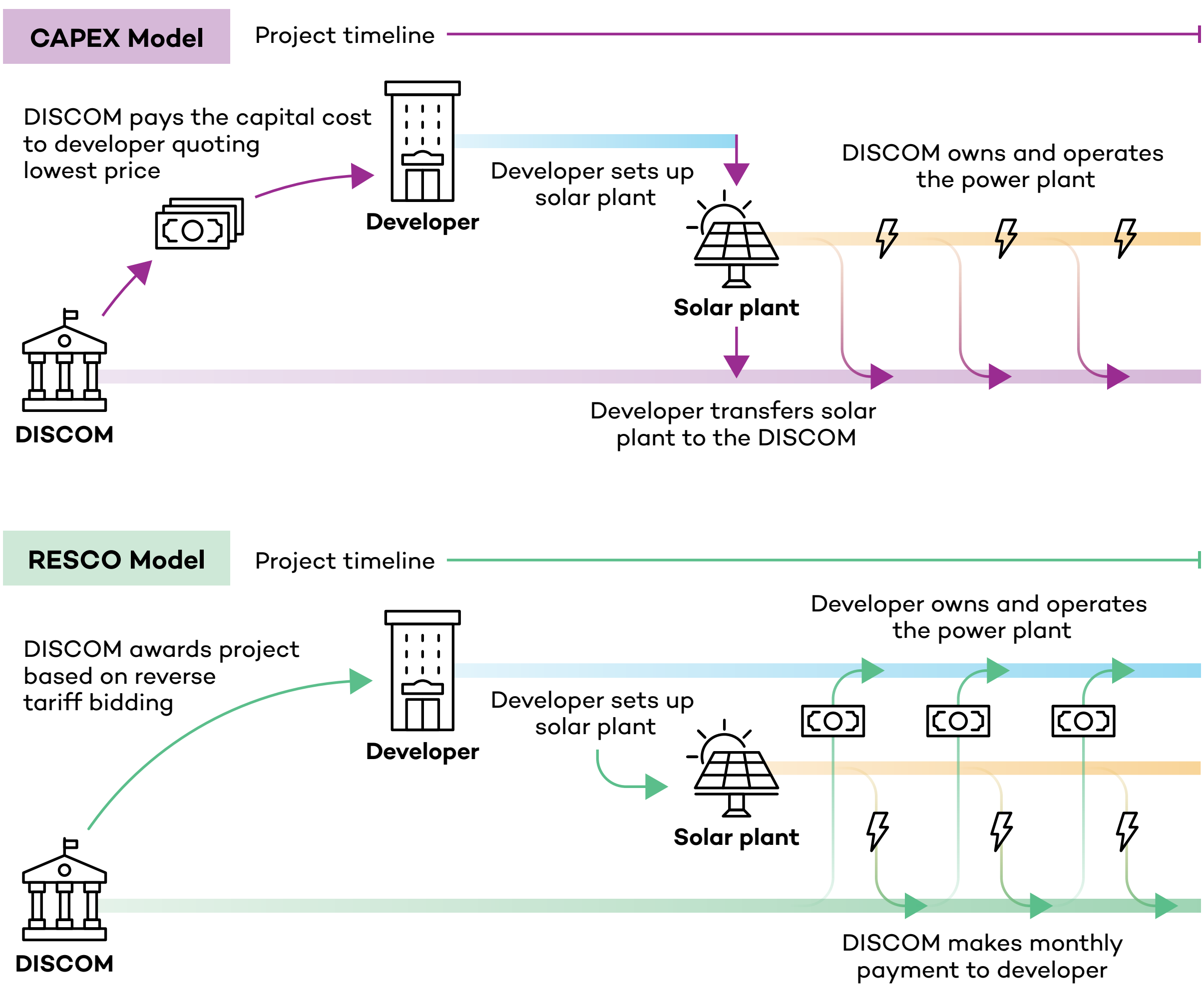
3.1 Why Does Financing Matter?

From a developer's perspective, a decentralized solar power plant is all about its viability as an investment. Any risks and opportunities that affect a scheme are therefore reflected in the ease of financing. This section uses financing as an anchor to investigate all the challenges that can face an investment and push up costs—and recommends measures to overcome them.

Broadly there are two types of financing for solar power plants: renewable energy service company (RESCO) and capital expenditure (CAPEX). Under the RESCO model, a private actor (a farmer or a developer) makes an upfront investment and sells power to DISCOM on a predetermined tariff for a fixed period. Under the CAPEX model, the investment is undertaken by DISCOM. The PM-KUSUM scheme allows the RESCO model under Component A and both the RESCO and CAPEX models under Component C. Given the extent to which DISCOMs across India are struggling financially, most states are relying on the RESCO model for scheme implementation.

Our consultations confirmed that financing is the biggest challenge to PM-KUSUM components on decentralized solar power plants—developers are not coming forward

Figure 7. Two models of financing solar power plants



to take part in the scheme. Developers and financiers both think the risks of decentralized solar plants outweigh the returns. But investments need to be made viable for the scheme to take off. There are two ways to achieve this:

1. Reduce the risks associated with investment.
2. Increase the tariff to make returns more attractive.

Increasing the tariff will diminish state benefits from the scheme. Hence, this section will examine how states can act to reduce investment risks while recommending best practices in deciding the tariff.

3.2 How Can States Reduce Investment Risks to PM-KUSUM?

Consultations found three broad categories of risks for decentralized solar plants:

1. Concerns arising due to the poor condition of the distribution infrastructure
2. Concerns arising due to higher administrative and regulatory costs
3. Concerns arising due to payment risks and poor creditworthiness of developers

3.2.1 What Are the Main Infrastructure Concerns, and How Can States Reduce Them?

Most states have weak grid infrastructure, especially at the distribution end. This results in two critical issues affecting the economic viability of solar power plants: grid unavailability and voltage variation.

Grid Unavailability and Voltage Variation

CHALLENGE

Solar power plants need a live grid for evacuating power. A grid can go offline due to faults at any part of the distribution chain—such as the poor quality of devices, grid overloading, and poor grid discipline—but the rate of such events is much higher at the local level, closest to end-users. Utility-scale power plants enjoy nearly 100% grid availability, but decentralized plants can face a much more variable situation, with the exact situation differing from state to state. If the developers factor this into their investment, the levelized cost of electricity (LCOE) increases.

Another closely linked issue is the variation in voltage at the substation busbar. This can be due to fluctuations in the upstream system or localized issues. Several studies have recorded chronic voltage fluctuations at the distribution substation, a point many stakeholders reiterated in consultations. Solar power plant inverters are designed to shut off when voltage variation exceeds certain limits. This causes generation loss, even when the grid is live. The frequent voltage fluctuations also adversely affect the life of inverters.

? But ... don't PM-KUSUM guidelines provide adequate compensation provisions through must-run status and compensation clauses?

The draft power purchase agreement (PPA) in the PM-KUSUM guidelines mentions a compensation clause if the grid is unavailable for reasons not attributable to the developer. It is a standard clause in most solar PPAs. However, in practice, the onus falls on the developer to prove that they are entitled to compensation. In our consultations, most developers were not confident in this mechanism. Developers recounted instances when states backed down, citing grid security as the reason, leading to losses.

SOLUTION

The solution to the issue is found in a two-pronged approach:

1. **Shift the onus for ensuring grid unavailability to the DISCOM:** Shifting the responsibility to the DISCOM will allay much of the developer's concern. For example, Maharashtra State Electricity Distribution Company Limited (MSEDCL) (Maharashtra) and Jaipur Vidyut Vitaran Nigam Limited (Rajasthan) have included a "minimum grid availability" guarantee of 98% and 95%, respectively. If the actual availability is lower than the minimum guaranteed percentage, the developers are eligible for compensation at a predetermined rate (Maharashtra Electricity Regulatory Commission [MERC], 2020e).
2. **Targeted improvement of the grid infrastructure:** Grid infrastructure improvement involves multiple activities. Some of them are capital intensive.
   a. Installation of capacitor banks for voltage support: Rural substations, especially those with a high proportion of agriculture consumers, can suffer from voltage drops due to the low power factor at which induction motors operate. Capacitor banks rectify the power factor and improve the voltage.
   b. Feeder restructuring and the bifurcation of overloaded feeders: Often, the actual load on a feeder is higher than the planned load, leading to feeder tripping. This can also affect the substation.

Box 4. PM-KUSUM—RDSS scheme convergence

The Revamped Reforms-based and Results-linked Distribution Sector Scheme (RDSS) seeks to strengthen distribution infrastructure using several measures. The scheme prioritizes substations designated for PM-KUSUM implementation to segregate agriculture feeders. Many measures mentioned in the indicative list of Distribution Infrastructure Works go well with PM-KUSUM, including feeder bifurcation, substation augmentation, and high-voltage distribution systems. There is a lot of scope to merge planning for PM-KUSUM with the RDSS action plan to ensure an optimal outcome.

c. Segregation of feeders: Segregating agriculture and other feeders has proven to be the most effective method of grid improvement. However, physical feeder segregation is capital intensive, with financial implications for states. Hence, the optimal load segregation approach should be based on the state's context (World Bank, 2013). Virtual feeder segregation is an innovative and cost-effective approach that states can consider (See Box 5).

Other cost-effective measures can also support grid infrastructure. According to a developer in one state, a survey of the low-tension lines before monsoons and the timely removal of tree branches helped improve grid availability significantly.

? But … is feeder segregation necessary for the PM-KUSUM scheme?

Feeder segregation helps improve the grid infrastructure. However, it is not a prerequisite for implementing PM-KUSUM. Specifically for each component, the following rules can be applied:

1. **Component A**—The component targets rural feeders (and not solely agriculture feeders). Hence it can also be implemented in substations with non-segregated feeders.
2. **Component C(FLS)**—Feeder segregation is highly desirable for this component because the aim is to only supply agriculture consumers. However, feeder segregation does not make economic sense in many states, where the average agriculture load is much smaller. In such states, mixed feeders can also be targeted.

Box 5. Virtual feeder segregation—a fresh look

Physical segregation of feeders is very expensive. States like Rajasthan and Haryana have instead tried out "virtual feeder segregation," in which the three-phase power, suitable for commercial and industrial uses, is limited to certain hours, restricting the use of motor pumps. However, these experiments generally did not achieve their intended outcomes. This has been attributed to a range of challenges, including inherent design problems (unbalanced load) and various workarounds adopted by farmers.

A recent study based on a pilot project in Rajasthan proposes and demonstrates a new virtual feeder segregation mechanism where Internet of Things devices attached to transformers control the power supply hours (Jethani et al., 2022). States can integrate these devices into existing transformers and schedule different supply times for agricultural and non-agricultural connections. The costs involved are much lower than physical feeder segregation, and the potential for savings is very large. States can implement PM-KUSUM Component C in mixed feeders as well by segregating feeders virtually.

3.2.2 What Are the Administrative and Regulatory Concerns, and How Can States Mitigate Them?

Administrative and regulatory procedures and compliance often create complications for developers. In the case of decentralized power plants, we identified two critical barriers.

Land-Related Challenges

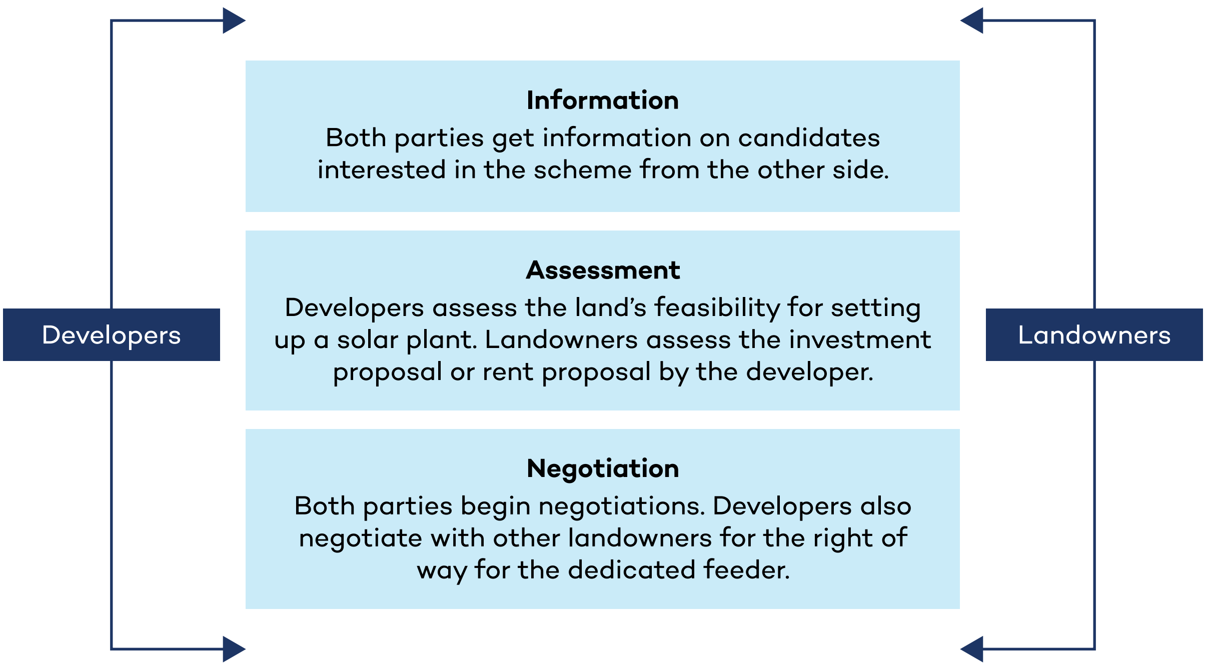
CHALLENGE

To set up a solar power plant, developers need to find suitable land, negotiate with the landowners, get the right of way for dedicated feeders from the solar plant to the substation, and complete administrative formalities for diversion of the land-use status from agriculture to non-agriculture. With the exception of solar parks, where the government facilitates access to land, similar challenges are faced by large utility-scale solar plants. However, on a proportionate (or per MW) basis, the logistical cost of activities mentioned above is much higher for a decentralized solar plant. This is especially true for large players whose business models rely on capacity aggregation.

SOLUTION

Most land-related challenges result from barriers to interaction between developers and landowners. It is part of the investment risk and cannot be wholly done away with. Landowner-developer interaction can be understood at three levels (Figure 8).

Figure 8. Landowner–developer interaction



States can facilitate interactions to varying degrees depending on the capacity and human resources of the state implementing agencies. States' facilitation measures corresponding to these levels are:

Interaction level	Information

Possible Facilitation Measures by the State

The state can act as an intermediary for sharing information between the developers and the landowners. The following measures are recommended in terms of components.

Table 4. Measures to enable information sharing between developers and landowners

For developers	For landowners
Component—A	
• Before tender publishing, states invite applications from landowners interested in participating in the scheme. The application form should contain details of the farmer, land revenue details, contact details, and whether the farmer would like to self-invest or rent out the land. • The state implementation agency shares the consolidated list of interested farmers and other necessary details with the registered developers in the state who are interested in participating in the scheme.	• Before tender publishing, states create a registry of solar developers. • States share the registry with the farmers who have applied for the scheme.
Component—C(FLS)	
• Prior to tender publishing, states invite applications from private landowners willing to rent their lands for the scheme. • DISCOMs assess vacant lands available in their substations. • The DISCOM also engages with other departments to identify vacant government lands suitable for the scheme. • The state shares the consolidated list (including the farmers' list from Component A) with registered developers in the state who are interested in participating in the scheme.	• States announce the scheme and inform the public about registered developers in the state.

Important notes:

- One critical factor for the success of these measures is publicity. For example, Maharashtra ensured wide publicity by branding a distinct initiative (called "Land Bank") and launching it in a ceremony attended by the chief minister. The initiative was highly successful.
- It is also essential to keep the application process very simple for farmers. Only the most important documents should be made mandatory. States can also enlist their Common Service Centre networks to facilitate applications using wide publicity and by fixing definite charges for the service.

Interaction level	Assessment

Possible Facilitation Measures by the State

For developers, assessing the feasibility of the land parcel for setting up power plants can be cumbersome. There are two ways to facilitate this process:

1. **The state does it by itself:** States can use the appropriate part of their administrative services to assess land parcels. DISCOMs can use their field staff for this purpose. Maharashtra took this approach for the MSKVY with much success. In consultations, scheme stakeholders stated that most of the subsequent bids were based on the lands registered in land banks.
2. **Data-based facilitation:** There is ample scope for using geospatial data to conduct at least a preliminary assessment of the land parcels. Many states have completed the computerization of land records, and many others are in the advanced stage of doing so. States can use this data along with the geo-location of substations to develop web applications that filter out feasible land parcels based on the distance to the substations identified for PM-KUSUM (See Box 6). Integrating other relevant geographic information system map layers (such as railway lines and roadways) can further enhance the utility for developers. For example, DISCOM or developers can approach the landowners of the identified parcels to set up power plants.

Box 6. Examples of online tools for solar plant site selection

1. SiteRight: The Nature Conservancy, Vasudha Foundation, Center for Science, Technology, and Policy (CSTEP), and Foundation for Ecological Security have collaborated to create this tool to identify barren lands within a given radius of a substation. They used the geolocation data of substations and the land classification data from the Bhuvan portal[3] to prepare the application. (At the time of writing, the tool is available for seven states, but more will be added in the future).
2. LifeLands: A tool developed by Auroville Consulting that uses satellite imagery, artificial intelligence, and geographic information system mapping to identify degraded/unused lands

Interaction level	Negotiation

Possible Facilitation Measures by the State

Negotiating the right of way for the dedicated feeders can be quite cumbersome and sensitive. States can use their networks, including frontline workers from DISCOMs, revenue departments, and panchayats, to speed up the process. There is not a lot of scope for state facilitation beyond these channels.

