Powering Agriculture in India

Strategies to Boost Components A and C Under PM-KUSUM Scheme

Anas Rahman, Shalu Agrawal, and Abhishek Jain

Report | August 2021

India has seen a massive growth in solar-powered irrigation with more than three lakh solar pumps installed in the last decade.

Image: Sasmita Patnaik

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Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation and clean energy finance.

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In ten years of operations, The Council has engaged in 278 research projects, published 212 peer-reviewed books, policy reports and papers, created 100+ new databases or improved access to data, advised governments around the world nearly 700 times, promoted bilateral and multilateral initiatives on 80+ occasions, and organised 350+ seminars and conferences. In July 2019, Minister Dharmendra Pradhan and Dr Fatih Birol (IEA) launched the **CEEW Centre for Energy Finance**. In August 2020, **Powering Livelihoods** — a CEEW and Villgro initiative for rural start-ups — was launched by Minister Mr Piyush Goyal, Dr Rajiv Kumar (NITI Aayog), and H.E. Ms Damilola Ogunbiyi (SEforAll).

The Council's major contributions include: The 584-page *National Water Resources Framework Study* for India's 12th Five Year Plan; the first independent evaluation of the *National Solar Mission*; India's first report on global governance, submitted to the National Security Adviser; irrigation reform for Bihar; the birth of the Clean Energy Access Network; work for the PMO on accelerated targets for renewables, power sector reforms, environmental clearances, *Swachh Bharat*; pathbreaking work for the Paris Agreement, the HFC deal, the aviation emissions agreement, and international climate technology cooperation; the concept and strategy for the International Solar Alliance (ISA); the Common Risk Mitigation Mechanism (CRMM); critical minerals for *Make in India*; modelling uncertainties across 200+ scenarios for India's low-carbon pathways; India's largest multidimensional energy access survey (ACCESS); climate geoengineering governance; circular economy of water and waste; and the flagship event, Energy Horizons. It recently published *Jobs, Growth and Sustainability: A New Social Contract for India's Recovery*.

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The Council has a footprint in 22 Indian states, working extensively with state governments and grassroots NGOs. It is supporting power sector reforms in Uttar Pradesh and Tamil Nadu, scaling up solar-powered irrigation in Chhattisgarh, supporting climate action plans in Gujarat and Madhya Pradesh, evaluating community-based natural farming in Andhra Pradesh, examining crop residue burning in Punjab, promoting and deploying solar rooftops in Delhi, Bihar and Meghalaya.

Acknowledgment

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"Decentralised solar energy has huge potential to improve irrigation access and farmers' income. The report highlights the importance of innovating and adapting the different models to suit the local context for PM-KUSUM to achieve its objectives sustainably."

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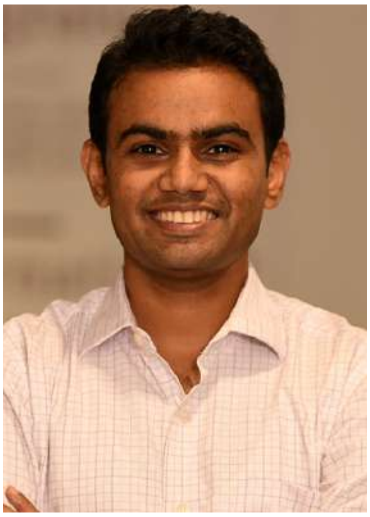
Shalu, a Senior Programme Lead, leads The Council's work on residential energy access, demand-side management and power sector reforms. She uses data to study the changing energy landscape and devise strategies to ensure universal access to affordable, reliable, and sustainable energy. She recently led India's first-ever Residential Energy Survey (IRES) that covered ~15,000 households across 21 Indian states. A Chevening scholar, Shalu holds an MSc from University College London and a BTech from IIT Roorkee.

"An integrated approach, which is sensitive to concerns of all stakeholders, the political economy of farm-power subsidies, and has farmers at its centre, can help unlock solar-power for Indian farms. Conducting pilots, demonstrations, and actively seeking on-ground feedback will provide critical ingredients for PM-KUSUM's success."



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As a Fellow at CEEW, Abhishek built and leads its practices on energy access, rural livelihoods, and sustainable food systems. He also directs 'Powering Livelihoods', a $3 million initiative. He co-conceptualised and leads CEEW's flagship research, 'Access to Clean Cooking Energy and Electricity – Survey of States'. With more than 10 years of experience, Abhishek has worked on multiple issues at the confluence of energy, development, and the environment. He is a Chevening Fellow and an alumnus of the University of Cambridge and IIT Roorkee.

"PM-KUSUM holds a massive potential to solarise Indian agriculture and enhance farmer incomes. We hope that this report will help address the implementation gaps to realise the potential on the ground."

Contents

Agriculture is one of the major power consuming sectors. Promoting solar-powered irrigation sustainably can ensure a more just and equtable transition to clean energy in the agri sector.

Figures

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Acronyms

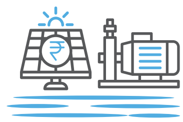
AC	alternating current
AGCC	avoided generation capacity cost
APEPDCL	Andhra Pradesh Eastern Power Distribution Company Limited
APPC	avoided power purchase cost
ARPC	avoided REC purchase cost
ATCC	avoided transmission capacity cost
BCD	basic customs duty
BESCOM	Bangalore Electricity Supply Company Limited
BLDC	brushless DC
CAPEX	capital expenditure
CBA	cost-benefit analysis
CERC	Central Electricity Regulatory Commission
CREDA	Chhattisgarh Renewable Energy Development Agency
CSPDCL	Chhattisgarh State Power Distribution Company Limited
DC	direct current
DGVCL	Dakshin Gujarat Vij Company Limited
DISCOM	distribution company
FOR	Forum of Regulators
GoI	Government of India
GUVNL	Gujarat Urja Vikas Nigam Limited
HESCOM	Hubbali Electricity Supply Company Limited
HP	horse power
INR	Indian rupees
ISTS	Inter-State Transmission System
JVVNL	Jaipur Vidyut Vitran Nigam Limited
KERC	Karnataka Electricity Regulatory Commission
KREDL	Karnataka Renewable Energy Development Limited
KSEB	Kerala State Electricity Board
LoA	Letter of Approval
MEDA	Maharashtra Energy Development Agency
MERC	Maharashtra Electricity Regulatory Commission
MGVCL	Madhya Gujarat Vij Company Limited
MNRE	Ministry of New and Renewable Energy
MPERC	Madhya Pradesh Electricity Regulatory Commission
MSKVY	*Mukhyamantri Saur Krushi Vahini Yojana*
MW	megawatt
NPV	net present value
OPEX	operational expenditure
PBI	performance-based incentive
PGVCL	Dakshin Gujarat Vij Company Limited
PM-KUSUM	*Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan*
PPA	power-purchase agreements
REC	renewable energy certificate
RPG	renewable power generator
RPO	renewable purchase obligation
RRECL	Rajasthan Renewable Energy Corporation Limited
SARFAESI	*The Securitisation And Reconstruction Of Financial Assets And Enforcement Of Security Interest Act*
SCADA	supervisory control and data acquisition
SECI	Solar Energy Corporation of India
SERC	state electricity regulatory commissions
SIA	state implementing agency
SKY	*Saur Kranti Yojana*
SME	small and medium enterprises
SNA	state nodal agency
SPV	special-purpose vehicle
UGVCL	Uttar Gujarat Vij Company Limited
VGRS	Valuing Grid-connected Rooftop Solar

In India, where agriculture is a significant contributor to growth and livelihoods, access to reliable irrigation is a major policy objective.

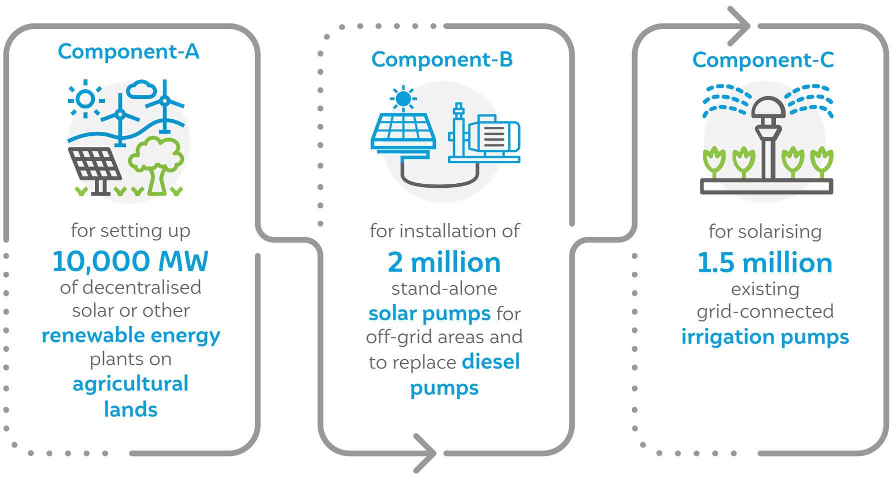
Image: iStock

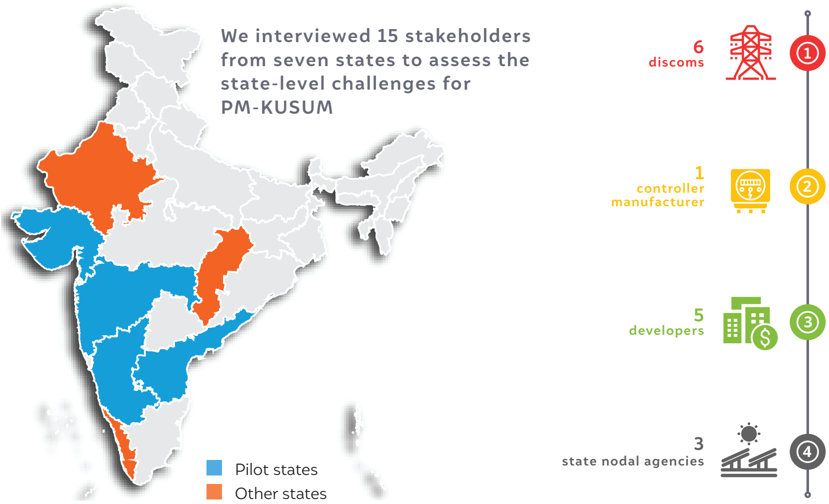
Executive summary

The Government of India launched the *Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan* (PM-KUSUM) scheme in 2019 to improve irrigation access and farmers' income through solar-powered irrigation. Under its components A and C, the scheme aims to promote innovative models for solar-powered irrigation by setting up solar power plants on agricultural land, and solarising existing grid-connected pumps, respectively. These components intend to support farmers to be net energy producers and earn an additional income. Concomitantly, the state governments are expected to reduce their agriculture power subsidy bills, while the discoms procure low-cost solar power sourced closer to the consumers through these models.



Components A & C of the PM-KUSUM scheme have not taken off in most states





Notwithstanding the pandemic-related challenges, with almost half the scheme's target period already over, these components have not taken off in most states. Only the Rajasthan government has offered letters of award for projects under Component-A. Rajasthan is also the only state that has begun installing grid-connected solar pumps under Component-C, that too on an experimental basis. In contrast, Component-B of the scheme promotes stand-alone solar pumps and is progressing well across many states. Therefore, this study investigates the reasons behind the slow uptake of the components A and C of the PM-KUSUM scheme and proposes solutions to overcome the key barriers.

Surplus contracted generation capacity and unattractive tariffs emerged as key challenges

We do so by capturing the experience of seven Indian states in the implementation of the components A and C of the PM-KUSUM scheme and related previous pilots. Our findings are based on detailed interviews with 15 key informants across power distribution companies, state nodal agencies, developers, system integrators, and manufacturers. During the semi-structured interviews, which lasted for 45-90 minutes, we focused on identifying potential administrative, regulatory, financial, operational, and technical challenges hindering the scheme's rollout. We also discussed possible solutions to address these challenges. In addition, we conducted a scenario-based economic analysis to assess the economic viability of Component-C for farmers, the power distribution companies (discoms), and the government. Below we summarise our key findings and recommendations.

Component-A

Under Component-A, farmers can set up solar or other renewable power plants on their land (directly or by leasing out land to developers), and the discom would purchase power from them. Most discom respondents were enthusiastic about this component due to its potential to reduce the power-purchase cost, but shared concerns about several implementation challenges, including surplus of contracted generation capacity. Unattractive tariffs for developers, delays in land leasing/conversion and inability of farmers to mobilise equity or debt finance also emerged as key challenges. To overcome these challenges, we propose the following recommendations for Component-A.

1. **Modify the scheme timelines to enable the inclusion of Component-A in discoms' power-purchase planning**

   Many discoms are not in a position to benefit in the short term from the component due to surplus contracted capacity and low variable cost of power from conventional power plants. Many are not in a position to shoulder the additional burden for long-term benefits, a situation further exacerbated by the pandemic-induced stress on discoms' finances. Savings from renewable purchase obligation (RPO) fulfilment also depends on the discoms' power-purchase plans and the level of enforcement of RPO regulations. The Ministry of New and Renewable Energy (MNRE) should modify the timelines for the scheme to enable the discoms to align the component with their power-purchase planning and gain maximum benefit from the component. The central government should also strengthen the RPO regulations enabling the discoms to plan for RPO fulfilment through Component-A power plants.

2. **Reduce risks and improve the competitiveness of decentralised power plants**

   The MNRE should study the impact of new customs duty on the cost competitiveness of small-capacity power plants and take appropriate measures to mitigate the associated disadvantages. The MNRE, in consultation with the Forum of Regulators (FOR), should also prepare a guidance note for the state SERCs to standardise an approach for tariff for Component-A power plants considering the factors like limited economies of scale, lower DC-to-AC conversion efficiency, etc. Two key risks concerning the deployments under Component-A are grid unavailability and counter-party risk. The MNRE should strengthen the compensation clauses in grid unavailability and put the onus on the discoms to ensure a minimum grid availability. The discoms should be penalised in the event of failure to honour the power-purchase agreements (PPAs) to reduce the counterparty risks for the developers.

3. **Undertake broader policy reforms to address the bias against distributed solar power plants**

   Under the current Inter-State Transmission System (ISTS) regulations, solar power plants are exempt from transmission charges, and no transmission losses are accounted for towards solar generation. This statute, which was brought in over a decade ago to promote the solar power sector, has unintendingly favoured large utility-scale solar power plants in a few states with high generation potential, like Rajasthan, over the distributed solar plants. The former offers cheaper rates due to favourable generation conditions and the discoms do not have to bear the inter-state transmission costs, thus reducing the effective cost of power by about INR 0.5-2.2 per kWh (Menghani 2021). The central government should do away with this archaic statute and initiate policies favouring distributed power plants if Component-A or similar schemes are to succeed.

4. **Streamline land regulations to ensure smooth implementation**

   State regulations concerning land leasing and land conversion from agricultural to non-agricultural uses have been a critical barrier in the scheme's implementation. Some states prohibit the leasing of agricultural lands for non-agricultural purposes. Even states like Karnataka, with provision for 'deemed diversion' of agricultural land for solar projects, have witnessed administrative delays in this regard. Implementing agencies should work closely with the state revenue department to identify and address these challenges.

5. **Adopt innovative models to overcome financing challenges with farmer-owned power plants**

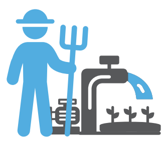
   Usual means of project financing for developers are inadequate for farmer-owned power plants for two reasons. One, farmers are not able to raise/contribute the 30 per cent equity for the power plant. Two, in the absence of any track record as a developer, they cannot access loans from banks without collateral. Banks do not take agricultural land as collateral for non-agricultural purposes. State nodal agencies (SNAs) need to work with financial institutions to try innovative models such as the farmer-developer special-purpose vehicle (SPV) piloted in Karnataka.

6. **Ensure inter-departmental coordination to mitigate any issues in the planning and implementation phases**

   Multiple agencies like the discoms, SNAs and revenue departments have roles to play at different stages of implementing this component. States should form a PM-KUSUM steering committee, led by the implementing agency, with state-level representatives from all the concerned departments. Such an arrangement can anticipate any inter-department coordination issues in the planning and implementation phases and address them.

Component-C

The Component-C of the PM-KUSUM scheme aims to support the solarisation of the existing grid-connected pumps through two models – individual-pump solarisation and feeder-level solarisation. In this study, we focused only on the individual solarisation model as many of the challenges and issues concerning feeder-level solarisation are akin to Component-A.