[3] Bhuvan is a Geoportal of the Indian Space Research Organization providing services and applications related to satellite remote sensing data for public use.

Restriction in land leasing and land-use regulation

Additional critical land-related challenges are the legal restrictions in leasing land and changing land-use status from agriculture to non-agriculture use. "Land" is a state subject, and hence regulations vary between states. We found two broad categories of restrictions, as follows:

CHALLENGE 1

Procedural difficulties in land-use conversion from agricultural to non-agricultural use: Most states in India have state solar policies, that simplify the procedure for converting the status of agricultural lands in order to accommodate solar plants. Some states, like Rajasthan, exempt solar power projects from the requirement for land conversion, while others, like Andhra Pradesh and Karnataka, immediately confirm the conversion on payment of fees (Kumar & Thapar, 2017). However, actual practice on the ground often varies from the official policy, leading to additional difficulties and cost increases for developers (K Law, 2021; Rahman et al., 2021). There is a need to give more clarity to both developers and field functionaries of land revenue departments.

SOLUTION 1

The main reason for this challenge is that different entities manage the state solar policies and land regulations—usually the state Renewable Energy Development Agencies and the land revenue departments, respectively. Close coordination between the two departments is needed to clarify the land leasing procedures. Specific mechanisms for engagement and coordination are described in Section 4.2.1.

CHALLENGE 2

Restrictions on transfer of land belonging to tribal groups: In many states, there are safeguards for preserving tribal ownership of land, which in some cases includes a ban on leasing tribal-owned lands to non-tribal entities. This can be a major issue in states with a significant share of tribal lands like Madhya Pradesh, Maharashtra, and Chhattisgarh. The solar policies of most states do not explicitly deal with such regulations.

SOLUTION 2

States should explore alternative business models to circumvent land restrictions without compromising the principles for the safeguards. A special purpose vehicle (SPV) model, for example, based on an equity share, is an attractive option. The farmers' share can come in the form of land as well as sweat equity (for farmers' contribution to land development). In this case, there is no need for any land transfer, reducing the legal restrictions. Thapar et al. (2017) estimate that a 5%–7% equity for the farmer is a viable alternative. In Karnataka's Solar Farmer Scheme, this model was successfully implemented. Another example is Kerala's solar policy, which mandates a revenue-sharing arrangement in which the solar plant is developed on tribal lands (Government of Kerala, 2013).

Box 7. Solar Farmer Scheme in Karnataka

Karnataka launched the Solar Farmer Scheme in 2014 based on the Karnataka Solar Policy 2014. Under the scheme, farmers could set up 1–3 MW capacity power plants on their land. The farmers were selected on a first-come-first-serve basis. The tariff was fixed at INR 8.4/kWh (Karnataka Electricity Regulatory Commission, 2017). The total installed capacity under the scheme was 296 MW. The scheme allowed farmers to form SPVs with developers. Attractive tariffs and the SPV model helped the farmers to secure loans and reduced financing challenges. However, the state discontinued the scheme after achieving the initial target (Rahman et al., 2021).

3.2.3 What Are the Challenges Related to Payment Risks and Creditworthiness, and How Can States Overcome Them?

Two critical aspects of financing are timely payment of dues and access to finance.

Payment-Related Challenges

CHALLENGE

Many DISCOMs are financially cash strapped and routinely default on payments to clean energy projects. This affects cash flow and adversely affects business viability. Utility-scale power plants are primarily developed based on PPAs with Central Public Sector Undertakings (CPSUs) like Solar Energy Corporation of India (SECI) and NTPC, which act as intermediaries between the developer and the DISCOM. These CPSUs are beneficiaries of the tripartite agreement between the union government, state government, and the Reserve Bank of India (RBI), on which basis they get paid directly by RBI from the state's account if the DISCOM defaults on payment. For decentralized power plants, the absence of such a mechanism in PM-KUSUM makes it a risky investment for many developers. This is especially true for small and medium-sized enterprises (SMEs), which form the bulk of interested developers in the PM-KUSUM scheme, who cannot absorb such costs, nor do they have the financial wherewithal to take such risks.

SOLUTION

The solution is not in innovation but in enforcement and compliance. States must recognize the unique challenges for developers in PM-KUSUM and prioritize payments to boost investor confidence.

1. **Issue unconditional revolving letters of credit:** A letter of credit (LC) is a mechanism for developers to hedge against payment default risk. Under this mechanism, the DISCOMs provide a revolving LC to the developer; if the payments are delayed, developers can cash them. Although the union government has developed regulations mandating the issuance of unconditional LCs for RE PPAs, these are not enforced in many states. State governments can, however, direct their DISCOMs to issue LCs under PM-KUSUM.
2. **Use CPSUs as intermediaries:** States can also replicate the model of utility-scale power plants for PM-KUSUM, where a CPSU like SECI or NTPC can act as the intermediary. This tried-and-tested system can

Box 8. Partnership with CPSUs

Several states are partnering with CPSUs to support decentralized solar power plants. There are multiple business models for these partnerships. Uttar Pradesh designated SECI as the implementing agency for PM-KUSUM Component C(FLS). As per the agreement, SECI will aggregate the state demand and sign PPAs with developers on behalf of the state's DISCOMs, thus replicating the intermediary model of solar parks. However, there hasn't been much progress with the scheme at the time of writing this guidebook.

Maharashtra partnered with Energy Efficiency Services Limited (EESL) to develop 500 MW under the MSKVY for a mutually agreed tariff (refer to case study). Two other CPSUs—NTPC Vidyut Vyapar Nigam Ltd and Braithwaite & Co. Ltd.—took part in the MSKVY but through the open bidding route.

significantly increase interest in the scheme.

3. **Flexibility in instalment frequency:** Several banks have provided a degree of flexibility to the borrower (the farmer or the developer) in the frequency of paying instalments. There is an option to choose monthly, quarterly, or yearly repayment. Opting for low-frequency repayment can help buffer any delay in payment from DISCOM or reduce working capital issues.

Access to Finance

The cost of finance is the other element that determines a project's viability. We found that the promoters of PM-KUSUM struggled to access affordable financing. The reasons for challenges in affordable funding were different for farmers and developers, and include:

Challenges Related to Loan Access for Farmers Under Component A

CHALLENGE

The main barrier to implementing PM-KUSUM Component A has been farmers' lack of financing options. Typically, banks only provide loans with a minimum of 25% upfront capital from the farmer. The MNRE benchmark capital cost for a 1 MW powerplant is about INR 3.5 crore at the time of writing. The corresponding upfront capital would be INR 87.5 lakh (~ USD 110,000), a huge investment for a farmer. Farmers do not have adequate capital to pay the loan down payment. Moreover, in the initial stages, banks were unwilling to consider agricultural lands as collateral due to the special safeguards for agricultural lands under the laws that govern the auctioning of properties to recover loans, as set out in the Securitisation and Reconstruction of Financial Assets and Enforcement of Securities Interest Act. Although many banks came out with guidelines allowing the use of agricultural lands as collateral, they are not yet widely adopted due to a lack of awareness among local branch and field-level banking officials.

SOLUTION

The main potential measures to overcome these difficulties lie with the banks and RBI, including relaxing lending norms for farmers. Recommendations on lending norms are outside the scope of this guidebook. However, these institutions have taken some critical measures recently that improve access to credit:

1. RBI has advised that loans disbursed by banks toward the PM-KUSUM scheme would be counted toward banks' Priority Sector Lending obligations. This incentivizes banks to approve more loans under the scheme.
2. Several banks, including the State Bank of India (SBI), Canara Bank, Bank of India, Union Bank, and Bank of Baroda, have come out with tailored financial products for PM-KUSUM. These products offer some relaxation of collateral requirements.

Experts from the banking sector suggested the following measures that states could take to mobilize financing.

1. **Building the capacity of bankers:** Although centralized lending guidelines are in place, bank officials are not well-versed in the scheme. State implementing agencies can facilitate awareness programs for bankers through the following steps:
   a. Work with the convener of the state-level banking committee (SLBC) to identify potential financiers for the scheme.
   b. Identify the concerned officials from these institutions to organize workshops on the scheme and share best practices among states, including the potential for convergence with other schemes.
2. **Facilitation and awareness measures for bankers and farmers:** States can work with SLBCs to create model templates for detailed project reports preparation and bank appraisal formats, which could streamline the loan sanctioning process. Further, the state implementing agency (SIA) can prepare short explanatory fliers that can be displayed in bank branches to target farmers detailing the following aspects:
   a. The process flow of the scheme
   b. Role and responsibilities of different agencies/stakeholders at each step
   c. Details on what mandatory clearances are needed for project commissioning (and what are not).
3. **Monitoring of the scheme:** States can work with SLBCs to include the PM-KUSUM scheme as an agenda point in the state and district-level meetings. Representatives from SIAs can review progress and address bankers' questions.
4. **Convergence:** States can explore convergence opportunities with allied schemes that different departments are implementing. For instance, some schemes to promote micro, small, and medium-sized enterprises (MSMEs) offer interest subvention for loans advanced to MSMEs. States can explore the possibility of registering farmers as MSMEs to take advantage of these schemes as has been undertaken in Rajasthan (Box 9). Similarly, states can explore opportunities to access the Agriculture Infrastructure Fund facility for Component A.

Box 9. Convergence of Component A with MSME schemes: Experience from Rajasthan

Rajasthan supported farmers who bid under Component A to access the interest subvention benefits offered under the state-level scheme for MSMEs—the Mukhya Mantri Laghu Udyog Protsahan Yojana. As per the state representative, 47 farmers benefited from this convergence.

Challenges Related to Financing for Developers Under Components A and C(FLS)

CHALLENGE

Concerns about project viability and implementation challenges increase the risk perception of PM-KUSUM for the financing agencies and translate to a higher cost of financing for the developers. Developers are facing a corresponding increase in the cost of finance for projects on account of higher rates of interest. In addition, most of the participating developers are SMEs that do not have the scale or the experience to access cheaper sources of finance.

SOLUTION

States do not have a role in credit access mechanisms and thus cannot directly influence the cost of financing for developers. However, they can play enabling roles in enlarging the finance pool available for SME developers.

1. Allowing joint ventures (JVs) to bid for the scheme: JVs allow firms with complementary strengths to come together. Opening PM-KUSUM projects for JVs would enable SMEs to connect to larger firms with the financial wherewithal or have access to low-cost financing by virtue of their superior credit rating.
2. Explore partnering with bilateral and multilateral development finance institutions (DFIs) to promote the scheme: DFIs have provided financing facilities targeting specific clean energy initiatives in the country. Our conversations with DFIs revealed that PM-KUSUM would be an area of interest for many of them, given its high potential impact on sustainable development goals. States can engage with potential DFI partners to explore special financing facilities for PM-KUSUM. The experience from the commercial and industrial (C&I) rooftop solar segment is very instructive in the kind of financing facilities that states can expect to set up in partnership with DFIs (Box 10).

Box 10. Alternative financing channels—experience from India's rooftop solar sector

The financing challenges faced by the C&I rooftop solar segment in India have some parallels with the PM-KUSUM; the individual projects are small-scale and widely spread out, and the developers participating in the segment are mostly SMEs. These factors increase the cost of financing in both sectors. Various financing agencies, especially DFIs, have supported the investment in the C&I rooftop sector through specialized financing instruments, including:

1. Concessional credit loans: DFIs set up funds to provide low-interest loans for C&I solar rooftop consumers. They partner with a scheduled commercial (domestic) bank to operationalize the funds.
2. Credit enhancement support: Credit enhancement measures are intended to increase the credit profile of a product, in this case, C&I rooftop solar projects. Enhancing credit profiles helps lower interest rates and expand the pool of financing options available. Credit enhancement measures are expected to mobilize funds in many multiples of what is invested as part of the measure itself. Some credit enhancement measures include:
    a. Credit default guarantee funds: The supporting agency establishes a corpus fund that a lender can access in case of a payment default. Default guarantee funds are typically sized as a percentage of the total target loan amount. The presence of default guarantee funds enables the lowering of interest rates and easier access to commercial loans.
    b. Securitization: This is the process of bundling a specific type of project together to create a new product for a loan. In the C&I rooftop segment, it solves the scale issue of individual projects and reduces the transaction cost for financing agencies. This also helps mobilize financing from large players who stay away from the sector due to the small-scale nature of the product.
    c. Technical assistance: Many SMEs are unaware of the various financing options available in the market and the measures they can take to improve their credit profile. Technical assistance is aimed at capacity building of SME enterprises in the C&I rooftop sector.

These instruments are often implemented as a package. For example, some DFIs may mandate securitization of the projects before providing concessional loans. Some examples of such innovative facilities in the C&I rooftop sector include the Rooftop Solar Private Sector Financing Facility supported by the World Bank, the U.S.–India Clean Energy Fund supported by Overseas Private Investment Corporation, and the World Bank–SBI First Loss Reserve facility.

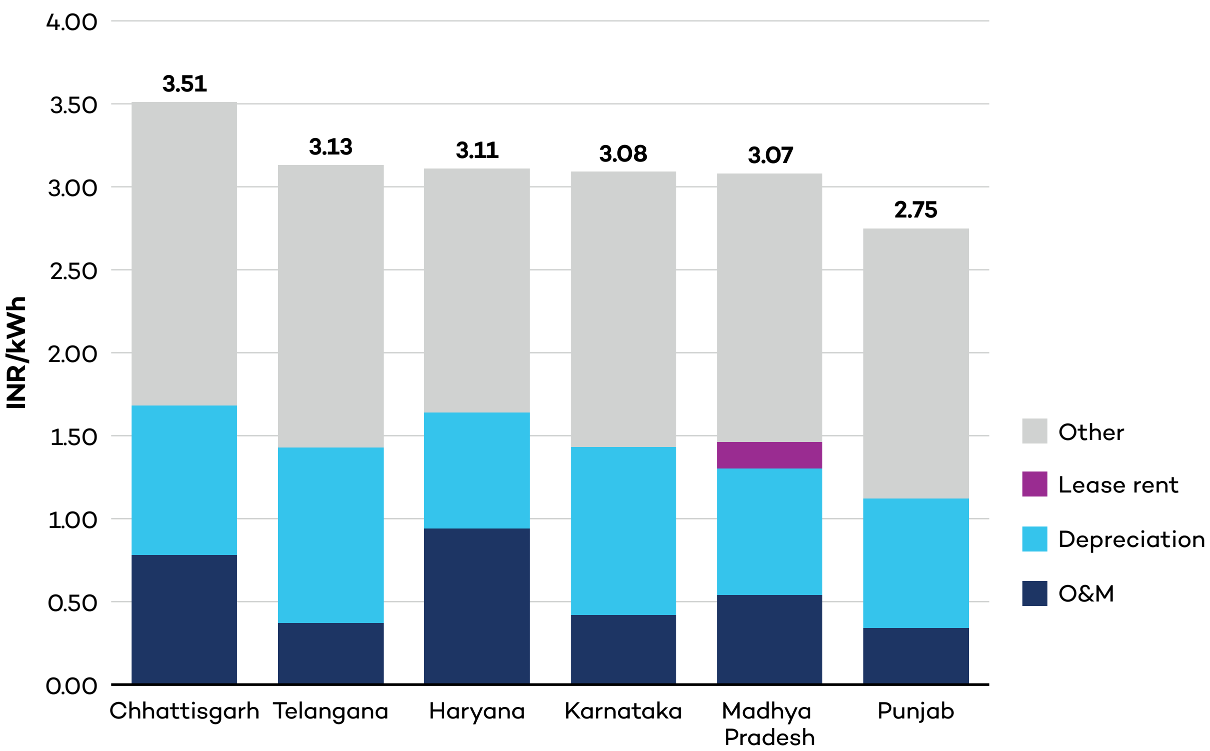
3.3 How Can the States Arrive at an Optimum Tariff?

We have discussed factors that increase the cost of a decentralized solar power plant but can be avoided or mitigated using various measures. However, even in the best-case scenario, the LCOE from a decentralized power plant may be higher than a utility-scale power plant due to its inherent characteristics. Understanding these reasons and setting a viable tariff for the PM-KUSUM scheme is essential to making the scheme financially viable for the developers.

Figure 9 and Table 5 provide a breakdown of the tariff calculations for PM-KUSUM Component A by different states. There are wide variations in the contribution of individual components, which suggests a lack of clarity among policy-makers on the factors contributing to the final tariff.

At the time of writing this guidebook, only two states, Gujarat and Karnataka, have prescribed ceiling tariffs for Component C(FLS). Gujarat's tariff calculation is based on an average of the tariff discovered for other solar projects (outside solar parks) in the previous 6 months. Karnataka's tariff calculation is not publicly available. Hence, we have limited our analysis to Component A.

Figure 9. Ceiling tariff for PM-KUSUM Component A determined by different states



Source: Authors' analysis based on data from SERC orders: Chhattisgarh State Electricity Regulatory Commission, 2021; Haryana Electricity Regulatory Commission, 2019; Karnataka Electricity Regulatory Commission, 2019; Madhya Pradesh Electricity Regulatory Commission, 2021; Punjab State Electricity Regulatory Commission, 2020; Telangana State Electricity Regulatory Commission, 2021.

Note: Other includes interest on term loan, interest on working capital, and return on equity.