Without farmer contribution, the economic viability of the individual grid-connected pump solarisation model is uncertain

We find that most stakeholders are *not* enthusiastic about this model. The discom representatives unanimously anticipated difficulty getting farmers to pay the upfront contribution, as most target farmers already benefit from free or highly subsidised power. In the absence of upfront beneficiary contribution from the farmers, the economic viability of the component is uncertain. The alternative financing options – either increasing the farmer's loan component or increasing the government subsidy share – both necessitate a lower feed-in tariff (FiT) while balancing the burden on the exchequer. In such cases, the opportunity cost of selling power becomes higher for the farmer, as they could benefit more by growing more crops or selling water to neighbours. We find that, in specific contexts, farmers have chosen such alternative options, which in turn affects the loan repayment and the financial viability of the model. We also found that the SERCs are not adequately equipped to assess the opportunity costs of selling surplus power while deciding the FiT, leading to a wide variation in the FiT under Component-C across states.

Carefully designed financial models should be piloted in different contexts before scaling-up Component-C

We also identify operational challenges for the discoms pertaining to metering and billing, free-ridership, and gaps in infrastructure. While metering is critical for accounting under Component-C, it is afflicted by issues of trust deficit between the farmers and the discoms and challenges in billing sparsely distributed agricultural connections. The free-rider problem emerges when only some farmers in a feeder participate in the scheme, while the rest gain access to reliable day-time supply without investing in the solar asset. Finally, inadequate maintenance of the agricultural feeders by the discoms due to poor revenue recovery is also a concern, as Component-C requires that feeders are well-maintained and on, at least during the daytime.

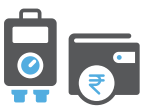
Overall, there remain significant uncertainties around the economic viability and operational sustainability of Component-C. We propose the following steps to address the unknowns before implementing the model at scale.

1. **Discoms should lead the component's implementation**

   The study makes it abundantly clear that the implementation of the component will throw up many challenges that only the discoms can tackle. The discoms' role in Component-C is pre-eminent, and all the states should appoint the discoms as the implementing agency for the component.

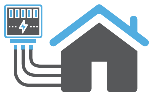
2. **Pilot the model in different contexts**

   The experience from the limited number of pilots on the individual-pump solarisation model so far suggests that the outcome of Component-C depends on an array of localised factors. The current cropping pattern, the existing power supply conditions and alternative options with surplus power are some of these determinants. Given that these factors vary immensely even within states, states must carry out pilots in different agroeconomic contexts before scaling up the model. The pilots should specifically test out the following aspects:



Beneficiary contribution and metering modalities: Farmer's willingness to pay for solarisation would depend on many factors like the current supply condition, the FiT and the metering modality. The discoms need to test out different combinations of financing structure and metering options acceptable to farmers and assess their economic viability.

Use of surplus power and impact on groundwater: Using surplus power for selling water or cultivating more crops can put more stress on the groundwater, particularly in water-scarce regions. The discoms should conduct pilots to study farmers' behaviour concerning surplus power and water use, to better plan their deployment strategy. They should also prioritise farmers using water-efficient practices to achieve the component objectives sustainably.

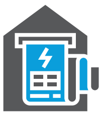


Feasible approaches to address metering, billing and free-rider problem: Technological solutions like smart meters and smart transformers can address some of the operational concerns but come with their own challenges. Network connectivity and trust issues with remote billing can pose a challenge. The discoms must engage with the farmers in the target feeder to ensure maximum participation in a feeder, build trust, and promote community ownership of the scheme during the pilots.

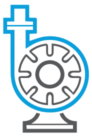
Infrastructure costs: The discoms should carry out comprehensive infrastructure assessment in the pilot projects to assess the infrastructure challenges and costs. The study should include pump sizes in use by the farmers, the status of grid infrastructure, and sources of other commercial losses before implementing the component in any feeder.

3. Complement the component with other key measures to make it viable

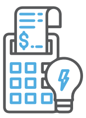
The states along with the MNRE could take some essential steps to make Component-C more feasible and sustainable.



Larger reforms in agriculture power supply: It is pretty difficult to get farmers to contribute to the scheme component in the backdrop of free agriculture power. Component-C cannot be decoupled from the larger reforms needed in the sector. Instead, it should be implemented in consonance with subsidy and tariff reform measures.



Pump replacement: Although the states are not receiving the central government's subsidy share for pump replacement, replacing old inefficient pumps with efficient ones is likely to have a net positive outcome for both the state and the farmer. The discoms can test out the overall benefit from pump replacement through pilot studies.

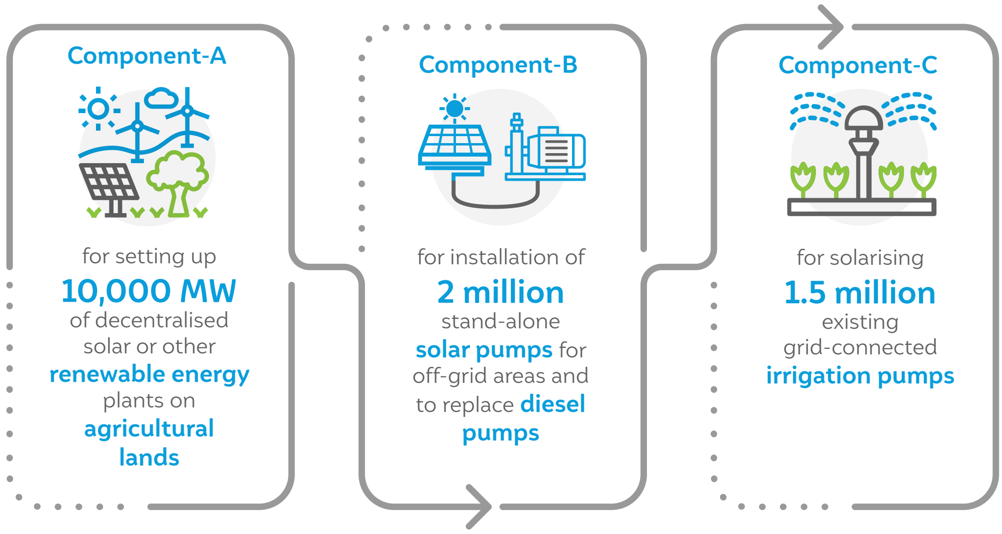


Framework for determining FiT: As the conventional methods of determining electricity tariffs are inadequate to capture the complexities of the scheme, the MNRE should create a framework to guide the SERCs to determine a FiT that is viable for the discom, farmers, and the state government.

The poor quality and unreliability of agricultural power supply has been a major impediment in improving productivy. Solar power can ensure quality daytime power supply.

1. Introduction

In March 2019, the Government of India launched the *Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan* (PM-KUSUM) scheme. The scheme has four main objectives: to improve farmers' income from agriculture, to improve access to reliable power, to reduce the agriculture sector's dependency on fossil fuels, and to reduce the power subsidy to agriculture (MNRE 2019). The scheme aims to achieve these objectives by facilitating the deployment of more than 25,000 MW of solar capacity by 2022 under three components. These are:



While the stand-alone solar pumps have been promoted in India for nearly a decade, components A and C are novel approaches, with only a few pilots so far. As of March 2020, more than 280,000 stand-alone solar pumps have been installed in the country (Figure 1). Under Component-B of the PM-KUSUM scheme, 24,688 stand-alone pumps have been installed (as of 24 March 2021), nearly 15 per cent of the targeted 0.17 million pumps for 2020-21; the installation is ongoing in 11 states (Lok Sabha 2021). However, halfway through the scheme's target period, components A and C are yet to take off in most states as planned.

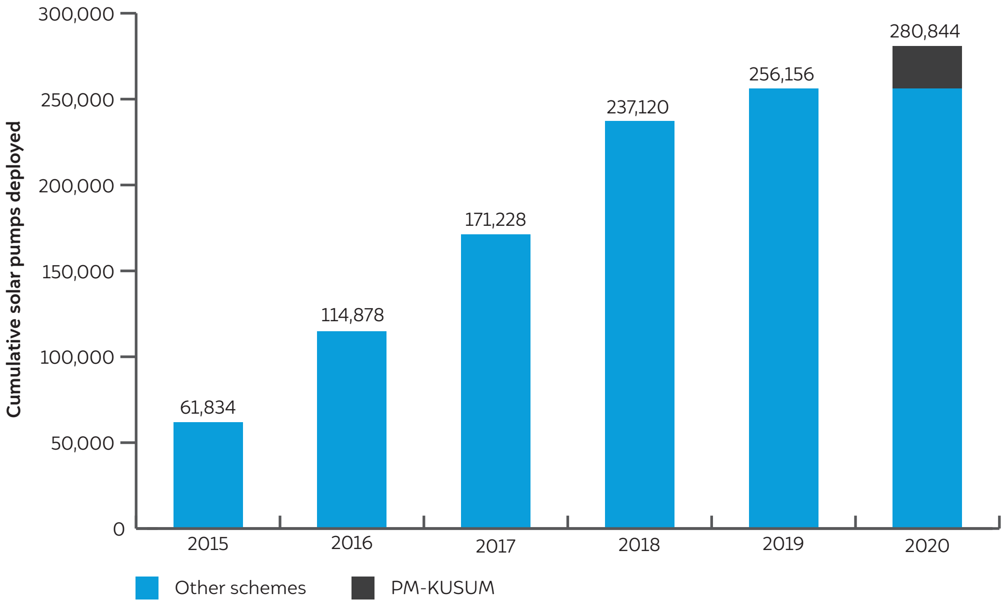


Figure 1
More than 200,000 standalone solar pumps have been deployed in India during 2015-20

Source: Authors' analysis of the MNRE annual reports and parliamentary questions

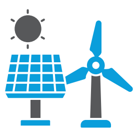
1.1 Component-A: Decentralised solar plants on farmlands

Under PM-KUSUM's Component-A, farmers can set up renewable energy power plants of 0.5-2 MW capacity on their lands. The concerned power distribution company (discom) would purchase the power at a predetermined levelised tariff. The participating farmers have two choices: (i) invest and own the power plant or (ii) lease their farmland to a developer.

Component-A is inspired by the Solar Farmer scheme launched by the Karnataka government in 2014, which allowed farmers to install solar power plants of 1-3 MW capacity on their land and sell the power to the discom. But unlike Component-A, the tariff under the Karnataka scheme was fixed (at INR 8.4/kWh) and not discovered through competitive bidding (KERC 2017). The farmers were selected on a 'first-come-first-serve' basis. Against a target of 310 MW by 2019, 296 MW of solar capacity was installed under the scheme (KREDL 2020). After completing the initial target, the state government did not scale up the scheme further.

The *Mukhyamantri Saur Krushi Vahini Yojana* (MSKVY) scheme in Maharashtra also promotes distributed solar power plants. The experience from the scheme provides insights on the potential commercial and technical challenges for Component-A.

Through Component-A, the PM-KUSUM scheme aims to benefit farmers by enabling an alternative income source from their agricultural lands. The power plant can also improve the power supply situation in the locality, especially in areas with poor quality supply, thus improving access to electricity for other farmers. The discoms are expected to gain by reducing their power procurement cost, transmission capacity requirements, and transmission and distribution (T&D) losses. To make the proposition attractive for the discoms, the MNRE provides a performance-based incentive to the discoms for the renewable energy generated under the scheme.



MNRE had kept a target of ~4.3 GW capacity for 2020-21 under Component A

The MNRE had kept a target of 4,344 MW for the year 2020-21 (MNRE 2021). Table 1 presents the scheme's progress in different states as of 31 March 2021. Only the Rajasthan state government has offered the letter of award (LoA) for 725 MW of solar capacity to successful bidders. The first solar power plant in the country under Component-A was commissioned on 31 March 2021 in Rajasthan (*The Hindu* 2021).

Table 1 Only Rajasthan has made any significant progress in rolling out Component-A

States	Notification of scheme	Determining ceiling tariff	Tender stage	Letter of approval for work	Commissioning
Rajasthan	✓	✓	✓	✓	✓
Haryana, Karnataka, Madhya Pradesh, Tamil Nadu, Kerala, Tripura, Uttar Pradesh, Odisha	✓	✓	✓		
Punjab, Telangana, Jharkhand	✓	✓			
Himachal Pradesh, Gujarat, Chhattisgarh, Maharashtra, Meghalaya	✓				
Total number of states reaching the stage of implementation	17	12	9	1	1

Implementing agency: blue - State nodal agency (SNA); black - discom
Source: Authors' analysis based on government notifications, SERC petitions and orders, and news articles

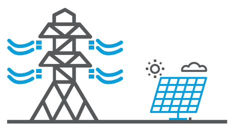
1.2 Component-C: Grid-connected solar irrigation pumps

Component-C of PM-KUSUM aims to reduce the power subsidy burden for states through the solarisation of existing agriculture feeders and connections. Solarisation would ensure good quality daytime power for the farmers. For the state, a one-time capital investment could help reduce the recurring power subsidy burden. Power procured from decentralised solar units and plants close to the consumption could reduce the cost of power supply for the discom. Component-C proposes two models:

1. **Solarisation of individual existing grid-connected pumps:** Under this model, farmers with existing grid-connected pump sets are eligible for subsidies to solarise their connections. In addition to the benefit of adequate daytime supply, farmers would be able to sell any excess power to the grid at a predetermined tariff, gaining supplementary income.
2. **Feeder-level solarisation:** Under this model, the discoms could develop decentralised solar power plants near agriculture feeders to cater to the entire feeder loads, to reduce their cost of power supply to agricultural consumers. This model, unlike the individual pump solarisation, does not have the involvement of farmers. This model has similarities with Component-A and took inspiration from an ongoing MSKVY scheme in Maharashtra (Box 1).

BOX 1 Mukhyamantri Saur Krushi Vahini Yojana (MSKVY)

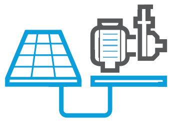
MSKVY, launched in 2015 in Maharashtra, aims to solarise agriculture feeders in the state through decentralised solar plants (2-10 MW capacity). Unlike Component-A in the PM-KUSUM scheme, solar plants under the Maharashtra scheme can also be set up on private and revenue lands, besides agricultural land. The primary aim of MSKVY is to reduce the cost of power supply to agriculture connections. Against a targeted capacity of 3,654 MW, the Maharashtra Electricity Regulation Commission (MERC) has granted approval for projects totalling 1,826 MW capacity. These projects are at various stages of development (Gambhir et al. 2021).



Solarising grid-connected pumps would ensure quality daytime power supply and help reduce subsidy burden

The MNRE introduced the feeder-level solarisation model only in December 2020. This study focuses only on the individual pump solarisation model.

There have been three previous or ongoing schemes by different state governments that supported grid-connected solar pumps.



There have been three previous or ongoing schemes by different state governments that supported grid-connected solar pumps

- *Surya Raitha Scheme (Karnataka):* This was a pilot project launched in 2015, in which Bangalore Electricity Supply Company Ltd (BESCOM) solarised 310 pumps of up to 7.5 HP capacity in a feeder (Institute of Social and Economic Change 2018). As per the respondent from the discom, the discom adopted unidirectional metering under which farmers can only feed-in power implying that the irrigation pump can run only on solar power. The farmers could sell the surplus power to the grid for INR 7.2 per unit. The project financing came from the MNRE subsidy and loans availed by the discom on behalf of farmers. The discom apportioned INR 6 per unit from the feed-in tariff for the repayment of loans. The discom also formed a collective of the participating farmers for smooth implementation of the project. The state government did not scale up the project beyond the pilot feeder.
- *Grid-connected pumps (Andhra Pradesh):* This was a pilot project launched by the Andhra Pradesh Eastern Power Distribution Company Ltd (APEPDCL) in 2016. Under this project, APEPDCL replaced 216 grid-connected pumps of up to 5 HP capacity with solar panels and brushless direct current (BLDC) pumps. In this arrangement, the farmer could run the pump exclusively on solar power, and sell any surplus power to the grid for a feed-in-tariff of INR 1.5/kWh. The discom fully financed the scheme from its fund. A farmers' cooperative, formed by the participating farmers, facilitated the implementation of the scheme. The state did not scale the project up beyond the pilot feeder.
- *Suryashakti Kisan Yojana or SKY (Gujarat):* Launched in 2018, the scheme solarised individual pumps with bidirectional metering (the pump can run both on solar power and grid power). The farmers make an upfront contribution of five per cent of the capital cost, the MNRE contributes 30 per cent of the cost, and the discoms source the remaining amount through loans on behalf of the farmers. The feed-in tariff for the scheme is INR 3.5/kWh. In addition, the state government provides an evacuation-based incentive to the farmer of INR 3.5/kWh (with an upper limit of 1,000 unit/HP/year). A part of the income generated from energy sale is apportioned for paying back the loans in seven years. Gujarat has implemented the scheme in 91 feeders constituting 97 MW solar capacity so far. As per the respondent from GUVNL, the state will continue the implementation of SKY on the 137 feeders initially targeted. The state plans to cover the remaining feeders under PM-KUSUM.

The remaining report will use the terms 'pilot schemes' and 'pilot states' for the three projects and states mentioned above.