Table 5. Key parameters for levelized cost calculation by different states

	Chhattisgarh	Haryana	Karnataka	Madhya Pradesh	Punjab	Rajasthan	Telangana
Year of order	2021–22	2019–20	2019–20	2020–21	2020–21	2019–20	2019–20
Capital cost (INR crore per megawatt peak (MWp))	3.35	3.4	3.4	3.35	3.4	3.4	3.6
Capacity utilization factor (CUF)	19%	20%	19%	21%	21%	20%	19%
Interest rate	9%	10.31%	10.50%	9.53%	9.67%	10.53%	10%
Repayment period (years)	13	10	13	15	15	13	12
Discount rate	9.27%	11.42%	11.55%	8.54%	8.61%	9.42%	11.20%
Operations and maintenance (O&M) expenses (INR lakh per MWp)	7.82	10.5	4.5	7	4.5	4.5	4.5
O&M escalation	5.72%	5.72%	5.72%	3.84%	3.84%	5.85%	4.04%
Land lease rate (INR lakh per MWp)	-	-	-	1.82	-	-	-
Land lease escalation	-	-	-	5%	-	-	-
Final tariff (INR/kWh)	3.51	3.11	3.08	3.07	2.75	3.14	3.13

Source: SERC orders: Chhattisgarh State Electricity Regulatory Commission, 2021; Haryana Electricity Regulatory Commission, 2019; Karnataka Electricity Regulatory Commission, 2019; Madhya Pradesh Electricity Regulatory Commission, 2021; Punjab State Electricity Regulatory Commission, 2020; Telangana State Electricity Regulatory Commission, 2021.

Challenges Related to Tariff Determination

CHALLENGE

There are three main reasons for the increased LCOE from a decentralized solar plant compared to a utility-scale plant.

1. **O&M costs:** O&M costs are not directly proportional to the size of the power plant. A 100 MW power plant will not need 100 times the personnel required for a 1 MW solar plant. As a result, O&M expenditure makes up a higher share of total costs for a decentralized plant. Reviewing tariff calculations by different states revealed a wide variation in O&M cost assumptions. Table 5 summarizes the findings—assumed costs varied between INR 4.5 lakh per MW in Karnataka to INR 10.5 lakh per MW in Haryana. Figure 9 shows the corresponding difference in the O&M contribution to total levelized costs in six states.
2. **Cost of the system:** The lower economies of scale for decentralized solar plants increases the capital cost for system installation. In addition, farmers or SMEs—who are the predominant scheme participants—would have less negotiation power in determining the raw material costs for setting up the power plant compared to a large utility-scale power plant. Hence, there is a need for a clear distinction between benchmark capital costs of solar plants of different scales.

Another key factor is the volatility of module prices internationally in the period following PM-KUSUM's launch. The ceiling tariff is typically determined based on a fixed capital cost parameter and is not linked to market data. However, with high price volatility, the value used in the LCOE calculation may become obsolete quickly. Hence there is a need to link the ceiling tariff to reliable market data. Changes in the Goods and Service Tax and Basic Customs Duty taxes on solar components resulted in a sharp increase in capital costs. However, states have been slow to respond to these changes by making appropriate amendments to the ceiling tariff.

In addition, the land cost in solar parks is usually kept at a nominal rate as most of them are set up on land acquired by the government and transferred to the developer. But this approach cannot be applied to decentralized power plants because the developer has to factor in the cost of land leasing, which is not insignificant. **Madhya Pradesh is the only state that has considered the land lease rate as a component of the LCOE.** Its contribution to the final LCOE in Madhya Pradesh is INR 0.16 per kWh, around 5% of the final tariff (see Figure 9).

3. **Logistical overheads** for a decentralized plant per MW basis are much higher than utility-scale power plants. This would include the challenges in identifying and negotiating land and right of way as described in Section 3.2.2. Even with excellent facilitation from the state, it is bound to take up more time and resources for the developers of decentralized solar plants.

SOLUTIONS

The main solution to this challenge is to refine the LCOE calculations. Figure 9 makes it clear that there is a wide disparity in how the tariff is calculated across the states. This should not be the case for PM-KUSUM because most factors contributing to energy costs are largely the same across the country, except for factors like land rent. **The variation likely emerges because tariff setting is under the jurisdiction of states, and the DISCOM (as the first petitioner) takes the lead.** There are a number of strategies that DISCOMs can pursue to improve accuracy for each parameter:

1. **Prior consultation with stakeholders:** Wide consultations can be organized with local developers, SMEs and market experts to assess the tariff parameters before filing the petition.
2. **Size category-wise tariff:** DISCOMs should create different categories of solar power plants based on sizes and determine tariffs for them separately.
3. **Using data from reliable sources:** DISCOMs can use reliable data sources like PFC or IREDA to create a detailed break-up of capital costs for comments from industry stakeholders. For O&M costs, DISCOMs can use data from the small-scale power plants installed under the Rooftop PV & Small Solar Power Generation Programme (RPSSGP) of the Jawahar Lal Nehru National Solar Mission (JNNSM) scheme in different states.
4. **Proactive measures:** Several policy changes, like GST and basic customs duty, affect the tariff and are announced in advance of their implementation. Non-consideration

of these factors can delay the implementation once the policy is in force. DISCOMs can include these scenarios in the tariff petition in advance.

Another solution is to rethink the approach to tariff design. Tariffs need not be based on an LCOE cost calculation, particularly if DISCOMs discover that actual costs are frequently not well reflected in the LCOE parameters, despite efforts to improve accuracy. DISCOMs can rethink their approach by asking, At what tariff level will the PM-KUSUM scheme benefit the state?

This can be answered by calculating the landed cost of power from a conventional source at the 11 kV substation targeted under the PM-KUSUM scheme. DISCOMs can undertake a study by identifying sample substations and analyzing the cost of power based on the prevailing consumption pattern and the DISCOM's power purchase portfolio. This exercise also benefits states by helping them gain insights into location-specific costs and plan the deployment accordingly under the PM-KUSUM scheme. DISCOMs can make use of existing tools for this exercise (See Box 11). If the discovered cost is higher than the tariff arrived at using the LCOE approach, states can use this difference as a buffer to increase the tariff to make the scheme attractive for developers. The decentralized solar plant model requires additional support to get off the ground. In the initial stages, this can come in the form of increased financial incentives for the developers.

A less scientific but simpler approach would be to take the average power purchase cost and factor in transmission charges and losses at the Central Transmission Unit, State Transmission Unit, and 33 kV levels. However, this would be an approximate calculation and will not give an accurate estimate of the actual costs and benefits of the scheme.

Box 11. Approaches to tariff determination

Experience from MSKVY

One critical factor for the relative success of the MSKVY project was the responsiveness of MERC and agility in tariff setting. Initially, MSEDCL used a comparison with a utility-scale solar power plant to determine the tariff but was also quick to adapt to policy changes and the scheme's progress (See MSKVY case study in Appendix). The MERC also gave sufficient liberty to MSEDCL to revise the tariff based on proper due diligence.

Online tools for analysis of potential benefits

Auroville Consulting has developed an online tool called Solva for conducting feeder-level power flow analysis for distributed solar power and evaluating their network benefits for DISCOM. States can use this approach to rethink their ceiling tariff.

Section Summary

Financing is linked with different aspects of the scheme's design and implementation, and any risks and opportunities affecting the scheme are reflected in the ease of financing. Hence, this section uses financing as an anchor to investigate challenges toward investment in the scheme and recommend measures to overcome them.

Financing remains the biggest challenge to the scheme's success. There are two ways to boost investment.

1. By reducing the risk perception of the scheme
2. By Increasing tariffs to make returns more attractive to the farmer/developer.

Three key concerns lead to a higher risk perception of the scheme among developers. Some proposed solutions that states can adopt to address these concerns are in Table 6.

Table 6. Key concerns on distributed solar power plants and proposed solutions to mitigate them

Concerns	Solutions
Concerns about poor grid infrastructure	
Developers suggest that the safeguards recommended in the PM-KUSUM guidelines for grid availability do not fully allay their concerns about the likelihood of outages due to the poor state of rural feeder infrastructure.	• Incorporating "deemed generation clauses" into the power purchase agreements. • Undertaking grid upgrading at the distribution level, potentially through convergence with the Revamped Reforms-based and Results-linked Distribution Sector Scheme. • Although Component C (FLS) mainly targets segregated feeders, states can opt for virtual feeder segregation in places where physical segregation doesn't make economic sense.
Concerns arising due to operational and regulatory costs	

Developers face a challenge in identifying and leasing affordable land for setting up a solar plant and the transmission and evacuation infrastructure.
Another key challenge is related to land revenue regulations, including the timely application of land-use regulations restricting land transfer in certain conditions.
	• Facilitating interactions between potential developers and landowners. This facilitation can happen at three levels:
	  • Identifying interested farmers by initiating a registry of landowners interested in the scheme—a so-called "land bank"—and connecting them with developers
	  • Supporting developers to assess the suitability of different lands using the DISCOMs' field staff and data-based facilitation.
	  • Supporting negotiations with landowners, especially for the right of way of transmission lines and evacuation bay.
	• Enabling close coordination with the land revenue department to address land-regulation concerns.
	• Promoting alternative ownership models like special purpose vehicles wherever land leasing is restricted.

Concerns	Solutions
Concerns arising due to payment risks and poor creditworthiness of developers	
Two key challenges concerning financing are the timely payment of dues and access to finance. DISCOMs' poor track record in making timely payments necessitates the creation of safeguards by states for timely payment. Access to credit from financial institutions is a challenge due to the low capacity of farmers to provide upfront capital and the poor creditworthiness of developers.	• Issuing letters of credit or state guarantees to allay payment concerns. • Exploring the possibility of bringing in central public sector units as intermediaries, which has been a successful model in the utility-scale solar segment. • Exploring alternative financing channels in partnership with development finance institutions. • Allowing joint ventures can also help interested parties with complementary strengths come together. • Enabling close coordination with banking officials, state-level banking committees, and developers to raise awareness, support bankers' training, and simplify procedures in accessing finance. • Explore convergence opportunities in financing with other schemes, including micro, small, and medium enterprises schemes and the Agriculture Infrastructure Fund.

Setting a tariff commensurate to the risks and efforts undertaken by developers is critical for the viability of the decentralized solar plant model. An analysis of the tariff adopted in different states indicates that there are a few critical issues in the process of setting a tariff. Three key aspects emerged as reasons for an unviable tariff set in many states, which led to limited developer interest:

1. The O&M costs of a small-scale power plant are much higher per MW than a grid-scale plant.
2. The actual capital cost reported during our interviews and other sources is higher than the assumptions used by most SERCs.
3. The logistical overheads of establishing a solar plant, such as land identification and negotiation, add to the cost but aren't properly integrated into the tariff.

States can either refine their tariff calculations or make them more responsive to market variations. States can also look for alternative tariff-setting options, including comparison with the present landed cost of power.

Further Guidance and Resources

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4.0
Implementation Design and Coordination

4.1 Why Do Design and Coordination Matter for Implementation?

The deployment of decentralized solar power plants poses unique challenges. Impacts are spread over multiple sectors like power, agriculture and land revenue. Managing them requires concerted actions from all these sectors. In consultations, however, stakeholders were unanimous that sharing responsibilities between multiple agencies will slow down progress in schemes like PM-KUSUM. In attempting to find the right balance, this section will address the following questions:

- What roles should the state implementing agencies take?
- What strategies are needed to maximize the outcome?
- How can other departments and agencies support implementation?

4.2 What Roles Should the State Implementing Agency Play?

State implementing agencies must do most of the heavy lifting to get schemes going. We identified the following critical functions for the SIA.

4.2.1 Facilitate Information Exchange

The novelty of decentralized solar power plants demands the very active engagement of the SIA with all the stakeholders.

With Other Departments and Agencies

In our consultations, stakeholders from outside the power sector, including different departments relevant to the WEF nexus and bankers, were typically unaware of the PM-KUSUM scheme and its components

on decentralized solar power plants. Equally, we learned of several instances in which implementing agencies only become aware of key information held by non-power-sector stakeholders at a very late stage. Hence, two-way knowledge exchange is needed in the design phase and around subsequent coordination. For knowledge exchange, the SIA is recommended to organize an inception workshop with a number of departments or agencies, as elaborated in Table 7.

Table 7. Recommended departments for inclusion in an inception workshop

Coordination measures to address land-related concerns and facilitate farmers in the scheme

Component A: Strongly relevant
Component C(FLS): Relevant if the state plans to target farmers' land under this component

Departments/ agencies	Key information to be shared with the department	Key information to be collected from the department
Land revenue department	• The opportunity for farmers to use their lands for setting up power plants • Different business models of ownership	• Regulations concerning land leasing and land-use conversion • Laws concerning scheduled areas or Tribal areas and business models suitable in those areas • Scope of expediting the land-related procedures through better coordination • Scope of using unused government lands for Component C(FLS)
State-level bankers Committee	• The opportunities in the scheme and the need for financing farmers	• Bank guidelines regarding the scheme • Avenues for continuous engagement and organizing training for the bank staff • Issues faced in the timely disbursement of loans
Gram Panchayat	• The opportunity for farmers to use their lands for setting up power plants • Different business models of ownership	• Avenues for engagement with farmers

Coordination measures to address WEF concerns

Component A: Relevant if the state plans to target agriculture feeders
Component C(FLS): Strongly relevant

Departments/ agencies	Key information to be shared with the department	Key information to be collected from the department
Agriculture/ horticulture department	• Initial plans on the scheme's geographic focus • Changes in the power supply to farmers due to the scheme • Scope of direct incentives in the scheme for water conservation	• Feedback on existing plans for geographic focus • General situation of irrigation practices in the state in the target feeders • Areas where the quality of power is poor • Likelihood of farmers shifting to more water-intensive crops due to the scheme • Scope of converging with the departments' schemes on water-saving practices
Irrigation department/ groundwater agency	• Changes in the power supply to farmers due to the scheme • Scope of direct incentives in the scheme for water conservation	• General situation of groundwater use in the state • Areas already facing groundwater stress that requires special attention • Scope of initiating a targeted long-term assessment of the impact on groundwater using existing and new monitoring wells • Scope of including the direct incentives under the Atal Bhujal Yojana's (in districts it is operational) Disbursement Linked Indicators
Farmer-focused non-governmental organizations	• Changes in the power supply to farmers due to the scheme • Scope of direct incentives in the scheme for water conservation	• General situation of irrigation practices in the state • Areas where the quality of power is poor • Likelihood of farmers shifting to more water-intensive crops due to the scheme • Scope of converging with the departments' schemes on water-saving practices

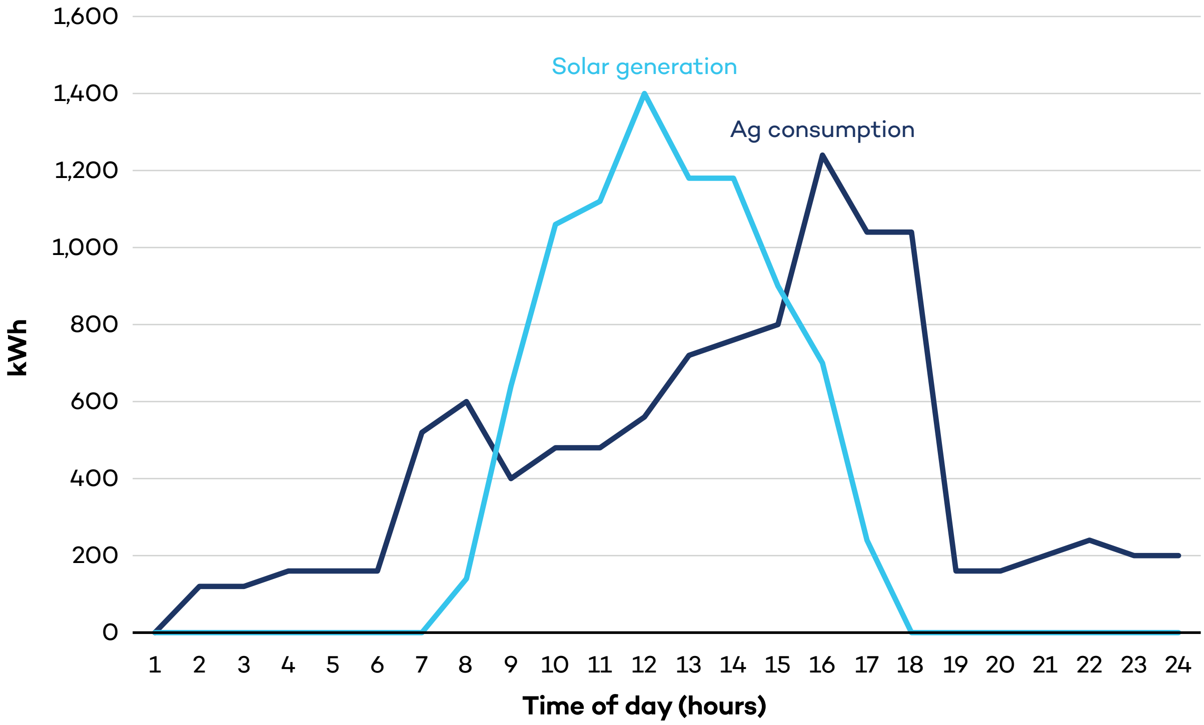
With Developers

The importance of engagement with developers is explained in the previous section. State implementing agencies should appraise them about the scheme and get information concerning tariffs and other operational concerns.

4.2.2 Undertake Infrastructure Planning

The optimal outcome from PM-KUSUM is only possible if it is complemented by good infrastructure planning. To illustrate the need for good planning, Figure 10 reproduces an analysis by Padole et al. (2022), who examined the power flow characteristics of a pilot solarized feeder in Maharashtra under the MSKVY scheme. It compares a typical day of power consumption and power generation in the feeder by the decentralized solar plant.[4] Net consumption and net generation are almost equal on that particular day, but the daily profile of the two varies significantly. As a result, power is imported at peak times and exported when there is a surplus. If surplus power is not consumed by some other feeder within the substation, some of the benefits from solarization are negated because power will flow upstream, causing transmission losses and congestion.

Figure 10. Agricultural consumption and solar generation profiles from a solarized agriculture feeder



Source: Image reproduced from Padole et al., 2022.

[4] It is worth noting that the power supply in this particular feeder is not restricted to 8 hours, but that is not the case with all the feeders in Maharashtra. Further, this feeder data need not necessarily represent the consumption pattern in all the agricultural feeders and throughout the year. We are using this data only for illustrative purposes.

Three questions are of importance in this context:

1. What feeders are most suitable for solarizing through decentralized solar power plants?
2. How can states decide the optimum capacity of the power plants?
3. What complementary activities are needed to maximize the output from PM-KUSUM?

Which Feeders Are Most Suitable for Solarizing Through Decentralized Plants? Component C(FLS)

The two main objectives of PM-KUSUM—improving power supply to farmers and reducing the state subsidy—can help guide feeder selection. To meet these objectives, implementing agencies can consider prioritizing feeders by applying the following three criteria. These criteria are not ranked, and states need to decide which of them apply to their specific contexts and to what extent. The data required to evaluate them are available with DISCOMs, who can use a simple ranking system to prepare the priority list of feeders.

1. **Substations with significant agricultural load:** This helps the scheme meet its objective of reducing subsidy, as savings will be the highest for solar plants catering to the largest possible load. Further, if the higher load is caused by a large number of consumers connected to the feeder, it will benefit more farmers.
2. **Substations with significant non-agriculture category load during daytime:** Agriculture load demand has high intra-day and intra-year fluctuation, which, as noted above, can reduce benefits due to instances where demand and supply are not well matched. Non-agriculture loads in the daytime, in addition to the agricultural load, are likely to help smooth out the peaks and troughs.
3. **Substations with poor power quality and unreliable power supply:** This helps the scheme meet its objective of assisting farmers who suffer from unreliable and poor power quality. However, this requires states to undertake investment in upgrading the distribution infrastructure. States can accomplish this by blending the scheme with RDSS (See Box 4).

How Can States Decide the Optimum Capacity of the Power Plants?

States need to consider two factors in sizing the power plant:

1. Central financial assistance for a solar power plant under Component C(FLS) is based on certain conditions laid out by MNRE (see Box 12). States can go beyond this size but will not receive assistance for the additional capacity. Further, the capacity calculated in this way may not necessarily be optimal for the substation.
2. For both Component A and C(FLS), the plant should be optimized for consumption in the substation. Optimizing the solar plant for energy demand within the substation requires a modelling and simulation exercise using standard solar PV design software. Such software can optimize the power plant for the load

curve within the substation. CSTEP conducted such an exercise for the Bangalore Electricity Supply Company in Karnataka, which can act as a template for other states (CSTEP, 2019). The key input parameter for modelling is the projected annual load curve. It is adjusted for the shift in power supply to daytime.

Box 12. Eligibility for central financial assistance under Component C(FLS)

PM-KUSUM guidelines describe a multistep process for computing the power plant size for central financial assistance eligibility under Component C(FLS). At the time of publishing this guidebook, as set out in MNRE (2021), the process is as follows:

1. Identify the load eligible for central financial assistance.
    a. Only agricultural connections are considered.
    b. The pump size is capped at 7.5 horsepower (HP). All pumps with a capacity of 7.5 HP or less are considered in full. For higher-capacity pumps, a capacity value of 7.5 HP is used for the calculation.
2. Calculate the annual energy demand corresponding to the eligible load.
    a. The average of the last three-year consumption is considered the annual load.
    b. If all or some of the pumps in the feeder are metered, the meter data can be used to extrapolate to the total eligible load in the feeder.
    c. If no pumps are metered, but the feeder meter data is available, it can be considered by calculating the proportional consumption of the eligible load.
    d. If none of the above is available, use the indexation provided by the State Energy Regulatory Commission.
3. Calculate the plant size corresponding to the annual energy demand.
    a. Use the following formula to arrive at the power plant size.

$$\textit{Power plant size (kW)} = \frac{\textit{Annual energy demand (kWh)}}{24 \times 365 \times \textit{Capacity utilisation factor (CUF)}}$$

    b. CUF can be arrived at based on the insolation of the locality, or 19%, whichever is higher.

States have the option to increase the size of the power plant beyond the size calculated above, but the central financial assistance will be limited to the capacity calculated in the above manner.

What Complementary Activities Are Needed to Maximize the Output From PM-KUSUM?

PM-KUSUM is a supply-side intervention—it can reduce the cost of power purchases. However, the main challenge for DISCOMs is the distribution infrastructure. In consultations to prepare this guidebook, many stakeholders emphasized the importance of embedding PM-KUSUM in broader strategies for reforming distribution infrastructure. In particular, states can leverage the recently launched RDSS for infrastructure upgrades. The steps required for targeted infrastructure upgrades and to reduce administrative costs have been explained in Section 3.2.1, so they are not repeated again here. Instead, we focus on linkages with energy and water efficiency measures.

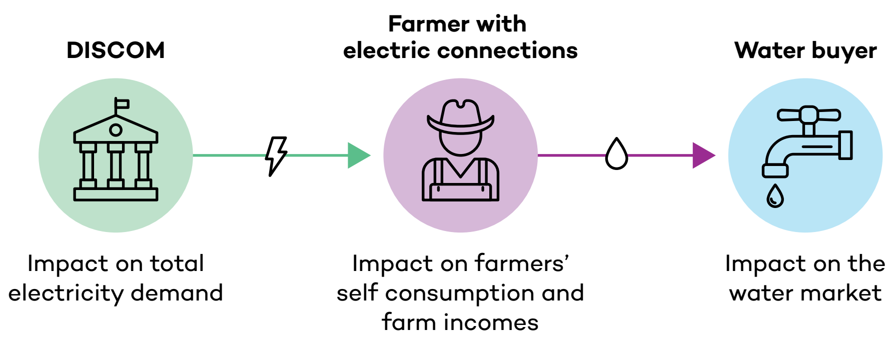
4.2.3 Promote Linkages to Energy and Water Efficiency Measures

In Section 2.5.2, we discussed how increased access to electricity might lead to increased consumption and groundwater use in certain situations. Thus, linking the PM-KUSUM with water and energy efficiency policies can be highly desirable, depending on the state context. While designing these linkages, states need to consider their impact on three key stakeholders, as illustrated in Figure 11: DISCOMs, farmers, and water buyers.

Direct Cash Incentives for Energy Conservation

The mechanism of a direct cash incentive for a reduction in electricity consumption, proposed in the PM-KUSUM guidelines, was explained in Section 1. It is proposed as a more politically feasible substitute for metered pricing of agricultural connections. For the beneficiary farmer, it is an opportunity to improve income. It does not affect their irrigation cost if they choose not to participate. However, water buyers may be affected negatively, as the water price will likely increase. Pump owners will now have an alternative option for the surplus energy and will not be willing to sell water unless it matches the income they would receive from saving electricity. Studies of past interventions that involved a change in the cost of power or the supply hours show that water buyers are disadvantaged if prices increase or supply hours reduce (see Box 13).

Figure 11. WEF linkages of feeder solarization



Box 13. How changing power supply affects water buyers: Lessons from West Bengal and Gujarat

West Bengal implemented mandatory metering of agriculture connections and conversion of billing from a flat rate to a pro-rata regime in 2000. Studies have shown that this severely affected once-fledgling informal water markets, with impacts on many small and marginal farmers who depended on them for their irrigation needs (Mukherji et al., 2009). Similarly, in Gujarat, the impact assessment of Jyoti Gram Yojana, under which agriculture feeders were separated and power supply restricted to eight hours, showed that the water market prices increased steeply as the hours of available power were reduced (Shah et al., 2008).

The direct incentive scheme is not yet widely tested, so proposing specific policy decisions in different agroeconomic contexts is challenging. However, based on interviews and a study of relevant literature, we can set out several broad principles. Two critical factors need to be considered: irrigation access and long-term groundwater use sustainability. We have also assumed that cost-reflective electricity pricing is not feasible in this context. Figure 12 sets out a decision tree identifying how different combinations of these factors can lead to different recommended actions.

Promoting Energy and Water Efficiency

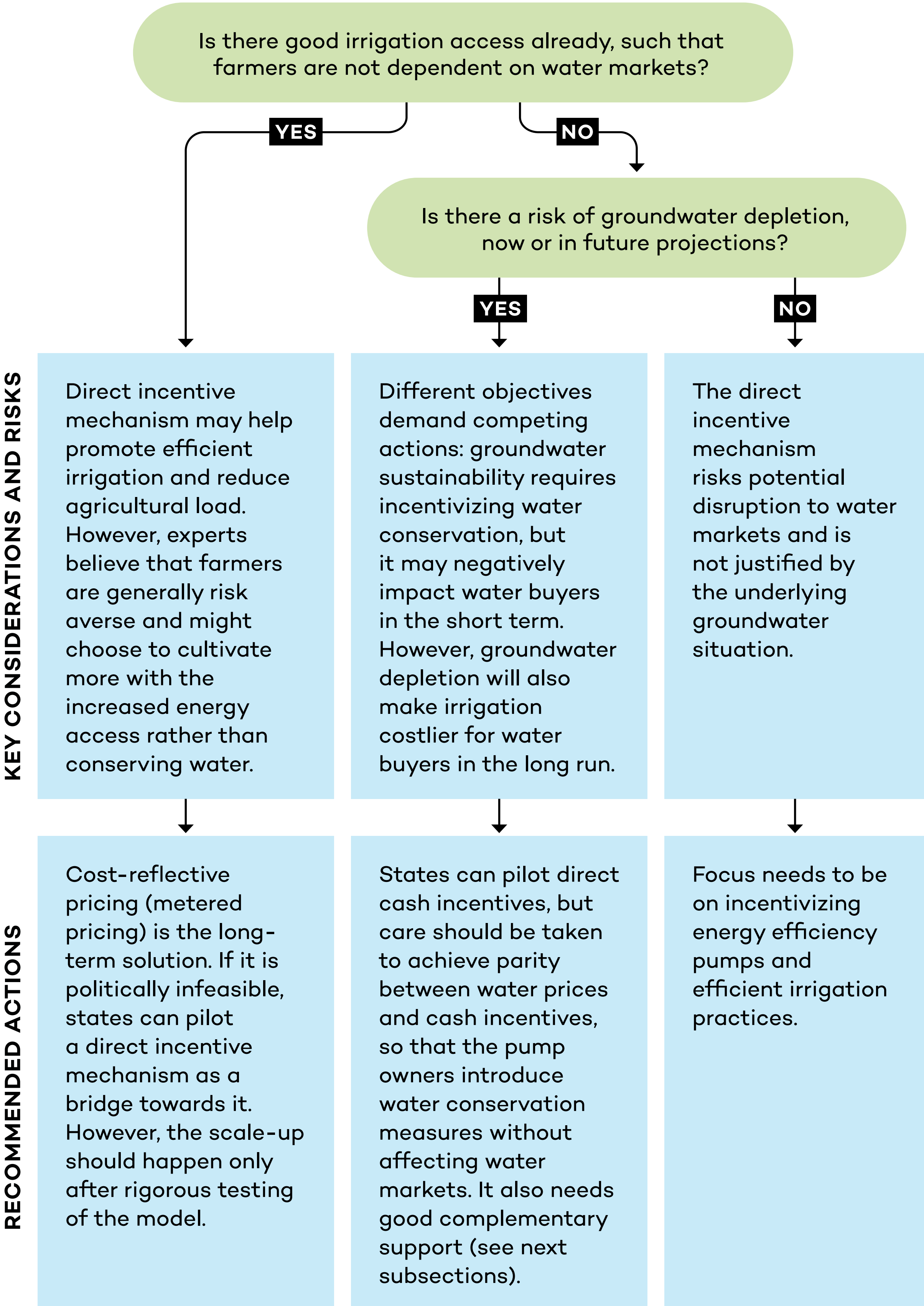
It is unlikely that farmers will change their cropping patterns solely because of the direct incentive. Interviews with implementing officials of the PBPK initiative reaffirm this with a lack of crop diversification undertaken by participating farmers in Punjab. A modelling study suggests that even when farmers can earn more income by shifting to less-water-consuming crops and conserving energy use, various other factors like the minimum support price for a particular crop or value chains for the current crop make it difficult for a transition to happen (Srinivasan & Neelakantan, 2022). Any potential improvement in water efficiency will most likely be driven by adopting better irrigation practices or energy-efficient devices. In the absence of a wider strategy for influencing cropping choices, states should focus on efforts to promote, first, energy-efficient pumps and, second, more water-efficient irrigation, as detailed below.

1. Energy-efficient pump replacement and capacitor bank installation

Many irrigation pumps across India have very low levels of efficiency. Studies estimate potential energy savings of 30-40% by shifting to more efficient pumps (Bureau of Energy Efficiency, 2019; Khobaragade et al., 2021). This means that replacing pumps in target feeders under PM-KUSUM can significantly decrease the total load and, correspondingly, the required size of the solar plants. This is predominantly a benefit for the state and the DISCOM. It is unlikely to affect farmers with electric pumps and water buyers significantly.

Another low-cost strategy for improving energy efficiency is to encourage the installation of shunt capacitors at the motors of irrigation pump sets. This is an inexpensive solution and is considered a low-hanging fruit to improve efficiency. However, a key challenge is that it is effective only

Figure 12. Decision tree—When to explore direct incentive schemes for energy and water conservation



when a majority of the farmers in a feeder adopt it, and hence it requires a coordinated outreach strategy from the DISCOM (Sagebiel et al., 2016). If only one farmer installs the capacitor, equipment damage quite often increases.

CHALLENGE

The main challenge in pump replacement is financing. Without an incentive to lower usage due to a flat rate tariff regime, farmers will not be willing to pay for replacements. A widely used financing model is the Energy Service Company (ESCO) model, where a third-party service provider undertakes the pump replacement in a feeder on behalf of the DISCOM. The DISCOM repays the service provider based on the estimated energy savings. The main drawback, however, is that the farmers do not have much incentive to maintain the pumps properly and, in many cases, implement practices such as bypassing capacitors to counter poor power quality. Further, due to non-standard accessories, such as piping and wires, the improved efficiency quickly deteriorates, reducing the benefit for DISCOM (Khobaragade et al., 2021). In sum, the farmers' lack of incentives makes the financing model challenging.

SOLUTION

In the absence of pro-rata pricing of electricity, the direct incentive mechanism mentioned above could offer a potential solution. States could achieve sustainable energy efficiency improvements by combining the ESCO model with direct incentives. DISCOMs can bundle the pump replacement with the power plant installation or outsource it to a separate service provider. This model is yet to be widely tested, so states may wish to undertake pilot studies before scaling it up.

Box 14. CESL-Goa partnership: Pump replacement included in the tariff

Convergence Energy Services Limited (CESL) has partnered with the state of Goa to implement a unique model under PM-KUSUM, where they will undertake both the solarization of a feeder and the replacement of all pumps in the feeder with energy-efficient pumps ("CESL to implement," 2021). The tariff decided for the project covers both costs. In our interviews, an official from CESL mentioned that this tariff is lower than the average power purchase cost. Thus, the DISCOM can implement demand-side management without having to bear the cost upfront.

2. Water-efficient practices

One way to reduce water and energy requirements is to improve irrigation efficiency. Irrigation efficiency can be improved primarily in two ways:

1. **Technologies:** Micro-irrigation technologies like drip and sprinkler irrigation can improve irrigation efficiency. However, they require high capital investment and are unsuitable for some crops. Schemes like Pradhan Mantri Krishi Sinchayee Yojana and Atal Bhujal Yojana have provisions for subsidizing micro-irrigation technologies. State implementing agencies can work with the respective departments to explore the possibility of targeting the schemes in the feeder areas selected for PM-KUSUM.
2. **Techniques:** Knowledge institutions in agriculture have developed and documented water-saving techniques for different crops across the country. These practices mostly do not require significant upfront investment and rely on farmers' technical capacity. For example, raised bed irrigation, alternative wet and dry irrigation, and tensiometer-based irrigation are some methods that can be used to save water (Surendran et al., 2021; Vatta et al., 2018). New technologies also typically require some degree of training in technique to ensure that they are used and maintained properly.

CHALLENGE

One key challenge in adopting water-efficient practices has been the lack of incentive to conserve water. It also requires extensive capacity-building exercises to bring behavioural changes to farmers.

SOLUTION

If the direct incentive mechanism shows promising results in pilots, there is an opportunity for coordination between different departments. Lack of proper engagement with farmers has been one of the main challenges faced by DISCOMs in demand-side management, and lack of incentives for the farmer has been one of the main challenges for agencies like agriculture and groundwater departments to promote water-saving schemes. Different departments can leverage each others' strengths and plan for a holistic intervention by combining a direct incentive mechanism with water-saving techniques. For this to occur, the following steps should be taken:

1. The feeders for PM-KUSUM should be decided in concurrence with other departments.
2. The agriculture department should take the lead on outreach to farmers.
3. Agriculture knowledge institutions like agriculture universities and Krishi Vigyan Kendras (KVKs) can play a central role in organizing capacity-building workshops.

Box 15. Effective coordination structures for water conservation: Experience from PBPK in Punjab

The MGSIPA (n.d.) has examined the experiences with the PBPK scheme on water incentives in Punjab in some detail. The study finds that the scheme created a multilayered institutional structure with mechanisms for interagency coordination, as well as vertical coordination between senior bureaucrats and field-level officials. The study also found that regular oversight of the chief minister provided strong political backing and empowered officials to make decisions.