The rollout of Component-C has been significantly delayed in most states. Only Rajasthan has started installing pumps, and that, on an experimental basis, without any financial contribution from the beneficiary. Table 2 summarises the progress of different states in the implementation of Component-C.

Table 2 Grid-connected solar pump model under Component-C is yet to take off in most states

States	Determining ceiling tariff	Tender stage	Letter of approval for work	Installation of pumps
Rajasthan	✓	✓	✓	✓*
Haryana, Gujarat, Kerala, Tripura, West Bengal	✓	✓		
Odisha, Jharkhand, Tamil Nadu, Punjab	✓			
Total number of states reaching the stage of implementation	11	6	1	1

Implementing agency: blue - SNA; black - discom

** 64 pumps installed on experimental basis*

Source: Authors' analysis based on government notifications, SERC petitions and orders, and news articles

1.3 Study objectives

Components A and C will have important implications for states' agriculture and energy landscape. It is essential to understand the reasons for the slow uptake of these models across states, identify solutions, and do any necessary mid-term course corrections.

With this motivation, we capture the perception and experience of relevant actors across select Indian states regarding the scheme design and implementation. While it is too early to do a comprehensive evaluation of the scheme, different stakeholders perspectives can provide useful insights into the teething problems experienced during scheme implementation or relevant pilots, along with potential solutions.

Devising context-specific deployment strategies, in line with feedback from farmers and other key stakeholders, would be critical to scale up solar-powered irrigation.

Image: Anas Rahman/CEEW

2. Methodology

PM-KUSUM components A and C are in the early stages of their implementation with limited publicly available data. Hence, we employ semi-structured interviews with key stakeholders, programme managers, and service providers to capture their experiences so far. Semi-structured interviews are excellent tools for formative evaluation in the early-stage implementation of a scheme (Wholey, Hatry, and Newcomer 2010). We complement the interview-based analysis with a cost-benefit analysis (CBA) to understand the viability of Components A and C.

We interviewed government officials, discom and SNA representatives, developers and manufacturers to capture their experience so far

Multiple stakeholders are involved in the implementation of PM-KUSUM components A and C, as discussed below.

- **State governments** provide subsidy support for grid-connected pumps. The scheme aims to replace the recurring power subsidy borne by the state with a one-time capital subsidy. The state's perception of the costs and benefits of the scheme is central to their participation in the scheme.
- **Discoms** are the primary interface with customers (farmers). The scheme has significant implications on the discom's finances and operations with its impact on the power-procurement cost. The discoms' full buy-in is necessary for the scheme's long-term success.
- **SNAs for renewable energy**, being the implementing agencies in many states, are also important stakeholders. They have domain expertise in many aspects of the scheme.
- **Developers' and system integrators**' perception of the viability of the scheme is also essential for their participation. For Component-C, given the novelty of the system design, they will have to work with controller manufacturers as well.

We consulted key informants from these stakeholder groups to understand their perspective and the challenges – administrative, financial, operational, and technical – they are facing in implementing the scheme. We selected informants based on two critical criteria: their prior experience in implementing pilots similar to PM-KUSUM components A and C and the state's relative progress in implementing these components. Andhra Pradesh, Karnataka, Maharashtra, and Gujarat have implemented pilot projects that inspired components A and C. Rajasthan is a frontrunner in implementing the scheme. Kerala was among the first states to notify the scheme, but the state delayed the later stages. Chhattisgarh is yet to launch the scheme despite being the leading state in deploying stand-alone solar pumps.

We conducted telephonic interviews with a total of 15 informants representing 15 organisations from seven Indian states, as described in Table 3. The study also covered publicly available documents of different states on the PM-KUSUM scheme. These include petitions and tariff orders of state electricity regulatory commissions (SERC), government orders and notification tender documents of multiple states, and news articles.

Table 3 The study covers 15 key informants from five stakeholder categories

S. No	Stakeholder category	Name of the organisation (state)
1	Power discoms	Gujarat Urja Vikas Nigam Ltd (Gujarat)
2		Bangalore Electricity Supply Company Ltd (Karnataka)
3		Andhra Pradesh Eastern Power Distribution Company Ltd (Andhra Pradesh)
4		Jodhpur Vidyut Vitran Nigam Ltd (Rajasthan)
5		Chhattisgarh State Power Distribution Company Ltd (Chhattisgarh)
6		Kerala State Electricity Board (Kerala)
7	State nodal agencies (SNAs)	Karnataka Renewable Energy Development Ltd (Karnataka)
8		Rajasthan Renewable Energy Corporation Ltd (Rajasthan)
9		Chhattisgarh Renewable Energy Development Agency (Chhattisgarh)
10	Developers	Developer 1: Participated in the Andhra Pradesh grid-connected BLDC pump pilot project
11		Developer 2: Participated in the SKY scheme of Gujarat
12		Developer 3: Participated in the MSKVY scheme of Maharashtra
13		Developer 4: Participated in the MSKVY scheme of Maharashtra
14		Developer 5: Participated in the MSKVY scheme of Maharashtra
15	Manufacturer	Controller Manufacturer: Worked with the Andhra Pradesh discom for implementing grid-connected BLDC pump pilot project

Source: Authors' compilation

3. Component-A: key insights and challenges

Most stakeholders expressed a favourable opinion for Component-A. However, concerns about its commercial viability for different stakeholders and the implementation challenges, as discussed below, have contributed to the delays in the scheme's implementation.

3.1 Commercial viability of the component

One critical factor for the sustainable adoption of Component-A is its economic viability for the key stakeholders, including the discoms, farmers and solar plant developers.

Discom perspective

To understand the discoms' viewpoint, we analysed the potential costs and benefits for the discoms from the component. We used the Valuing Grid-connected Rooftop Solar (VGRS) framework developed by Kuldeep et al. (2019), which takes the following components into account:

1. Avoided generation capacity cost (AGCC): The power generation from a Component-A power plant will reduce the discoms' requirement to add new capacities from a conventional plant. This benefit will manifest as a reduction in the fixed charges of power procurement in the future.
2. Avoided power purchase cost (APPC): Procuring solar power would reduce the quantum of conventional power purchase. Accordingly, the discom can expect a reduction in its outlay against the variable cost of power procurement.

3. Avoided transmission capacity cost (ATCC): With the reduction in power procured from conventional power plants comes the additional benefit of reducing the requirement for new transmission capacity. This would help reduce associated transmission charges, which are fixed in nature.
4. Avoided REC purchase cost (ARPC): Under RPO regulations, the discoms must purchase a fixed portion of their power from renewable energy sources. In the event of a shortfall, the discoms have to make it up by purchasing renewable energy certificates (RECs). Component-A will reduce the discoms' requirement to purchase RECs.
5. Performance-based incentive (PBI): Under Component-A, the central government offers a PBI of INR 0.4/kWh for energy generated from the solar power plants for the first five years.

Note: The savings from reduction in T&D losses are accounted for in AGCC and APPC. We have assumed that the power generated from the Component-A power plant is consumed within the supply area of the substation.[1]

Discoms can benefit from Component-A in the long term. But several considerations influence their decision in the short term

Figure 2 demonstrates the costs and benefits of setting up a 1 MW solar plant under Component-A for a discom in Karnataka. Our analysis shows that, in the long term, the Karnataka discoms are expected to benefit by INR 0.54 for every unit of power they purchase under Component-A. However, several considerations influence the discoms' decision in the short term.

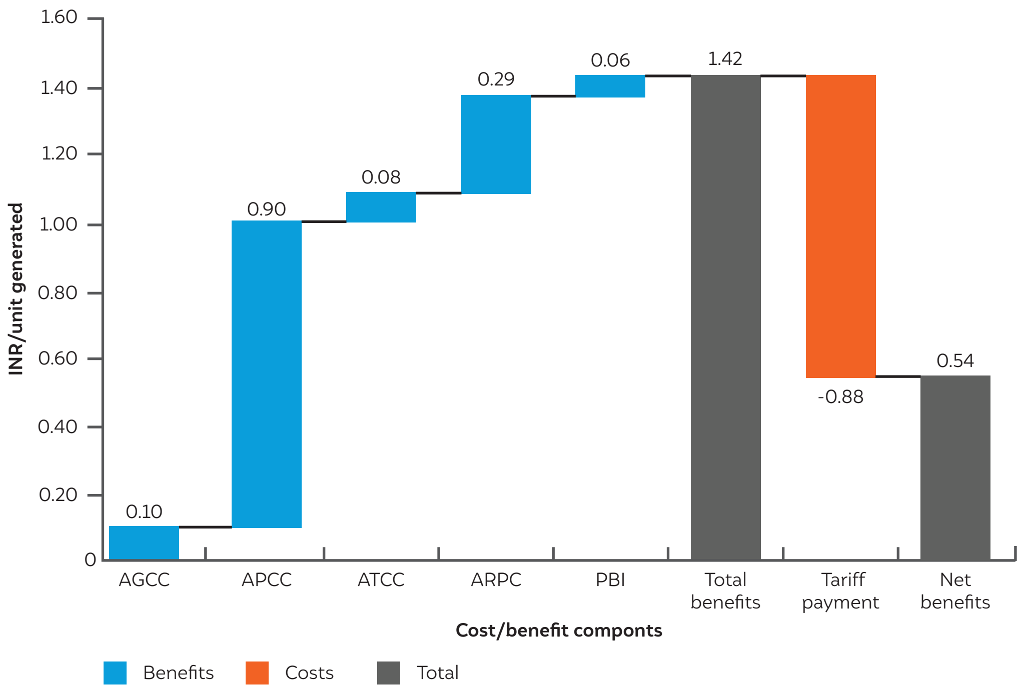


Figure 2
A Karnataka discom would gain a net benefit of INR 0.54 for each unit produced from the Component-A power plant over 25 years

Source: Authors' analysis using VGRS framework developed by Kuldeep et.al. (2019). See Annexure I for detailed calculations and assumptionsand parliamentary questions

First, the power procurement costs vary across states. Figure 3 illustrates how the average cost of power (including variable and fixed component) compares with the FiT notified by select states under Component-A. In states like Kerala and Odisha, where the current power cost is lower than the FiTs, Component-A offers a limited incentive. However, in most other states, solar power FiT is lower than the total power costs and may lead to cost savings.

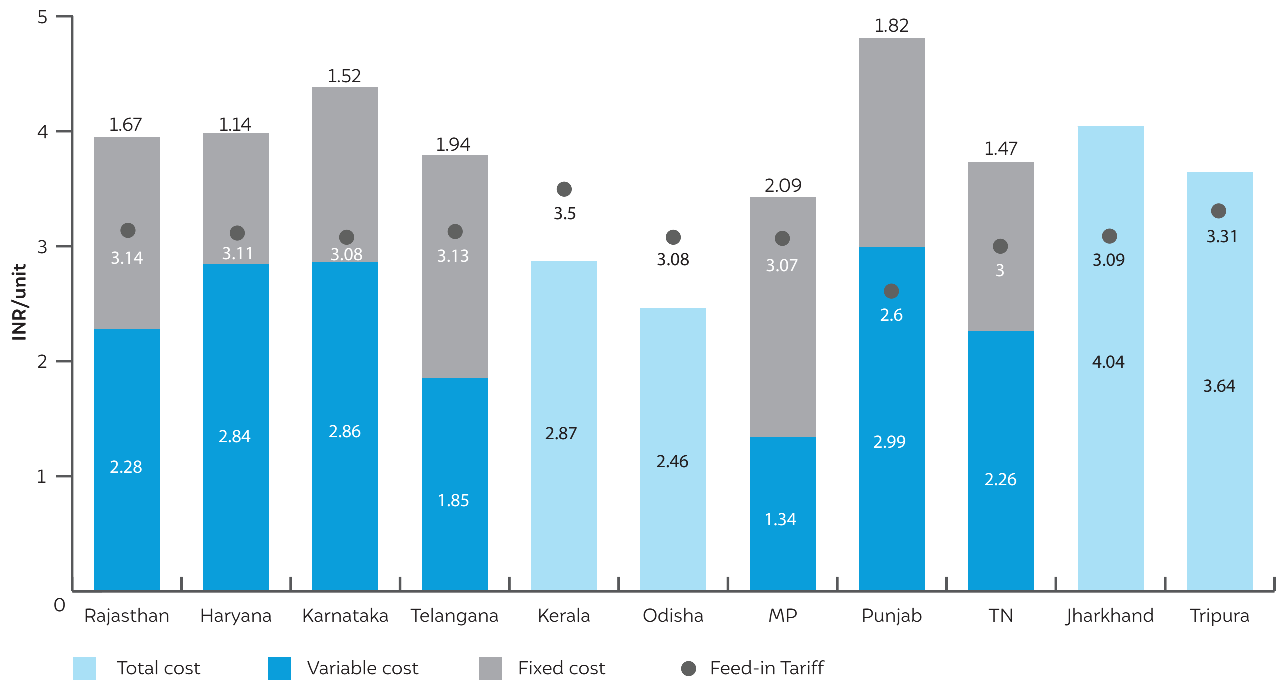
However, most discoms in India have contracted capacities in excess of their current demand (CERC 2020). Such discoms will have to continue paying the fixed generation and

1 As per the respondents from multiple discoms, the discom has kept an upper limit for the Component-A power plant, typically at 60-70 per cent of substation capacity. We assume that this practice would limit the instances of generation exceeding the demand from the substation.

transmission charges throughout the contract period. In the short term, their benefits from procuring solar power under Component-A would be limited to the variable cost component and savings from T&D losses. But it is also pertinent to note that some states like Karnataka and Rajasthan provide only six hours of power supply to agricultural connections and many other states provide power supply to pumps at night-time to balance load. This practice discounts the actual power demand and the consumers end up paying for it with reduced productivity. If the actual demand is considered, the AGCC savings will kick in early on.

Component-A still makes economic sense for states like Punjab, with variable cost higher than the FiT. However, in most states, the FiT is higher than the current average variable costs. It should be noted that, though here we have used average variable cost, there will be many PPAs with variable costs higher than the FiT. It is quite possible that the power purchase avoided due to Component-A are from such PPAs, in which case the component is beneficial for the discom even in the short term. However, it would depend upon the time of the day and seasonal factors, and not all conventional power can be replaced by solar power. Thus, savings for the discoms in the short term would depend on the current power-purchase scenario. In Karnataka, for instance, the electricity regulator raised this concern during the tariff hearing and approved only a pilot phase with a capacity of 50 MW, according to the representative from the SNA.

Figure 3 In most states, the ceiling tariff for Component-A is lower than their average cost of power purchase



Source: Authors' analysis of latest SERC tariff orders from respective states and CERC[2] documents

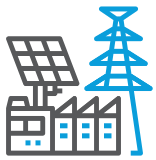
Second, the savings against RPO fulfilment are not a significant factor for most discoms simply because these are poorly enforced. Most states have achieved less than 60 per cent of the mandated target under RPO (Mercom India 2019). For states with a renewable share in excess of the RPO mandate, such as Karnataka, the option of selling the surplus in the REC market is not a powerful incentive due to the subdued REC prices. However, the Ministry of Power has increased the target for solar RPO steeply, from 2.75 per cent in 2018-19 (Lok Sabha 2017) to 10.5 per cent in 2021-22 (MoP 2021). Depending on the RPO enforcement, savings from RPO could become a significant incentive for implementing Component-A for many states going forward.

2 The tariff orders of Kerala, Odisha, Jharkhand, and Tripura do not provide enough data to disaggregate the power-purchase cost into variable and fixed costs.

Regardless of the current power-purchase scenario and RPO fulfilment states, energy demand will only increase for all the discoms in the future. Under Component-A, there is an excellent opportunity for the discoms to reduce their power-procurement cost in the medium and long term. However, most discoms are in a poor financial state, and their current priority is to improve their financial health in the short term. Respondents from one of the discoms pointed out that the PM-KUSUM scheme in its current form, with time-bound targets, does not give enough space for the discoms to include it in their power-procurement planning. The central government should modify the scheme to provide more flexibility with timelines and let the discoms realise its full commercial benefit. States like Maharashtra have included distributed solar-power generation in their power-procurement policy, giving adequate time for the discoms for planning and implementation (MEDA 2020).

Utility-scale vs distributed solar plants

From a strictly commercial perspective for the discom, utility-scale solar power plants currently have an advantage over distributed solar plants. The tariff for utility-scale solar plants is much lower than the Component-A ceiling tariff set by the states, predominantly due to economies of scale. The lowest tariff for utility-scale solar power plants discovered so far is INR 1.99/kWh (*The Hindu BusinessLine* 2020). Other advantages, like avoiding generation-capacity cost and avoiding REC cost, as described in Figure 2, apply to utility-scale plants.