The scheme's implementation relied on input from multiple departments and representatives of agricultural universities and farmers' commissions. Officials from the state DISCOM, however, highlighted that despite an initial positive response, support from other departments eventually tapered off due to competing priorities during the COVID-19 pandemic. This demonstrates the difficulty of maintaining continuous engagement across many departments during the scale-up of any scheme in the absence of incentives for coordination.

A three-tier monitoring and implementing structure was set up for the PBPK scheme's implementation, including:

1. **A state-level steering committee:** This was chaired by the chief secretary, with the secretary of power as the convenor. The committee included the following members: secretaries from the departments of agriculture, planning and finance, and water resources; the chairman and managing director of PSPCL (the DISCOM); vice-chancellor of Punjab Agriculture University; and the chair of the Farmers' Commission. The primary role of this committee was to monitor the scheme's progress and make policy-level decisions.
2. **District-level implementing committee:** This committee was chaired by the deputy commissioner of the district, with the superintending engineer of PSPCL as the convenor. The district heads of agriculture and soil conservation are members of this committee. It focused on the scheme implementation and sharing feedback with the state-level committee on issues faced by farmers.
3. **Field-level implementation committee:** This committee was chaired by the sub-divisional officer with the executive engineer of PSPCL as its convenor. The assistant divisional officer (agriculture), sub-divisional officer (water resources) and heads of KVKs were its members.

4.3 How Can Other Departments and Agencies Support Implementation?

Support from other departments and agencies can significantly improve the outcome of the PM-KUSUM scheme. In addition to information sharing, proactive participation from these actors can boost implementation. The degree of participation required varies and depends on the scheme design.

Table 8. Relevant agencies and their supporting roles

Department or agency	Functions
Land Revenue Department	• **Information sharing:** Share clear information on procedures for land-use conversion of agricultural lands for solar power and restrictions in land leasing. • **Facilitation of land-use conversion and leasing:** Land-related procedures for Component A happen at the district or taluk level, requiring information and support for field officers. The department can designate a state-level officer to coordinate field officers in liaison with the SIA; and to link farmers and developers to the department to help address grievances. • **Supporting a land aggregation initiative:** If the SIA plans such an initiative (see Section 2), the department can help assess lands and speed up approvals. • **Supporting data-based solutions:** The department can explore integration with digital land records if the SIA plans IT-based solutions to land challenges.
SLBC	• **Information sharing:** Share information on bank guidelines and procedures for farmers to obtain loans. • **Monitoring of loan sanctioning:** SLBC meetings typically occur once every 3 months. The SIA can use this platform to monitor progress in loan sanctioning and identify and resolve bottlenecks in the appraisal and sanctioning process. • **Training and capacity building:** SLBCs can organize training sessions for zonal loan sanctioning committees on PM-KUSUM scheme Component A.
Agriculture Department	• **Information sharing:** Supporting feeder selection by providing ground-level information on power supply situation and irrigation practices. • **Outreach with farmers:** Feeder solarization and direct incentive mechanisms require intense outreach activities with farmers. The agriculture department has the most reliable grassroots network and can support outreach. • **Training, capacity building, and scheme convergence:** There is great scope for convergence between schemes on water efficiency and the direct incentive mechanism. The agriculture department can plan to target such schemes to farmers in PM-KUSUM feeders. The knowledge institutions associated with the department, like agriculture universities and KVK, can also support in conducting training and capacity building of farmers on techniques.

Department or agency	Functions
Groundwater Department	• **Information sharing:** Supporting feeder selection by giving ground-level information on groundwater. • **Long-term impact study:** The impact of solarization on groundwater is not yet studied at scale. The department can initiate monitoring in the target feeders to generate learning for future policy-making. • **Scheme convergence:** There is great scope for converging schemes like Atal Bhujal Yojana, which the department implements with the PM-KUSUM scheme. The department can take the initiative in this regard.

4.3.1 What Are the Mechanisms for Coordination Between Departments?

Well-defined mechanisms can help sustain coordination between departments. In our interviews, stakeholders from all departments agreed on the need for coordination. However, they also highlighted the challenge of sustaining engagement. When there is no proper sharing of responsibilities and channels of communication, coordination can fizzle out and lead to delays in implementation.

Our previous guidebook on solar pumps highlighted four mechanisms of coordination between water–energy–food schemes. We recommend the same mechanisms for Components A and C.

1. **Interdepartmental bodies:** This is a dedicated working unit comprising officials from all concerned departments that will act as the SIA. The unit would be headed by a secretary or joint-secretary level official from the energy department to expedite decision making, facilitate timely approvals, and gain the necessary support from other departments and financial institutions. The officials from different departments and agencies would typically be involved in executive functions and scheme implementation.
2. **Convergence and steering committees:** This is a lighter option than dedicated working interdepartmental bodies. The committees typically include senior officials from different departments and are convened monthly or quarterly to monitor scheme progress, discuss challenges, and take decisions on the next actions. In this case, the SIA remains a separate entity. The steering committee monitors and advises the SIA.
3. **Delegation of planning and implementation responsibilities to different departments:** This model focuses on establishing clearly defined responsibilities for departments, drawing from their strengths. Coordination and time-bound implementation can be facilitated by developing a dashboard for tracking progress on tasks that is visible to all stakeholders.
4. **Partnerships with financial institutions:** Partnership with financial institutions is critical for enabling loan access for both farmers (Component A) and the state (Component C). In most states where Component A has progressed, the state has formed a close partnership with one or two scheduled commercial banks to extend loans to farmers. Similarly, scaling up Component C(FLS) requires adequate financing for DISCOMs to improve their distribution infrastructure. This can be achieved through partnerships with institutions such as the National Bank for Agriculture and Rural Development and the PFC.

Section Summary

Decentralized solar power plants impact multiple sectors like power, agriculture, and water. Hence, a well-thought-out implementation design plan is needed for states to maximize the scheme's outcomes, with input and participation from all relevant departments.

Participation of all concerned departments is desirable, but sharing responsibilities equally between multiple departments can slow implementation. Hence, there needs to be a proper balance for optimal coordination. The SIA is responsible for implementation and must ensure coordination with other departments.

Role of the State Implementing Agency

1. **Facilitating information exchange**

   Our consultations suggest that many non-implementing state departments are unaware of the scheme due to its newness. In facilitating information exchange with these departments, the SIA will also gain important information on land-use change regulations, the local groundwater situation, and geographical areas for other schemes. It is recommended that SIAs organize an inception workshop and subsequent coordination meetings with agriculture and land revenue departments, groundwater agencies, and SLBCs. An indicative list of key information to be shared and collected is provided in Table 7 of Section 4.

2. **Undertaking infrastructure planning**

   To maximize the scheme's outcomes, the SIA should:

   - Identify the most suitable feeders for the scheme
   - Decide the optimum capacity of the plants
   - Support the scheme with complementary activities to strengthen the grid.

   To maximize the economic outcomes, the SIA should select substations with a high agriculture load and a significant non-agriculture load to prevent the upstream flow of power in the non-irrigation season. Targeting substations with poor-quality power may increase the scheme's social outcomes through improved power quality for farmers. MNRE has issued sizing guidelines for the upper limit of solar plants eligible for CFA. SIAs are recommended to conduct a base load analysis at a substation level and optimize plant size to reduce upstream flow in the non-irrigation season.

3. **Promoting linkages to energy and water efficiency**

   Linking PM-KUSUM with water and energy efficiency policies is highly desirable. But states need to consider the impact of a policy on three stakeholders—the DISCOM, farmers with electricity connections, and farmers depending on water markets.

Promoting Energy and Water Efficiency

States need to select and identify the right set of measures. The impacts of some of these measures are well established, and others require pilot testing before scaling up. In locations where direct cash incentives can work and are desirable, states can use them as a tool to incentivize energy and water efficiency.

Figure 13. Measures to increase efficiency and suitability in specific contexts

Proven measures for increasing efficiency	Measures suitable in certain contexts
Energy-efficient pump replacement: Studies show potential savings of 30%–40% energy through pump replacement. However, a lack of incentives to maintain the pump effiency quickly leads to deterioration in a few years. **Capacitor bank installation:** Installation of capacitor banks at the load end (i.e., with the motor) significantly improves the power factor. However, a key challenge is that it is effective only when most farmers in a feeder adopt it and hence need a coordinated approach from the DISCOM. **Water-efficient practices:** Water-efficient irrigation technologies and techniques can significantly save water and energy. However, the absence of incentives and need for capacity building make it challenging to implement at a wider scale.	**Direct incentive mechanism:** The direct incentive mechanism under PM-KUSUM may help reduce electricity and water consumption in specific contexts but may also increase the water market rates and disadvantage water buyers. The net financial benefit or cost of implementing direct incentives for states requires further analysis. A decision tree on whether to explore the direct incentive mechanism or not is provided in Figure 12.

Support from other departments can significantly enhance the scheme's implementation. The functions of different agencies are provided in Table 8 of Section 4.

Further Guidance and Resources

Goel, S., Murali, R., Rahman, A., Swain, P., Viswanathan, B., Agrawal, S., Beaton, C., Govindan, M., Jain, A., & Debajit Palit. (2021). *Implementing solar irrigation sustainably: A guidebook for state policymakers on maximizing the social and environmental benefits from solar pump schemes.* International Institute for Sustainable Development. https://www.iisd.org/publications/implementing-solar-irrigation-sustainably

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5.0 Learning By Doing

5.1 Why Is It Important to Adapt By Learning?

When deployed effectively, decentralized solar plants can help states reap the economic, social, and environmental benefits of solar irrigation. However, achieving all of this is complicated. Many implementation challenges can emerge, such as administrative bottlenecks, financing concerns, and other issues outlined in the previous sections. Some of these challenges have already become apparent in the scheme's first-mover states, but other unexpected outcomes may yet continue to emerge in different contexts. Scheme outcomes ultimately depend on the unpredictable behavioural responses of different stakeholders, like farmers and developers, and the ability of SIAs to remain responsive and agile across various aspects of implementation. Therefore, "learning by doing" is essential: gathering data on implementation and using learnings from that data to refine deployment plans so the scheme can be optimized for maximum benefits. This section highlights some tools and approaches that states can use, particularly the Solar Energy Data Management (SEDM) platform and feeder-level monitoring.

The PM-KUSUM scheme guidelines also provide an opportunity for states to test many new policy innovations, such as water incentives and agrivoltaics. Water incentives are a policy tool that balances increasing demand for irrigation with finite groundwater reserves. They need to be complemented with measures such as support for DISCOMs in determining the appropriate benchmark consumption level, as well as outreach measures to address farmer apprehension about metering and water conservation. Agrivoltaics is a key technology of interest. With the increase in solar power capacity, there is a concomitant rise in land requirements impacting the water–energy–food nexus. Agrivoltaics offers a potential solution to this food–energy conflict for land and may grow in importance in the coming decade. Agrivoltaics can also increase the total possible income streams for farmers whose land is used for solar power production. These innovations have been piloted in a few projects, but scaling them up at a state level will require strategies to test them out in different contexts and to monitor and assess their impacts.

5.2 Implementing Monitoring and Evaluation

A learning-by-doing approach for scaling up Components A & C(FLS) requires a well-defined monitoring and evaluation framework. The framework should clearly identify the parameters and tools for monitoring and the timelines for evaluation.

5.2.1 What Are the Tools Available for Monitoring and Evaluation?

Much primary data on power generation and consumption can be captured using existing tools:

- **SEDM platform:** Under PM-KUSUM, MNRE has established an SEDM platform to consolidate data from all remote monitoring systems (RMS) installed in solar irrigation systems. In the context of Components A & C(FLS), there are two types of RMS:
    - **RMS from the solar power plant (for Components A & C[FLS]):** The RMS installed at the interconnection point will share data on solar power generation data

with the SEDM portal. The solar generation data can be used to capture critical information like the power plant's CUF, grid availability, and the generation profile.

  - **RMS from individual pumps (for Component C[FLS]):** If states intend to implement the direct incentive mechanism or install meters at connections in the target feeder, they can integrate the associated RMS with the SEDM portal. The RMS can capture data on energy consumption and pump usage patterns.

- **Feeder meter data:** Most states have implemented metering at the feeder level. These meters can give baseline data on pumps' average power consumption and the voltage status in the feeder. In the absence of any RMS on individual pumps, they can also act as a proxy for consumption data after the scheme implementation. For Component C(FLS), states can compare the RMS-generated data and the baseline figure for impact evaluation.

Data on aspects other than energy, including crop and groundwater data, is not usually available at a feeder or village level. Hence the SIA will have to work with other concerned departments based on the parameters it would like to capture. They are mentioned in the next subsection.

5.2.2 What Parameters Should States Monitor, and How Can They Do It?

There are four broad criteria of scheme impact that the state can evaluate.

Economic Impact on the State

This depends on the solar power generation and how much of it is consumed within the substation.

Table 9. Measuring economic impact of the scheme

Parameter	Source
Total energy generation from solar power plant	RMS data from the solar power plant
The coincidence of solar power generation and consumption within the substation	RMS data from the solar power plant and feeder meter data from the target feeder(s)

Impact on Farmers' Energy Access

This depends on the prevailing electricity supply situation and how solarization changes this situation.

Table 10. Measuring impact on farmers' energy access

Parameter	Source
Energy consumption by farmer.	In the absence of a meter or RMS at the pumps, feeder meter data can be considered to estimate average energy consumption before and after solarization. In addition, data on pump set size needs to be considered in case farmers upgrade them after supply improvements.
Voltage level: Voltage usually drops from the substation toward the end of the feeder.	The feeder meter gives the voltage value at the beginning of the feeder. This can be a good proxy for the overall voltage level. DISCOMs can also undertake voltage monitoring in different buses of the feeder.
Farmers' crop choices and productivity.	Primary survey of beneficiary farmers, in coordination with the agriculture department and agriculture knowledge institutions.
Intangible benefits, including convenience due to a shift in power supply to daytime.	Primary survey of beneficiary farmers, in coordination with the agriculture department and agriculture knowledge institutions.

Social Impact of the Scheme

Evaluating the distribution equity of the scheme requires close engagement with other departments.

Table 11. Measuring social impact of the scheme

Parameter	Source
Land size category of the farmers benefiting from the scheme	The SIA would need to conduct a preliminary survey of the farmers in coordination with the agriculture department. If the state is installing RMSs with individual pumps, this data can be entered into the SEDM portal.
Water prices in the local water market	It is very difficult to capture informal water market dynamics. SIAs would need to use the established network of agriculture departments to gather price data.

Impact on Groundwater

The effect of solarization on groundwater will be visible only in the medium to long term. Further, it is not easy to attribute a variation in groundwater levels to any single source. Hence, states are encouraged to use energy consumption data as a proxy for impacts in the short term.

Table 12. Measuring impact on the groundwater

Parameter	Source
Water consumption	Complement energy consumption data with surveys to identify the average energy-to-water conversion rate, which depends on pump efficiency.
Groundwater level (long term)	The SIAs can coordinate with the groundwater department to establish monitoring wells and piezometers in the feeder area, which will provide data on long-term changes in the water level.

5.3 Piloting and Evaluating Innovative Aspects of Scheme Design for Sustainability

At the time of writing, rapid deployment is a priority for PM-KUSUM, following challenging years for implementation during COVID-19. In this context, piloting innovative ideas can seem like a distraction. Nonetheless, we recommend that states start to pilot and evaluate methods to maximize scheme sustainability. Such pilots can be organized alongside a small share of new projects and receive support from external partners. It can take 1 or 2 years for such experiments to produce knowledge that is ready to support larger-scale rollout—by which time, they may be in high demand.

5.3.1 Efficiency Incentives and the PBPK Scheme in Punjab

The first phase of the PBPK scheme achieved a 33% enrolment among the targeted farmers in six feeders (MGSIPA, n.d.). Consultations with experts and implementing officials suggest this was largely driven by intensive outreach campaigns to convince farmers in the initial feeders to sign up, as well as through the timely payment of the incentive by the DISCOM to farmers. The second phase of the PBPK pilot was disrupted by the COVID-19 pandemic and farmer protests, which led to a limited 4% of the targeted enrolment in 250 feeders (Table 13) (Mitra et al., 2022).

A study of the PBPK scheme carried out by IWMI found that the combination of daytime electricity provision and cash incentives for unused electricity led to farmers reducing their self-reported irrigation hours by at least 7.5% and up to 30%, without affecting paddy yields (Mitra et al., 2022). The study also found a reduction in electricity consumption at the treatment feeders compared to the control feeders. However, there was no significant effect on pumping hours from the uninterrupted daytime electricity supply alone, suggesting that a shift in electricity and groundwater pumping behaviour will depend on the entitlement and cash incentive offered under the scheme combined with the daytime supply. However, interviewed state officials and experts cautioned that more data is required from a larger sample size before any definitive conclusions are drawn regarding the scheme's impact on electricity and groundwater consumption.

The PBPK pilot scheme included several unique measures in both design and implementation that can help address sustainability concerns of solar irrigation. The main findings include the following:

Direct Benefits Transfer Scheme for Agriculture

The PBPK pilot scheme used a direct benefits transfer (DBT) model to incentivize farmers to use electricity and water judiciously. PBPK's design is based on one of three DBT models, where farmers do not receive an upfront cash incentive (Mitra et al., 2022). They are instead allocated a seasonally adjusted predetermined amount of electricity based on their capacity (HP) of connected load and are paid a monetary incentive directly in their bank accounts if they use less than their allocated consumption. The electricity consumption of farmers enrolled in the scheme is monitored using smart meters. As availing cash incentives under PBPK are linked to

Table 13. Enrolment in the PBPK scheme

	Number of feeders	Enrolled farmers	Target	Enrolled %
PBPK Pilot Phase 1	6	309	942	33%
PBPK Pilot Phase 2	250	2,200	51,280	4%
Total	**256**	**2,509**	**52,150**	**4%**

Source: MGSIPA, n.d. and authors' analysis.