The main advantage of the distributed solar power plants over utility-scale solar plants is the reduced T&D losses due to localised production and the avoided transmission capacity requirements. However, the current policy framework on solar power negates this advantage. Presently, solar power plants connected to the Inter-State Transmission System (ISTS) are exempted from the ISTS charges, and no transmission losses are attributed to solar power plants (CERC 2010). This statute implies that the discoms can get solar power at the state periphery from a distant solar power plant without incurring any transmission cost or losses. According to one estimate, the benefit of ISTS-sharing rules to utility-scale power plants is anywhere between INR 0.5-2.2 per kWh based on different approaches of calculating the ISTS charges and losses (Menghani 2021).

Waiver of ISTS charges for solar plants gives a cost advatage for utility-scale solar plants over distributed ones

Thus, it makes more commercial sense for the discoms to procure power from a utility-scale power plant from distant locations rather than promote small-scale solar power plants in their operational area. States like Rajasthan and Gujarat can offer very low tariffs for utility-scale plants due to favourable generation conditions. If PM-KUSUM or similar initiatives to promote distributed solar power generation are to succeed, the central government needs to make broader policy reforms to address the bias against distributed solar plants.

Developer perspective

The developers raised a concern that the tariffs being set for Component-A by states are not commercially viable. The experience from Maharashtra's MSKVY is pertinent here. In the initial stages of the scheme, MERC had allowed a ceiling tariff of INR 3.09 (MERC 2018). But the tenders elicited very few bids, potentially due to the non-viability of the projects at that rate. MERC has acknowledged this in their subsequent orders, and since then, has gradually revised the tariff upwards, reaching INR 3.30 (MERC 2020). MSKVY allows up to 10 MW capacity plants. Given that the cost per MW increases with a decrease in plant capacity, Component-A, with a 2 MW ceiling, is likely to elicit even lesser interest among developers.

Most states have fixed a ceiling tariff of less than INR 3.14 (see Figure 3). The developers interviewed believed that these rates were not viable, and the states may find it difficult to get interested bidders. The reason for the lack of interest is the increased cost expectations of developers for Component-A power plants due to the factors discussed below.

Rise in module prices

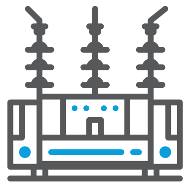
The MNRE has recently introduced basic customs duty (BCD) for solar PV modules and cells (MNRE 2021). Along with other taxes and surcharges, the new rules constitute a tax rate of ~46 per cent and ~27 per cent for solar PV modules and cells, respectively. This is a quantum jump from the safeguard duty (~15 per cent) that used to exist earlier. This measure is meant to promote the domestic solar manufacturing sector. However, the domestic manufacturing capacity faces multiple challenges (Jain, Dutt, and Chawla 2020), due to which the price of domestic modules is also likely to go up by almost the same amount as the imported ones in the short term. Further, many government schemes, including components B and C of PM-KUSUM, mandate domestically manufactured solar modules and cells. Given limited domestic manufacturing capacity, there could be a supply constraint to meet the demand for Component-A.

One of the respondents among the developers estimated an effective increase of INR 0.50/kWh in solar tariff due to the new rules. Market experts also share this viewpoint (*ET EnergyWorld* 2021). Developers are not clear whether the increase will be passed through to the discom or be borne by them. If passed through, the component becomes an economic burden for the discom. If not, the projects are no longer viable for the developers at the rate decided by many states.

Higher CAPEX and OPEX for small-scale solar power plants

Compared to large-scale solar plants, many factors increase the costs of distributed small-scale plants. These include higher equipment cost due to lower economies of scale, lower DC-AC ratio[3] for smaller capacity plants (Marcy 2018), and higher cost of the feeder infrastructure on a per watt basis. The operation and maintenance (O&M) cost of small power plants is also considerably higher than the large utility-scale power plants due to the higher staff capacity required per MW. One respondent stated that the O&M costs for a utility-scale plant are INR 2-2.5 lakh/MW; the same for a small-scale distributed power plant increases to INR 4.5-5 lakh/MW.

We also learnt that developers in the small and medium enterprise (SME) category and big farmers are most likely to participate in the scheme. Big developers will typically stay away from the distributed solar power space as the economics and operations are different from their current business model. Typically for utility-scale power plant developers, they work with an intermediary to manage the land aggregation and administrative procedures. But for small power plants, the overheads in dealing with multiple farmer landowners in different locations become very high. For SMEs and farmers, the cost of debt is much higher than large utility-scale developers, adding to the project cost.



Frequent outages at 11 kV substations increases the cost of electricity from Component-A power plants

Poor-quality grid infrastructure

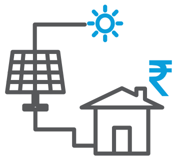
Multiple stakeholders, including officials from SNAs, expressed concern about the poor quality of grid infrastructure at the tail end, as the 11 kV feeders are often prone to faulting. Since the Component-A power plant is connected to the substation, faulting of individual feeders should not be a concern since, theoretically, the power can then flow to some other feeder within the substation or even upstream. However, respondents said that poor maintenance of tail-end substations by many discoms often leads to frequent tripping of the whole substation. The generation potential during this period gets wasted.

3 DC-AC ratio, also known as inverter load ratio (ILR), is the ratio of power DC capacity of the PV arrays to the AC capacity of the inverter. A higher DC-AC ratio implies that the inverter capacity required is lower which reduces the cost. DC-AC ratio is typically higher for larger solar power plants (Marcy 2018).

To illustrate the challenge, a respondent who participated in the MSKVY scheme mentioned that the grid availability of their MSKVY power plants is 95-96 per cent, while the same for their utility-scale solar plants is 99.5-99.8 per cent. The same respondent mentioned that Maharashtra is far better than other states when it comes to grid availability. When they had operated a similar project in another state, the grid availability was less than 80 per cent. Consequently, it is compulsory to deploy permanent staff in all power plants to manage the outages, escalating the O&M cost.

The guidelines of Component-A provide a mechanism to address the issue of grid unavailability. The relevant portion of the guidelines is reproduced below:

> “*In the event of backdown, subject to the submission of documentary evidences from the competent authority, the Renewable Power Generator (RPG) shall be eligible for a minimum generation compensation, from DISCOM, restricted to the following and there shall be no other claim, directly or indirectly against DISCOM:*
>
> *Minimum Generation Compenstaion*
>
> $$= 50\% \text{ of average generation per hour during the month} \times \text{Number of backdown hours during the month} \times \text{PPA tariff}$$
>
> *The RPG shall not be eligible for any compensation in case the backdown is on account of events like consideration of grid security or safety of any equipment or personnel or other such conditions.*”



The MNRE should study the impact of new taxes on small solar plants and enact measures to protect them from cost escalation

Some developers said the compensation provided might not be sufficient as there are many exemptions for this condition. It is not clear if grid unavailability due to tripping or other substation faults is eligible for compensation. Moreover, since the grid unavailability is considerably high for distributed solar plants, even a 50 per cent compensation would not be sufficient to ensure viability. One respondent suggested that the approach adopted in the latest MSKVY tender may be much more business-friendly. In the MSKVY tender released in April 2021, the discom set a benchmark of 98 per cent grid availability in a year. In the event of grid availability going below 98 per cent, the discom will compensate the developer for generation loss at 75 per cent of the tariff calculated against average hourly production in the year. This provision puts a minimum guarantee in terms of grid availability.

Counter-party risk

Developers also expressed concerns about the track record of the discoms in honouring PPAs. As per some respondents, apart from the discoms of a few states like Karnataka, Maharashtra and Gujarat, most other discoms have routinely faulted on timely payment and delayed the payments for many months. The developers prefer PPAs with central government entities like Solar Energy Corporation of India (SECI), where payment security exists.

To sum up, there are significant challenges in the component’s uptake both from the perspective of the developers and the discoms. While the increase in the module prices may still keep the utility-scale solar power plants competitive from the discoms’ perspective, the same is not true for small-scale solar plants due to their higher overhead costs and risks involved. The MNRE should study the impact of new taxes on small solar plants and enact measures to protect them from cost escalation. It should consider other factors that increase the cost of small-scale plants and create a guidance note for the states in determining the tariff. It should also reconsider the grid availability clause in the model PPA and put the onus on the discoms to keep a minimum percentage of grid availability for the PM-KUSUM plants.

Benefit for the farmers

> **States can mandate a minimum lease rent as a share of the tariff to ensure remunarative income for farmers**

Component-A benefits farmers in two ways – (i) farmers taking part in the scheme directly benefit from the additional income from energy sale or the rent, and (ii) the larger community-level indirect benefits due to improvement in the power supply quality and duration. Here we focus on the challenges associated with the former.