Photo: Akash Sharma/CUTS

electricity consumption, an interviewed expert suggested that farmers were keen to install meters in their fields in the scheme's first phase instead of previously resisting them. However, limited enrolment in the second phase highlights the challenge of scaling up metering across the state. As previously outlined in Box 3, a study found that the water use of participating farmers was lower than farmers who chose not to enrol (Mitra et al., 2022).

Context-Specific Approach to Fixing Quota

Under the PBPK, an average monthly electricity quota based on the pump motor capacity was fixed for each agriculture feeder (MGSIPA, n.d.). The formula used to determine the quota was based on the previous year's electricity usage divided by the total tubewell load at a feeder level. The average was worked out on a seasonal basis with a higher allocation for paddy, as it is a more water-intensive crop and a lower average for the non-paddy season. Consultations with experts involved in the scheme's implementation suggested that landholding size was a better measure for the baseline calculation to prevent the overestimation of the quota. However, the electricity usage-based quota was chosen for practical reasons.

Focus on Water-Saving Techniques in Demonstration Farms

The state created demonstration farms on scheme feeders to highlight the benefits of water-saving techniques and resource-conservation technologies (PSPCL, 2022). States could consider similar demonstrations to promote the adoption of micro-irrigation and other conservation technologies along with solar irrigation. However, an evaluation study did not find any changes in farming practices, such as changes in crop choice, shifting to a shorter-duration paddy variety, or adopting improved water management techniques such as direct seeding of rice and bunding (Mitra et al., 2022). This is likely a consequence of the study being conducted in the first year of enrolment for most farmers, whereas behavioural change and efficient farming practices take more time (Gulati, 2021).

Coordination structures and incentives for implementing agencies: Aside from water conservation, the PBPK design also focused on creating institutional structures that promote effective interagency coordination and better implementation. Consultations with state officials and research institutes that were involved in pilot implementation highlighted these as critical in addressing sustainability concerns. Some of the key elements included:

1. **Consultations** with farmers, agriculture and water experts, and the field staff of DISCOMs, to adjust the scheme's design. The implementation of the scheme also relied on three independent advisors who were experts in the agriculture, power and water sector.
2. **Ensuring high-level political and administrative commitment** to the scheme through the chairing of implementation by the chief secretary and regular briefing meetings with the chief minister. Apart from this, the scheme established transparent communication channels between agencies (power, water, agriculture, extension, and finance).
3. **A multilayered and empowered institutional mechanism** was created (as elaborated earlier in Box 15) to monitor implementation and make timely decisions.
4. **Inputs from multiple stakeholders,** including government departments, representatives of agricultural universities, and farmers' commissions.

Inclusion of Tenant Farmers

Eligibility criteria for enrolment in the scheme mandated that the participant should be a consumer of an agricultural electricity connection (Government of Punjab, n.d.). This initially excluded tenant farmers that leased land as well as farmers that inherited land from their ancestors. Despite these initial hurdles, amendments were introduced to enable joint electricity connections in the name of legal heirs and to enable cash transfer of the incentive directly to tenant farmers after the enrolment of the landowner. This highlights the need for an adaptive approach by the state to overcome emerging implementation hurdles.

5.3.2 Agrivoltaics

Agrivoltaics refers to the simultaneous use of land for agriculture and photovoltaic power generation. This is achieved by designing a solar power plant to enable cultivation between or below the PV panels. Agrivoltaics is still in the early stages of deployment in India, with only a handful of pilots attempted so far (The National Solar Energy Federation of India maintains an inventory of these pilots, which readers can access on this website). This means that knowledge gaps exist at various stages. The background paper on agrivoltaics that supplements this guidebook, investigated these knowledge gaps in detail. In this section, we present the main recommendations for the state to adopt a learning-by-doing approach in agrivoltaics.

The pilots, to date, have demonstrated the technical feasibility of growing certain crops with an agrivoltaics setup. Still, they need to be replicated with viable business models in the real world and explored in a range of contexts across the country. In particular, the use of agrivoltaics in combination with more mainstream crops, like paddy and wheat, is yet to be piloted. Hence, it is critical for states to further test and evaluate the innovative aspects of the model before scaling up.

Business Models of Agrivoltaics

Scaling up agrivoltaics requires feasible business models. Knowledge institutions and developers have so far led the pilots in India, with farmers having only a secondary role in the system. Mainstreaming agrivoltaics needs the development of new business models with the primary involvement of farmers. The following potential business models have emerged from our consultations.

1. **Model I – Partnership between farmer and developer:** Farmer and developer negotiate and co-design the system. The farmer continues the ownership of cultivation with a minor land loss to the agrivoltaics setup but gets compensated through land rent. The developer manages solar generation.
2. **Model II – System wholly owned and operated by one entity:** An individual farmer, a group of farmers, or a developer owns and operates the entire system to maximize revenue from a given land parcel.
3. **Model III – Developer as a primary promoter, farmer as a partner:** In this model, agriculture is not usually the central design criteria for the power plant but a secondary activity. In arid areas where crop cultivation is not viable in summer, this model may offer farmers an opportunity to use the land all year round.

The suitability of each business model may vary with the agroeconomic situation. Models I & II are best suited where the land rent is very high and there is a good market for high-value and exotic crops. Model III (developer as a primary promoter and farmer as a partner) is not prevalent in industrialized nations and will not qualify as agrivoltaics per most countries' standards and definitions. The imperative of protecting agricultural land drives their standards and design in agrivoltaics. However, in arid and semi-arid regions, excess evapotranspiration is the main constraint for crop growth, and agrivoltaics can potentially support increasing the cultivated area in these regions. Model III can be a potential option where land is not cultivated due to poor productivity. However, care should be taken not to apply this model in productive and cultivated lands. The background paper on agrivoltaics further elaborates on this point.

Stakeholders are best able to choose for themselves which business models are most suitable. States, however, can play a facilitative role by executing the following functions:

- **Organizing state-level workshops for developers and farmers:** States can invite the implementors of pilots across India to share their findings. The SIA can coordinate with the agriculture department to get entrepreneurial farmers to participate in the workshop.
- **Encouraging participant stakeholders to submit proposals on agrivoltaics:** This is likely to include any requests that stakeholders may have for incentives from the state. States can consider small incentives like the transfer of performance-based benefits to the developers or an additional incentive over and above the standard tariff based on meeting various conditions.

States can evaluate the outcomes of such special projects to create standardized definitions for future projects. Such standardized definitions are important in the future if states intend to promote agrivoltaics at a large scale. Lack of standardization will lead to regular solar power plant owners free-riding on such incentives with minor tweaks in the design.

Based on a review of literature from existing pilot projects in India and consultations with pilot project implementers, below is an indicative list of parameters that should be considered for evaluating agrivoltaics.

1. **Techno-commercial evaluation:** Multiple designs of agrivoltaics are available with varying heights and structure types. Each has different advantages and disadvantages. States would do well to work with first movers on planning a systematic techno-commercial evaluation right from the beginning, exploring how different technical characteristics can influence likely commercial performance, including convenience and profitability. Such assessments should also consider strategies for overcoming the increased cost barriers associated with agrivoltaics.
2. **Effective land area for agriculture and crop yield:** For business Models 1 and 2, states should evaluate the extent to which proposals and projects have changed the effective available area in the field for agricultural cultivation. Based on initial projects, states can prescribe a minimum percentage of cultivated area to be retained in the future. Similarly, the crop yield change should be evaluated using a baseline estimate. States can involve agricultural knowledge institutions in the evaluation.
3. **Impact on water resources:** Agrivoltaics can potentially create opportunities to improve water efficiency. In principle, the water used for panel cleaning can also be used for irrigation. However, during interviews, developers reported possible complications, particularly when sharing resources between the farmer and the developer. States must monitor water usage characteristics in different contexts and plan scale-up accordingly.
4. **Shading characteristics and guidelines for crop selection:** The optimum agriculture output from agrivoltaics is obtained when suitable crops are chosen depending on shading conditions. Within an agrivoltaics setup, the insolation levels vary throughout the plot. Optimizing output requires proper zonation based on shading characteristics, which in turn depend on the agrivoltaics design. For scale-up, the states should encourage stakeholders to create a standard document that can be used for future replication. The creation of such a standard document could be one condition for receiving financial incentives. States can work closely with KVKs and agriculture universities to implement this recommendation.
5. **Operational challenges:** Because the technology is still in its infancy, some of the operational concerns of agrivoltaics are yet to be documented well. Our preliminary study showed concerns like accelerated structural decay due to humid micro-climates and challenges with the maintenance and safety due to raised solar PV panels. States need to work with first movers to identify such challenges and develop guiding points for the future.

Section Summary

PM-KUSUM Component A and C (FLS) has not yet been widely deployed. New challenges for implementation and sustainable scheme outcomes may arise in the future. Furthermore, policy innovations recommended in the PM-KUSUM scheme guidelines, such as water incentives and agrivoltaics, can offer sustainable solutions for states. However, they require evidence-based strategies to suit different contexts. Hence it is critical to learn by doing—gather data on implementation and constantly refine deployment approaches based on the data.

Strategy for Monitoring and Evaluation

Figure 14. Strategy for monitoring and evaluation

Tools for gathering data

- **The Solar Energy Data Management Portal**
  Consists of functioning data from the distributed power plant and the pumps in the target feeder
- **Feeder meter data from the target feeder**
  For baseline data on energy consumption. If RMS is not installed with pumps, it can also act as a proxy for consumption data after the scheme implementation

Criteria and parameters for evaluation

Economic impact on the state
- Total energy generation from solar power plant
- The coincidence of solar power generation and consumption within the substation

Impact on farmers' energy access
- Energy consumption by farmer
- Voltage variations
- Farmers' crop choices
- Intangible impacts due to the shift in power supply to daytime

Social impact of the scheme
- Land size category of farmers benefiting from the scheme
- Water prices in the local water market

Impact on groundwater
- Water consumption
- Groundwater level (long term)

States can allocate a small share of new projects for piloting innovative models, including water incentives and agrivoltaics. This approach would generate evidence for subsequent scale-up of these models without hampering current deployment. We explored two key innovative models: i) efficiency incentives for water conservation and ii) agrivoltaics.

Efficiency Incentives

The PBPK scheme is the first large-scale initiative piloting the direct cash incentives proposed in the PM-KUSUM guidelines. Initial studies by research organizations found that the combination of daytime electricity provision and cash incentives for unused electricity led to farmers reducing their self-reported irrigation hours under the PBPK scheme. However, more data and impact evaluation studies are needed before any definitive conclusions are drawn. The PBPK scheme offers some unique learnings in addressing implementation challenges (See the PBPK case study in the Appendix for further reading).

1. **DBT scheme for agriculture:** PBPK's design is based on one of three DBT models, where farmers are allocated a seasonally adjusted predetermined amount of electricity based on their connected load and are paid a monetary incentive directly into their bank accounts if they use less than their allocated consumption. Initial trials showed that with adequate communication activities, a sizable share of farmers was interested in enrolling in the scheme.
2. **Context-specific approach to fixing quota:** Although calculating the electricity quota based on a farmer's land size holding is more desirable, PBPK used the prevailing electricity use-based quota for practical reasons.
3. **Water-saving techniques in demonstration farms:** Popularizing water-efficient practices is critical to ensuring sustained reduction in groundwater usage. Punjab created demonstration farms on scheme feeders to highlight the benefits of water-saving techniques and resource-conservation technologies.
4. **Coordination structures and incentives for implementing agencies:** Aside from water conservation, the PBPK design also focused on creating institutional structures that promote effective interagency coordination and better implementation. The scheme was based on extensive consultation with all stakeholders; there was high-level political and administrative commitment; and there was a clearly defined multilayered administrative structure in place (elaborated in Box 15).
5. **Measures to include tenant farmers:** The state introduced amendments to its electricity policies to enable joint electricity connections in the name of legal heirs and enabled cash transfer directly to tenant farmers after the enrolment of the landowner.

Learnings from the Punjab PBPK scheme may not apply to other parts of the country with different agroeconomic contexts. Indeed, a pilot study conducted in Gujarat that trialled electricity-linked incentives for farmers found a high enrolment for metering but no impact on water consumption.

Agrivoltaics

Agrivoltaics refers to the simultaneous use of land for agriculture and photovoltaic power generation. This is achieved by designing a solar power plant to enable cultivation between or below the PV panels. There have been only a handful of pilots on agrivoltaics in India. Mainstreaming them requires the development of new business models, regulations and standards, promotional measures and creating evaluation frameworks for continuous learning.

Table 14. Key lessons from agrivoltaics pilot projects in India

Business models	There are three broad business models that we have explored in agrivoltaics: 1. Partnership between farmer and developer 2. System wholly owned and operated by one entity 3. Developer as a primary promoter, farmer as a partner The suitability of the models varies with the agroeconomic situation—the first two are suitable where high-value crops are cultivated, and land rent is high; the third model is suitable for arid and semi-arid regions.
Promotional measures	The state can facilitate the uptake of agrivoltaics through awareness and financial incentives. Organizing state-level workshops for developers and farmers could generate awareness. Creating a mechanism to fund special projects based on proposals from stakeholders can help innovate new models.
Evaluation	States should evaluate the first set of future projects along five criteria: i) techno-commercial evaluation to understand the viability and technical characteristics of different technology models, ii) effective land area of agriculture and crop yield, which can form the basis of standards in the future, iii) impact on water resources, iv) shading characteristics of different models to create guidelines for crop selection, and v) other operational challenges.

Further guidance and resources

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Appendix. Case Studies

A1 Case Study 1: Mukhyamantri Saur Krishi Vahini Yojana, Maharashtra

The Government of Maharashtra launched the Mukhyamantri Saur Krishi Vahini Yojana (MSKVY) scheme in 2017 for solarizing agriculture feeders in the state using decentralized solar power plants of 2–10 MW capacity. The main objectives of the scheme were to ensure daytime power supply to farmers and to reduce the power subsidy burden on the state.

A1.1 Context

In Maharashtra, the agriculture category accounted for more than 30% of the electricity consumption in 2019–20 (Maharashtra Electricity Regulatory Commission [MERC], 2020a). Electricity for agriculture is highly subsidized in Maharashtra. The average revenue from the agriculture category is only about INR 0.53 per unit against the average power supply cost of INR 8.30 per unit (PFC, 2021), putting a significant burden on the state and DISCOM finances. The tariff approved by MERC, including the state subsidy, constitutes about 50% of the actual cost of supply (MERC, 2020a). Consequently, the state rations power for agriculture consumers and supplies in the off-peak hours. MERC mandates a minimum power supply to agriculture connections of either 8 hours during the day or 10 hours at night (MERC, 2011). According to state officials, in practice, much of the supply happened during the night, causing safety hazards such as electrocution and snakebites and other difficulties for the farmers. Daytime power supply has been a longstanding demand from farmers. The Maharashtra Ag Pump Electricity Policy 2020 has kept a target of providing 8 hours of reliable daytime power supply to farmers without any additional burden to the state and farmers as one of its primary objectives (Maharashtra State Electricity Distribution Company Limited [MSEDCL], 2020).

Maharashtra's Comprehensive Policy for Grid-connected Power Projects Based on New and Renewable Energy Sources—2015 targeted 7,500 MW solar power generation capacity in the state by 2020 (Government of Maharashtra, 2015). The policy targets fulfillment of the renewable purchase obligations (RPOs) through this planned capacity. Although the state saw rapid growth in solar power capacity addition in the following years, its generation consistently fell short of the target to fulfill its RPO obligations. The cumulative shortfall in RPO between 2016 to 2019 is about 3,468 million units (MERC, 2020b). The state has kept an RPO target of 25% by 2025.

In the context of these two objectives, the state rolled out the MSKVY scheme to promote decentralized solar power plants to solarize agricultural feeders.

Box 16. MSKVY scheme design

Under the MSKVY scheme, the state plans to develop 2–10 MW solar power plants for solarizing agriculture feeders. The power plants are installed on vacant government or private lands and connected to the 11 kV busbar of the 33/11 kV or 22/11 kV substations under MSEDCL. The power supply to the targeted agriculture feeders is shifted to daytime, and the power generated from solar plants primarily caters to the agriculture load. Any deficit or surplus in solar power generation is drawn or fed into the grid.

In terms of objectives, the scheme is like the PM-KUSUM Component C (FLS), ensuring daytime power supply to the farmers and reducing the subsidy burden. The solar plants target agriculture feeders and can be developed on any type of land and are not limited to farmer's land. However, like Component A, there is no direct subsidy from the government involved in the scheme, and solar plants are developed purely based on their commercial viability for the DISCOM.

Scheme Launch and Progress

The Government of Maharashtra came out with the first MSKVY guidelines in 2017. The initial focus was on developing solar power plants on government lands. According to the stakeholder from MAHAGENCO (Maharashtra's state power generation utility), the land identification process had started much earlier. They collected district-specific data on vacant government lands and assessed the feasibility of setting up power plants.

The state approved two solar plants of 2 MW each—one in Ralegaon Siddhi and one in Kolambi districts—as pilots under the public–private partnership (PPP) model. MAHAGENCO selected private developers based on reverse tariff bidding and entered a power purchase agreement. At the same time, MAHAGENCO signed an memorandum of understanding (MoU) with EESL to develop 100 MW solar power plants in the vacant lands within distribution substations under the scheme. The experience from the pilot projects and work with the EESL influenced subsequent implementations.

Over 5 years, the scheme underwent many changes. In the initial phase, MAHAGENCO was responsible for developing the identified lands and constructing the evacuation bay infrastructure. It was to be financed using the Green Cess Fund in the state. As the state found limitations in developing state-owned lands, it shifted focus to solar power plants on private lands.

The scheme faced enormous implementation challenges from the beginning, primarily due to poor responses to the tenders from developers (Table A1). But the scheme started picking up pace in late 2019, although the performance is still much lower than initially planned. Subsequent sections will describe the implementation challenges and the measures taken by the state to overcome them.

Table A1. Details of tenders published under the MSKVY scheme

Sr. No.	Date of Tender	Cumulative capacity (MW) in the tender	Capacity (MW) for which bids were received	Capacity (MW) for which PPAs were signed
1	Apr 27, 2018[1]	1,000	235	235
2	Sept 15, 2018[1]	1,400	180	0
3	Jan 7, 2019[1]	1,400	1170	10
4	Sept 20, 2019[1]	1,350	5	5
5	Dec 31 2019[2]	1,350	283	283
6	Apr 22, 2021[3]	1,300	111	111
7	Oct 28, 2021[4]	1,250	385.3	385.3
8	Jan 31, 2022[5]	865	535	535
Cumulative capacity of PPAs (MW) signed under the scheme by MSEDCL				**1,564.3**

Source: 1. MERC, 2020d; 2. MERC, 2020b; 3. MERC, 2021; 4. MERC, 2022a; 5. MERC, 2022b.

Costs and Benefits

One of the scheme's objectives was to reduce the power purchase cost for DISCOM. Although the DISCOM has not conducted any comprehensive post-implementation assessment, the utilities used the following justification for the scheme in their tariff petition:

- The average tariff discovered under the scheme—between INR 3.00 to INR 3.30 per unit—is lower than the average power purchase cost, which is about INR 6 per unit.
- Even if the state bought power from a utility-scale power plant whose tariff ranged between INR 2.4 to INR 2.8 (at the time of filing the petitions), the landed cost would be in the same range if they considered the following losses:
  - State transmission utility loss
  - 33 kV wheeling losses
- Reduced transmission infrastructure usage and avoided transmission upgrade costs are some additional benefits of the scheme.

Supplying power during the daytime is intended to benefit farmers. Other additional benefits envisaged included improved quality and reliability of the power supply. The actual scheme outcomes have not yet been evaluated.

A1.2 Financing

Since its inception, the state has experimented with three power procurement models involving MSEDCL and MAHAGENCO. The multiple business models are a result of the state's effort to overcome certain challenges. The three broad models are as follows:

1. **PPP mode with MAHAGENCO:** MAHAGENCO aggregates vacant government lands and leased private lands and transfers them to private developers identified through reverse tariff bidding. MAHAGENCO enters into a PPA with the successful bidders. Simultaneously, it enters into a power sale agreement with MSEDCL, charging its commission of INR 0.05 per unit over and above the discovered tariff. Most of the initial installations were planned under this model. However, it soon ran into trouble:
    a. MERC mandated MAHAGENCO to procure an intra-state trading licence since it acted as an intermediary in the scheme.
    b. Further, although MERC approved INR 0.05 per unit commission margin for MAHAGENCO, the final tariff was much higher than the tariff discovered under other models. In the end, MAHAGENCO chose not to levy any commission.
2. **MoU between MAHAGENCO and EESL:** MAHAGENCO signs MoUs with EESL to purchase power on a mutually agreeable tariff. It also executes a power sale agreement with the DISCOM. This model was adopted when the initial tenders under the PPP mode did not elicit any responses from private developers. EESL proposed a competitive tariff for a 200 MW solar power plant on government lands, which was increased to 500 MW later. However, MERC has suggested that the MoU route goes against the spirit of competitive bidding and should not be preferred (MERC, 2020c).
3. **Renewable energy service company (RESCO) model with MSEDCL:** MSEDCL directly signs PPAs with private developers based on reverse tariff bidding. Most PPAs signed so far are through this route, and the DISCOM has big plans for the coming years.

Despite these quick policy responses, the scheme implementation faced many teething troubles. The main challenge was the poor response to tenders from the developers. But the state has been consistent in overcoming these challenges through policy measures. The main concerns identified during the study and the state's policy responses are outlined below:

Viability of Tariff

Many developers found that the proposed ceiling tariff for MSKVY was not proportional to the risks and costs involved in setting up decentralized power plants. The state adopted the following unique method to arrive at the ceiling tariff.

1. Tariff from a utility-scale solar park is taken as the base price.
2. On top of it, the following costs were added
    a. Central transmission utility charges and losses
    b. State transmission utility charges and losses
    c. Wheeling losses in the 33 kV lines

Thus, the logic of the tariff design was to peg the tariff to the landed cost of a utility-scale power plant. This method is very different from the levelized cost calculation method followed by the other states. However, the final tariff still fell short of expectations for many developers. After repeated tenders eliciting poor responses, MERC suggested that the tariff could be the main reason and instructed MSEDCL to adopt a market-responsive tariff. Through the course of the scheme, the ceiling tariff increased from INR 3.10 per unit to INR 3.30 per unit, and recent tenders have started eliciting a better response.

Grid Availability

The availability of the grid at the 11 kV level was another primary concern. According to stakeholders, although Maharashtra's rural power supply situation is better than in many other states, it is still not up to the mark. Load-shedding and transformer breakdown are quite common at the 11-kV level. A study of one of the pilot projects at Kolambi showed that the average grid availability in the first 7 months of the power plant operation was less than 73% (Padole et al., 2022). However, this pilot connected the power plant directly to the Ag Feeder rather than the 11 kV busbar at the substation. The situation was abysmal in the first 2 months when availability was below 50%, mainly due to the high load-shedding rate. Assuming that load-shedding will not affect a powerplant directly connected to the substation, there is still only about 91.5% grid availability—the remaining is lost due to breakdowns. In comparison, a solar power plant connected at the extra high voltage level (voltage levels exceeding 33 kV, which is the typical injection point for a solar power plant) enjoys more than 99% grid availability. The state introduced two critical measures to address these issues:

1. Introduction of deemed generation clause: The state guarantees a minimum of 98% grid availability. In case of a shortfall, the developers can claim compensation at 75% of the PPA tariff for lost generation units. As per several stakeholders, this has been a significant step in improving investors' confidence.
2. Upgrading of the distribution infrastructure: The state undertook critical infrastructure upgrades at the distribution level. State officials realized the importance of such activities only once the installations started coming online. According to developers, learning from the initial experience, they constantly liaised with the DISCOM field officers. They took pre-emptive steps for grid maintenance, including cutting tree branches along the feeders to avoid short circuits. State officials suggest that it is critical for a scheme for decentralized power plants to consider the distribution sector holistically.

Land-Related Challenges

According to the stakeholders, another significant roadblock was that developers struggled with the logistics of identifying land parcels for the power plant. Land aggregation challenges were one main reason for large investors to avoid the scheme. The state instituted a "land bank" scheme to overcome this challenge—the state notified a separate mechanism where interested private parties, including farmers, could register their land for leasing to developers. The DISCOM officials surveyed, verified, and assessed the feasibility of the registered lands, thus creating a ready inventory of lands suitable for the solar plants. According to stakeholders, the initiative has been highly successful, and in the latest tenders, the lands registered through land banks were the basis for most bids.

Payment-Related Challenges

Maharashtra is among the better-performing states regarding the timely payment of dues to solar developers. However, stakeholders believe a delay of 2 to 3 months is still common in the state. And this was a main concern for the developers. Large investors can manage cash flow constraints for a few months. The state also provides the letter of credit (LC) guarantee, which ensures payment within a few months. However, that is not enough for small investors. In the MSKVY scheme, most participants were small enterprises investing in one or two solar plants. Even a month of payment delay may cause serious trouble for such enterprises. The state's primary measure to counter this was by developing trust. According to the developers who commissioned power plants, the state ensured timely payment for the investors. The state depends on word-of-mouth publicity to allay the concerns of potential developers.

A1.3 Implementation Design and Coordination

In the initial scheme design, the state envisaged roles for multiple organizations, with MAHGENCO as the primary implementing agency. However, as the scheme evolved, and the RESCO model became the favoured option, the state designated MSEDCL as an implementing agency. Since then, MSEDCL has been the main driver of the scheme.

Roles of the Three Agencies

MSEDCL

As the primary implementing agency, MSEDCL identifies target substations and decides the corresponding capacity of the solar power plants. It does the due diligence for the tender and commissioning. Two notable steps by MSEDCL have significantly helped in the advancement of the scheme:

- **Creation of land banks:** The preparation of a list of privately owned land parcels that are investment ready is a significant achievement for the state and is expected to boost the scheme's implementation. MSEDCL aggregated the land information and verified each land parcel for the feasibility of solar power plant installation, thus significantly reducing the logistics costs for developers. The DISCOM also gave wide publicity to the land bank initiative—the land bank portal was launched by the chief minister—giving it wide coverage and a good response from the public.
- **Open tender:** One main implementation constraint MSEDCL identified was that the tender cycle was too long, and many successful bids were not converting to PPAs. Small investors, who form the bulk of the participants in the scheme, were finding it difficult to stick to the timeline because if they failed or missed one tender, they had to wait until the cycle was completed for the next opportunity. To alleviate this, MSEDCL opted for open tender, where the substation-specific capacity is updated and published every month, and the bidding takes place at the end of every month. This gives a continuous stream of opportunities for investors.

  A significant drawback of this setup, also noted by MERC, is that it undermines the competitive spirit of bidding. Firms will only bid at ceiling tariff as there is enough chance even if they lose one tender. MSEDCL acknowledged this but argued it is a necessary compromise, as the previous tenders did not elicit the expected competitive spirit. They justified that power purchase at the ceiling tariff is still comparable to the landed cost of power from a solar park.

MAHAGENCO

MAHGENCO's primary role was to develop vacant government and substation lands for the solar plant developers. According to the representative from MAHGENCO, their work in this matter predated MSKVY. They collected data on vacant lands with different government departments by liaising with district collectors. Their field staff verified and assessed these lands for the viability of solar power plants. This exercise gave an excellent jumpstart to the scheme, with most of the initial installations coming through MAHGENCO. MAHGENCO also negotiated with established developers to bring down the cost of power. They signed a PPA for INR 3 per kWh with the EESL when the prevailing tariff for large-scale power plants was in the same range.

In the initial design, the primary role envisaged for MAHGENCO was that of an intermediary between developers and the DISCOM (PPP model with MAHGENCO). However, when they could not offer competitive prices under the PPP route, they had to cut their commission margins, which upended the business model. With the focus shifting to the RESCO model with MSEDCL, MSPGCL's role in the scheme implementation became very limited.

MEDA

As the nodal agency for RE in the state, MEDA has specific statutory roles like the registration of developers. Especially when the bulk of developers are small investors and venturing into the solar power generation business for the first time, MEDA's role becomes vital in the implementation. In addition, for some of the projects implemented by MAHGENCO, the construction of the evacuation and metering infrastructure, which were MAHGENCO's responsibility, was financed through the Green Cess Fund managed by MEDA.

Political Backing for the Scheme

One critical factor that makes Maharashtra stand out among other states in implementing feeder solarization is the political support for the program. The scheme is named after the chief minister, showing its flagship status, and it was launched with much publicity and fanfare. The scheme enjoys broad political support—even after a change in the party in power, the scheme continues to enjoy strong political support. The government has also been very responsive in policy-making to overcome implementation challenges. When the DISCOM identified land procurement issues as the main roadblock to the scheme implementation, the state came out with the land bank initiative launched by the chief minister, giving it high visibility.

Balancing WEF Nexus Objectives

Two critical aspects of balancing water–energy–food (WEF) nexus objectives for feeder solarization are targeting and supporting the sustainable development of groundwater (ref. main guidebook).

1. Targeting of the Scheme

The scheme's objective is to eventually solarize all agriculture feeders in the state. The state did not use any WEF considerations to limit the scheme to particular feeders. In the feeder selection for the current phase, the state's main criteria are the intensity of agriculture measured through the agricultural load in substations and the availability of government lands. This approach has helped to extend the scheme in all regions except the Konkan region, where the geographical setting is unfavourable for the scheme due to hilly terrain and dense forest. There is a comparatively higher concentration in Pune, Nashik, and Marathwada regions (Prayas Energy Group, 2021).

In parallel to the MSKVY scheme, the state also has huge ambitions for the PM-KUSUM Component B to cater to farmers without electricity connections. Maharashtra has demanded the highest allocation among all states—1-lakh pumps under Component B. The state aims to ensure equitable access to irrigation through this two-pronged approach.

2. Managing the Impact on Groundwater

Groundwater concerns have not influenced the scheme's design. The stakeholders' views varied regarding its potential impact and relevance in scheme design. Some stakeholders suggested that since the overall hours of power supply are now less than the earlier nighttime supply, the scheme is likely to improve the groundwater situation in the state. Further, with an uninterrupted guaranteed daytime power supply, farmers are more likely to act responsibly in their water use and less likely to use an auto-on switch, which causes a lot of water wastage. But some other stakeholders acknowledged that there could be negative impacts on the groundwater. Since the farmers now get water throughout the day without any incentive to conserve its usage, it may lead to the growing of more water-intensive crops. However, experts suggested such impacts on the groundwater are detectable only in the long term and need a few more years of implementation to be studied properly. According to them, any consideration of groundwater in the scheme design stage will be purely speculative.

Interdepartmental Coordination

According to the stakeholders interviewed, other departments like the agriculture department and groundwater agencies do not play a role in implementing the scheme. The revenue department's role is in the diversion of land use. However, in the State Renewable Energy Policy 2015, the state had conferred "deemed diversion" status to solar projects, meaning that the revenue status of land need not be changed if agricultural land is used for solar power plant installation. But they acknowledged that a consultative mechanism with agriculture and groundwater departments would have helped them assess the scheme's impact on aspects like farmers' income, crop choices, and groundwater sustainability.

A1.4 Key Learnings for PM-KUSUM

Maharashtra's challenges in implementing the MSKVY scheme and how it overcame some of those challenges can be instructive for other states in the implementation of the PM-KUSUM scheme. Here are the three main takeaways:

1. Both MSEDCL and MERC have been quick to make policy amendments and corrections, including refining the tariff after each tender. This helped overcome the lack of interest among developers in the early stages.
2. Process innovations like the land bank initiative, the logic used for setting the tariff, open tender, and deemed generation clauses were instrumental in getting the scheme off the ground and can be replicated in other states.
3. Political backing is key in addressing implementation challenges and ensuring interdepartmental coordination.

A2 Case Study 2: Paani Bachao Paisa Kamao scheme, Punjab

The state government of Punjab, in consultation with the World Bank and the Abdul Latif Jameel Poverty Action Lab–South Asia (J-PAL SA), implemented an innovative pilot scheme in 2018 to test solutions to the challenge of over-withdrawal of groundwater in the agriculture sector. The Paani Bachao Paisa Kamao (save water, earn money) (PBPK) scheme provided a direct incentive to participating farmers to conserve electricity within a stipulated limit, indirectly curtailing groundwater depletion.

The scheme used a direct benefit transfer of electricity (DBTE) mechanism and aimed to tackle the interlinked challenges of falling groundwater tables and growing financial debt of electricity utilities. This behavioural change scheme was implemented in two phases and complemented with several measures to promote water-use efficiency practices, such as piloting water-saving techniques at demonstration farms (Government of Punjab, 2019). A study has found positive evidence of the scheme's impact on self-reported irrigation hours and feeder-level electricity consumption, but further impact evaluation studies are required (Mitra et al., 2022).

A2.1 Context

According to surveys conducted by the state's agriculture department, around 85% of water blocks in Punjab were designated as overexploited or critical (MGSIPA, n.d.). Groundwater depletion is not limited to Punjab, with 60% of all blocks in India expected to reach a critical condition by 2025 if current depletion rates persist (Pahuja, 2010). This is mainly driven by agricultural consumption since the sector accounts for 80% of total freshwater withdrawals in the country (World Bank, 2020). A study by the MGSIPA, Punjab, suggested that groundwater depletion linked to agricultural electricity supply not only added to Punjab's financial woes but also increased the burden on farmers, with an estimated INR 11,000 (~USD 133) per annum being spent by individual farmers for the expansion of tube wells to access deeper groundwater tables (MGSIPA, n.d.).

The provision of subsidized electricity supply also has an adverse impact on the finances of the local electricity utility, Punjab State Power Corporation Limited (PSPCL) and the state government, which incurred an annual subsidy burden of INR 9,675 crores (USD 1.2 billion) in FY 2020 (Aggarwal et al., 2020). Of this subsidy burden, over 60% is driven by agricultural electricity consumption (Aggarwal et al., 2020). Again, this is not only restricted to Punjab, with a CEEW-IISD study estimating that total direct electricity subsidies from state governments across India amounted to INR 110,391 crore (USD 15 billion). An additional INR 75,027 crore (USD 10.2 billion) was incurred as cross-subsidies through higher tariffs imposed on industrial and commercial consumers (Aggarwal et al., 2020). Subsidized electricity also impacts farmers, with a World Bank study finding that the poor quality of unmetered power supply and inequitable distribution of subsidies harmed small and marginal farmers the most (World Bank, 2001).

Linkages With the PM-KUSUM Scheme

The PBPK pilot scheme has linkages with the PM-KUSUM scheme, where under component C (FLS), states are given an option of providing direct incentives to farmers to limit their consumption of energy following the solarization of agricultural feeders (PIB, 2020). Subsequent revisions have made it clear that metering is not mandatory under the PM-KUSUM scheme but optional for states to consider. However, the PBPK experience demonstrates that providing incentives linked to electricity consumption can encourage farmers to opt for individual metering, even in states where metering is challenging from a political economy perspective (Gulati, 2021). DISCOM officials in Punjab confirmed that prior to PBPK's implementation, metering had only been undertaken at the feeder level rather than at an individual farm level, which changed following the scheme's rollout.

A2.2 Overview of the PBPK Scheme

The PBPK scheme was entirely voluntary and used a DBT model to incentivize farmers to use electricity and water judiciously. PBPK's design is based on one of three DBT models, where farmers do not receive an upfront cash incentive. They are instead allocated a seasonally adjusted predetermined amount of electricity units based on the capacity (HP) of their connected load. They are paid a monetary incentive directly in their bank accounts if they use less than their allocated consumption (Asian Development Bank, 2020). The electricity consumption of enrolled farmers is monitored using smart meters.

The PBPK scheme was initially implemented in 2018 on a pilot basis in six agriculture feeders, covering a total of 942 farmers (MGSIPA, n.d.). DISCOM officials highlighted that the selection of feeders was undertaken mainly based on an assessment of areas where there was likely to be limited resistance from farmers. Despite initial enrolment challenges (highlighted in the next section), the scheme was well-received, with 276 farmers enrolling in the first year (MGSIPA, n.d.). This constituted 29% of the 942 farmers targeted for enrolment under the scheme. The timely payment of subsidies by PSPCL and intense outreach campaigns conducted by several organizations involved in implementation was considered a key factor in encouraging more farmers to participate in the PBPK pilot (MGSIPA, n.d.).

Following its initial enrolment success, the scheme was scaled up in June 2019 to 256 agriculture feeders and targeted roughly 52,000 farmers in the state. Interviews with DISCOM officials suggest that the selection of feeders in the second phase was instead based on an assessment of regions with rapidly falling groundwater tables. By March 2020, an additional 2,000 additional farmers had enrolled in the scheme in the second phase before the

Covid-19-induced lockdown temporarily halted enrolments (MGSIPA, n.d.). This disruption was closely followed by strong protests from farmer unions against new laws passed by the government that aimed to reform the agriculture sector. These developments affected the scheme's implementation, and only 2,200 farmers (4% of the targeted 51,280 farmers) enrolled in Phase 2 before the scheme was put on hold due to the pandemic (MGSIPA, n.d.).

Table A2. Enrolment in two phases of the PBPK scheme

	Number of feeders	Enrolled farmers	Target	Enrolled %
PBPK Pilot Phase 1	6	309	942	33%
PBPK Pilot Phase 2	250	2,200	51,280	4%
Total	**256**	**2,509**	**52,150**	**4%**

Source: MGSIPA, n.d. and authors' analysis.

Interviewed experts cited findings from a survey conducted during the scheme's implementation to suggest that a higher number of farmers were keen to enrol in the scheme but faced red tape and bureaucratic hurdles in participation as their electricity connections were under a different name. This highlights the uncertainty of drawing conclusions on the PBPK's enrolment outcomes in the absence of a more detailed study of the scheme.

Coordination Mechanism in the PBPK Scheme

The PBPK pilot scheme was mainly implemented by the PSPCL, the state electricity utility. Aside from the utility, the state government of Punjab created a multilayered institutional structure for implementing the PBPK scheme with mechanisms for interagency coordination as well as vertical coordination between senior bureaucrats and field-level officials. The regular oversight of the chief minister provided strong political backing and empowered officials to make decisions (MGSIPA, n.d.).

The scheme's implementation relied on the inputs of multiple departments as well as representatives of agricultural universities and farmers' commissions. However, officials from the state electricity utility highlighted that despite initial support from other departments, their support eventually weaned off due to competing priorities during the Covid-19 pandemic and the farmers' protests, highlighting the difficulty in maintaining continuous engagement with different departments during the scale-up of any scheme.

A three-tiered monitoring and implementing structure were set up for the scheme's implementation, including:

1. **A State-Level Steering Committee:** Chaired by the chief secretary with the secretary of power as the convenor. The committee included the following members: Secretaries from the agriculture, planning and finance, and water resources departments, the chairman and MD of PSPCL (the DISCOM), the vice-chancellor of Punjab Agriculture University, and the chairman of the Farmers Commission. The primary role of this committee is to monitor the scheme's progress and make policy-level decisions.

2. **District-Level Implementing Committee:** This committee was chaired by the deputy commissioner of the district with the superintending engineer of PSPCL as the convenor. The district heads of agriculture and soil conservation are members of this committee. It focused on scheme implementation and sharing feedback with the state-level committee on issues faced by farmers.
3. **Field-Level Implementation Committee:** This committee is chaired by the sub-divisional officer with the executive engineer of PSPCL as its convenor. The assistant divisional officer (agriculture), sub-divisional officer (water resources) and heads of Krishi Vigyan Kendras (KVKs) are its members.

A2.3 Outcomes

A study carried out by the International Water Management Institute (IWMI) found that the combination of daytime electricity provision and cash incentives for unused electricity has the potential to incentivize farmers to reduce electricity consumption and self-reported irrigation hours by at least 7.5% and up to 30% without impacting paddy yields (Mitra et al., 2022). The study also found a reduction in electricity consumption at the treatment feeders compared to the control feeders. However, there was no significant effect on pumping hours from the uninterrupted daytime electricity supply alone, suggesting that a shift in electricity and groundwater pumping behaviour will depend on the entitlement and cash incentive offered under the scheme combined with the daytime supply. However, interviewed state officials and experts cautioned that more data is required from a larger sample size before any definitive conclusions are drawn regarding the scheme's impact on electricity and water consumption. Consultations with experts revealed that crop diversification was not a priority objective, given farmers' assured income from paddy and wheat cultivation.

A2.4 Financing of the Scheme

In the first phase of the scheme, no budget had been allocated by the state government to PSPCL for providing timely subsidy payments and metering costs, which affected the timely payments of subsidies to beneficiaries, given the financial difficulties faced by PSPCL. This was addressed in the second phase of the PBPK scheme, where an allocation of INR 40 crore was provided in the state's agriculture subsidy budget for the PBPK scheme, of which INR 5 crore was reimbursed to PSPCL for scheme implementation. Interviews with utility officials revealed that the majority of that amount had already been spent (INR 4.7 crore), highlighting the need for additional budgetary allocation.

An IWMI study estimated that the state could theoretically make subsidy savings through the scheme (Mitra et al., 2022). Their calculations were based on the following assumptions: Punjab provided an incentive of INR 4 per unit of electricity under PBPK, whereas the electricity tariff in the state was INR 5.66 per unit. The state would have saved INR 1.66 per unit from the agricultural subsidy bill. With a total electricity consumption of almost 12 billion units in agriculture in the FY 2021–2022, a 10% reduction in electricity consumption would translate into a reduction of USD 26 million in government subsidies (Mitra et al., 2022). However, further data is required to confirm this hypothesis, particularly taking into account the upfront capital and operational cost of implementing the scheme.

A2.5 Challenges and Solutions

Farmer Enrolment Due to Lack of Trust

The scheme faced initial resistance from farmer unions, particularly over apprehensions surrounding the metering of agricultural electricity supply (MGSIPA, n.d.). Although the scheme clearly excluded a disincentive for overconsumption beyond the stipulated limit, consultations with government officials revealed that the deep-rooted resistance to metering given its perceived linkages with billing—as well as farmers' lack of trust with DISCOMs in receiving payments—were the main reasons that many farmers were initially reluctant to join the scheme. This deep-seated opposition to metering by farmers is not limited to Punjab, and an MGSIPA study highlighted that in other states—Karnataka, Tamil Nadu, and Telangana—metering and billing had been vehemently opposed by farmer unions and representatives (MGSIPA, n.d.).

The challenge was addressed in the scheme's implementation through outreach and farmer engagement campaigns. The following steps were taken to boost enrolment:

1. PSPCL and the Agriculture Department conducted door-to-door campaigns. The involvement of the agriculture department played a key role in building trust with individual farmers (MGSIPA, n.d.).
2. The local district administration, PSPCL, and agriculture department officials organized large-scale awareness camps and meetings.
3. The World Bank and J-PAL SA teams designed leaflets in local languages and distributed them in target villages.
4. Local NGOs dealing with environmental issues and civil society organizations were also involved in helping build awareness of the environmental impact of excessive groundwater extraction.
5. In the first year, the timely payment of subsidies by PSPCL helped bolster enrolment as the scheme's benefits were communicated through word of mouth among farmers.

All of these factors played an important role in bolstering enrolment in the first phase of the PBPK scheme.

Monitoring and Enrolment Challenges

A study found that there were some cases where farmers with multiple tubewell connections enrolled one of their tubewells in the scheme and utilized the other tubewell for irrigation, which enabled them to earn a higher incentive without the accompanying reduction in groundwater extraction (MGSIPA, n.d.). This challenge was overcome through a modification issued by the state government, which mandated the enrolment of all tubewells owned by farmers (within the targeted PBPK feeders) for participation in the scheme (MGSIPA, n.d.).

Furthermore, there were other bureaucratic challenges faced in scheme implementation since only farmers whose names were registered under an electricity connection could initially access incentives under the scheme (Asian Development Bank, 2020). This made it challenging for tenant farmers and legal heirs of deceased farmers to participate in the scheme initially. Although the transfer of land titles was relatively straightforward, the transfer of an electricity connection was difficult, given the restrictions over new agricultural electricity connections in the state. Expert consultations revealed that the state overcame this challenge by issuing an amendment to enable electricity connections to be held jointly in the name of legal heirs. Similarly, tenant farmers were reluctant to participate because landowners with registered electricity connections would receive the incentive under the scheme rather than cultivators who worked in the field. The scheme's design was modified to enable the transfer of the incentive to the tenant farmer (Asian Development Bank, 2020).

A study also highlighted the potential challenge of power theft through the bypassing of electricity meters (MGSIPA, n.d.). Although this was not observed during the two phases of the PBPK scheme, it was highlighted as a possibility, underscoring the need for regular monitoring by utility officials in other states. The use of smart meters could help address this challenge by helping the utility monitor power supply, tubewell usage hours, and remotely monitor load. Although smart meters weren't used in the first phase of the scheme, several electronic meters were replaced with smart meters in late 2021 (MGSIPA, n.d.).

Capacity Building of the DISCOM

The implementation of the PBPK scheme relied on several initiatives to be undertaken by PSPCL, including feeder separation, grid upgrading to ensure daytime power supply to farmers, outreach and awareness campaigns, monitoring and vigilance to prevent farmers using multiple pumps or bypassing meters, the purchase and use of innovative IT tools, and timely payments of water incentives to farmers. Given PSPCL's financial situation, dedicated budgetary funding from the state and the support of external knowledge partners, such as the World Bank, J-PAL SA, and The Energy and Resources Institute, were essential for implementing the scheme.

Interviews with DISCOM officials also highlighted the problem of a lack of dedicated human resources for the scheme's implementation, which significantly burdened the electricity utility. Given the phasedown in the involvement of other departments after a few years of the scheme, the DISCOM faced a human resources constraint in implementing PBPK. A study also highlighted that regular training and capacity-building activities for the field staff of the DISCOM and agriculture department were critical factors for the scheme's success since they were the primary touchpoints on PBPK with farmers (MGSIPA, n.d.).

Supply of Daytime Electricity to Farmers

During the implementation of the second phase of the PBPK scheme, a technical challenge emerged regarding the provision of daytime electricity supply to the targeted 250 feeders (MGSIPA, n.d.). Significant investments were required to upgrade the electricity infrastructure at the substation level in order to cope with the higher system loads, which were unfeasible given the poor financial situation of PSPCL, the state electricity utility (MGSIPA, n.d.).

In order to overcome this challenge, the state steering committee decided to revise the scheme's design so that feeders would be supplied power in shifts and not during the daytime as had been originally envisaged due to constraints in the state's electricity transmission system. This underscores the potential for combining feeder solarization under the PM-KUSUM scheme with PBPK to provide a daytime electricity supply.

A2.6 Learnings and Recommendations

The PBPK pilot scheme included several innovative measures in both the scheme design and its implementation that can help address some sustainability concerns of solar irrigation. These include:

DBT Scheme for Agriculture

The PBPK pilot scheme used a DBT model to incentivize farmers to use electricity and water judiciously. The use of DBT models can help improve subsidies targeting and address the groundwater depletion challenges that have emerged over the past few decades from the provision of subsidized and unmetered electricity in the agriculture sector as well as mitigate the risk of groundwater depletion being accelerated by solar irrigation in specific contexts. The main challenge is likely to be the implementation capacity of state agencies to implement both the PM-KUSUM scheme as well as water incentive mechanism schemes like PBPK, given the multitude of implementation challenges that have been previously highlighted.

PBPK's design is based on one of three DBT models, where farmers do not receive an upfront cash incentive. They are instead allocated a seasonally adjusted predetermined amount of electricity units based on their capacity (HP) of connected load and are paid a monetary incentive directly in their bank accounts if they use less than their allocated consumption. The electricity consumption of farmers that enrol in the scheme is monitored using smart meters. Because availing cash incentives under PBPK are linked to their electricity consumption, a study found that farmers were keen to install meters in their fields instead of resisting them as they had in the past (Gulati, 2021).

Focus on Water-Saving Techniques in Demonstration Farms

Punjab created demonstration farms on three of the scheme's feeders to highlight the benefits of water-saving techniques and resource-conservation technologies and to encourage farmers to scale up these practices across the state (PSPCL, 2022). A similar setup of demonstration farms could be considered by states to promote the adoption of micro-irrigation and other resource-conservation technologies along with solar irrigation.

The technologies and practices that were showcased on the demonstration farms included short-duration paddy variety crops, alternate wetting and drying irrigation, plotting, no-till farming, as well as flow meters and remote operation devices for turning on and off pumps. Farmers could voluntarily select which of these technologies and practices they were interested in and receive a demonstration.

An evaluation study by the IWMI did not find any changes in farming practices, such as changes in crop choice, shifting to a shorter-duration paddy variety, or adopting improved water management techniques such as direct seeding of rice and bunding (Mitra et al., 2022). This is likely a consequence of the study being conducted in the first year of enrolment for most farmers, whereas behaviour change and efficient farming practices take more time.

Coordination Structures and Incentives for Implementing Agencies

Aside from water-conservation practices and incentives, the PBPK scheme's design also focused on creating institutional structures that could promote effective interagency coordination and better implementation. Consultations with state officials and research institutes that were involved in the pilot's implementation highlighted these as critical in addressing sustainability concerns. Some of these elements include:

1. Consultations with farmers, agriculture and water experts, as well as field staff of DISCOMs to adjust the scheme's design. The implementation of the scheme also relied on three independent advisors who were experts in the agriculture, power, and water sectors.
2. Ensuring high-level political and administrative commitment to the scheme through the chairing of the implementation by the chief secretary and regular briefing meetings with the chief minister. Apart from this, the scheme ensured that transparent communication channels were established between agencies (power, water, agriculture, extension, and finance)
3. A multi-layered and empowered institutional mechanism was created (as elaborated earlier) to monitor the scheme's implementation and make timely decisions.

However, challenges have emerged over time, with officials highlighting the drop in involvement of other departments in PBPK due to multiple competing priorities.

The Model for Determining Benchmark Electricity Consumption

Under the PBPK, an average monthly electricity quota based on the pump motor capacity was fixed for each agriculture feeder (MGSIPA, n.d.). The formula used to determine the quota was based on the previous year's electricity usage divided by the total tubewell load at a feeder level. The average was worked out on a seasonal basis with a higher allocation for paddy, as it is a more water-intensive crop and a lower average for the non-paddy season. In Phase 1, this entitlement during paddy season was about 200 KWh/HP/month, and in the second phase feeders, it is feeder-wise, in the range of 110–180 KWh/HP/month (Asian Development Bank, 2020).

Interviews with agriculture experts have suggested that the state should have used landholding size instead of connected load to determine benchmark electricity consumption since the current model benefits large farmers with a higher benchmark consumption. However, this would necessitate investments in updating land records and correlating them with the consumer list used by the electricity utility before implementation. Therefore, the electricity usage-based quota was chosen for practical reasons.

The Potential for Replicating the Scheme in Other States/Contexts

Learnings from the PBPK scheme in Punjab may not be applicable to other parts of the country with different agroeconomic contexts. Indeed, a pilot study conducted in Gujarat that trialled electricity-linked incentives for farmers found a high enrolment for metering but no impact on water consumption (Fishman et al., 2016). Learnings from Punjab also suggest that the scheme design needs to be carefully calibrated in areas with a high share of tenant farmers.

Therefore, it is important for states to adopt a learning-by-doing approach and constantly gather data on implementation.

An IWMI study suggested there are three broad considerations determining the general applicability of the scheme to other parts of water-stressed regions in North-West India (Mitra et al., 2022).

1. A farmer's decision to reduce pumping hours (and electricity consumption) will depend on the marginal return from pumping, which is determined by the groundwater depth, cropping pattern, and existing or potential future markets for agricultural produce.
2. The prevalence of water markets and pump ownership patterns are likely to affect the efficacy of a similar scheme. In Punjab, most farmers have their own pumps, which results in virtually no sharing of water with non-pump owners. However, in regions with a collective well ownership (e.g., Gujarat) or a market for selling water (e.g., Bihar and West Bengal), the PBPK scheme may be less effective since, in these areas, the revenue earned through water sales may be higher than the incentive provided.
3. Another consideration for policy-makers in improving the scheme's design is setting up a different benchmark for electricity consumption at a monthly level. Under the PBPK scheme, aside from different allocations between the main kharif and rabi seasons, monthly allocations of electricity units are the same within a specific period, for example, June to October. However, as electricity use is highest during the June to August period, modifying the fixed monthly entitlement to one that reflects the variation in demand within the season might result in greater electricity savings.

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