PM-KUSUM presents a peculiar challenge for the SERCs in determining tariff – it is not just a scheme for promoting renewable energy but also to generate income for farmers. As the tariff petition for Component-A in the Madhya Pradesh ERC (MPERC) puts it, "*the word 'Utthaan Mahabhiyan' in 'Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan' specifies the sole purpose of the scheme, which is to increase the income of farmers*" (MPERC 2020). The comment was in respect to the concern raised by one of the parties that the farmers would not benefit from the scheme if the lease rent is not remunerative. MPERC tried to accommodate this view by raising the tariff, considering a lease-rent component that is remunerative for the farmer.

However, respondents from multiple discoms opined that Component-A should be seen purely as a commercial enterprise. Out of the two ownership models, only the developer-owned model can benefit the poor farmers. If a farmer can arrange even 10 per cent equity for a 0.5-2 MW solar power plant (INR 5-20 million), he/she should not deserve special consideration from the state. Further, in the developer-owned model, higher tariffs may not necessarily translate into higher incomes for farmers, as there is no surety that the farmers can negotiate for higher rent from the developer. Thus, most discom respondents supported leaving the lease rent determination to the market, a practice adopted by most SERCs in India. As an exception, Kerala State Electricity Board (KSEB) has mandated a minimum INR 0.1/kWh generated as lease rent for the developer-owned model (KSEB 2020). This model would ensure a minimum remunerative lease rent for the farmer and could be a viable model for states wishing to promote the lease model.

It is also pertinent to ask who the direct beneficiaries of the component are. In Rajasthan and Karnataka, the respondents mentioned that more than 40 per cent of applicants have chosen to self-invest in the power plant. It indicates that the well-off farmers, who can arrange equity, are the primary beneficiaries of the component. Only a few farmer collectives applied for the scheme in these states, and the remaining were individual applicants opting for the developer-owned model. Most respondents suggested that the farmer collective model could bring benefits to small and marginal farmers. However, at least in the initial phases, the states have not put much effort into roping in farmers' collectives.

3.2 Financing farmer-owned projects

Financing farmer-owned projects is another key challenge in implementing Component-A. During the interviews, we identified two issues related to financing. First, many farmers who bid successfully for projects did not have enough funds to provide the project's 30 per cent equity. This has been a key challenge in Rajasthan, due to which the implementing agency had to extend the last date for submission of performance security multiple times. Farmers in Rajasthan have been demanding a 90:10 ratio of loan-to-equity to access bank loans. But the proposition is not acceptable to banks.

Secondly, even if the farmers can arrange the equity, it is not easy for them to get loans from the banks, which require collateral in the absence of a third-party guarantee (Bank of Baroda 2020). According to the state implementation agency (SIA) respondent from Rajasthan, often farmers want to keep their land as collateral for the project. However, the banks have not agreed to keep the land in use for solar projects as collateral, as, despite the state's 'deemed diversion' law, it is still agricultural land in legal documents. Since security interest is not enforceable for agricultural lands under the SARFAESI Act's provisions, banks do not take agricultural lands as collateral for non-agricultural loans, as debt recovery in the instance of loan default becomes quite complicated (GoI 2002; Sudha and Chakraborty 2019). Moreover, due to the poor track record of the discoms in payment, banks are unwilling to take the risk without any alternative collateral. In Rajasthan, for instance, out of 623 farmers selected for the component based on their applications, only 170 were able to sign PPAs with the discoms (*Times of India* 2021).

To overcome the financing challenges, the state government in Karnataka allowed farmers who were allotted the projects under the Solar Farmer scheme to form SPVs with developers. Under the SPV route, farmers and developers share the initial investment and the annual returns based on a mutual agreement. Banks were also ready to sanction loans based on the financial track record of the developer. This provided the farmers easy access to financing.

3.3 Challenges related to land regulations

Challenges related to leasing or conversion of agricultural land for non-agricultural uses emerged as another key barrier to the uptake of Component-A. Land is a state subject in the Indian constitution, and land regulations vary across states. Land leasing is either not permitted or strictly regulated in many states, while land conversion can be expensive and time consuming. In Madhya Pradesh, the discom, in its petition for Component-A, stated that the state land-leasing laws do not allow agricultural lands to be leased for more than six years (MPERC 2020). Under such provisions, only the farmer-owned model would be workable.

In contrast, Karnataka allows 'deemed diversion' of agricultural land for solar projects, simply based on the application. But, in the Solar Farmer scheme, despite the 'deemed diversion' laws, delays in notification of procedures and lack of clarity led to delays in project implementation (KERC 2017). In Rajasthan, solar power projects do not require land conversion of agricultural lands (Kumar and Thapar 2017).

All states need to carefully review, and if needed, revise their existing land-regulation laws before planning the implementation of the PM-KUSUM scheme. The states also need to consider expeditious clearance of land-conversion applications for the project.

States should institute a steering committee for better inter-departmental coordination

3.4 Gaps in inter-departmental coordination

The Component-A design involves features that typically fall under the domain of more than one department or agency, necessitating inter-departmental coordination for its implementation. The stakeholder experience from Karnataka's Solar Farmer scheme indicates the possible challenges in such coordination. In Karnataka, multiple agencies had roles to play:

- The SNA was the implementing agency for the scheme.
- The revenue department was responsible for approving the conversion of land for non-agricultural use.
- The transmission company was tasked with approving the evacuation infrastructure and interconnections.
- The discoms' role extended to approving interconnection and construction of an evacuation bay in the substation.

Many developers had to face delays in obtaining all the requisite approvals in the absence of institutional coordination. Consequently, such developers could not commission the projects in time and had to face penalties in the form of a reduced tariff (KERC 2017). The reasons for such delays could be many – the respondent from the SIA indicates that developers did not follow the procedure. But it also appears that there was a lack of coordination between departments.

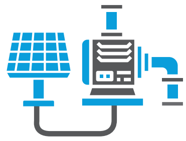
In many states where Component-A is yet to be implemented, respondents from SIAs were unaware of possible coordination challenges like those which cropped up in the Solar Farmer scheme. To ensure smooth and timely implementation of the projects under the component, state governments should proactively form a PM-KUSUM steering committee at the state level, led by the SIA and composed of representatives from all the concerned departments. Such an arrangement would allow anticipation and resolution of any inter-departmental coordination issues in the planning phase itself. The steering committee should also involve other departments and agencies related to agriculture and groundwater. This would enable a holistic planning of the component and achieve its objectives sustainably.

Metering is an important step in solarising agriculture connections, yet past attempts on metering have faced strong resistance from the farmers.

Image: Abhishek Jain

4. Component-C: Key insights and challenges

The Component-C of the PM-KUSUM scheme aims to support the solarisation of the existing agriculture feeders and connections to help reduce the power subsidy burden of the state governments while enhancing farmers' income through the sale of surplus solar power. The discoms are the primary actors in implementing this component. However, during our interviews, almost all the discom respondents were sceptical about the feasibility of the grid-connected solar pump model due to significant implementation challenges and concerns about economic viability.



Only Gujarat has implemented individual grid-connected solar pump model at scale, under its SKY scheme

The general perception is that the scheme would not work in states that give free or nearly free agricultural power. Among the states that had piloted the model, only Gujarat has implemented the model at a reasonable scale. Karnataka government did not find the *Surya Raitha Scheme* suitable for scaling up due to multiple implementation challenges. According to the respondent from the discom, Karnataka strongly favoured introducing a feeder solarisation model within Component-C during their consultations with the MNRE. Respondents from multiple discoms, including Andhra Pradesh – the other pilot state – said that their states prefer the feeder solarisation model as it is much easier for the discom to implement.

When the MNRE introduced the feeder solarisation model under Component-C in December 2020, most states with high irrigation demand preferred it over the individual pump solarisation model.[4] Notably, most of these states had not progressed in the initial year when solarisation of individual pumps was the only option available (Table 2). But they have raised sizeable demands under the feeder solarisation model for the financial year 2020-21 (Annexure I). Among the large states that have opted for the individual solarised pump, only Gujarat has made progress.

In this chapter, we reflect on the commercial viability of the grid-connected solar pump model and discuss the key challenges in its implementation as highlighted by various stakeholders.

4.1 Commercial viability of the component

PM-KUSUM guidelines propose a financing model with a 60 per cent subsidy (30 per cent each from central and state governments) and the remaining as a contribution from the beneficiary. The scheme envisages a 10 per cent upfront contribution from the beneficiary

4 States which raised demand for feeder-level solarisation include Karnataka, Madhya Pradesh, Maharashtra, Punjab and Telangana.

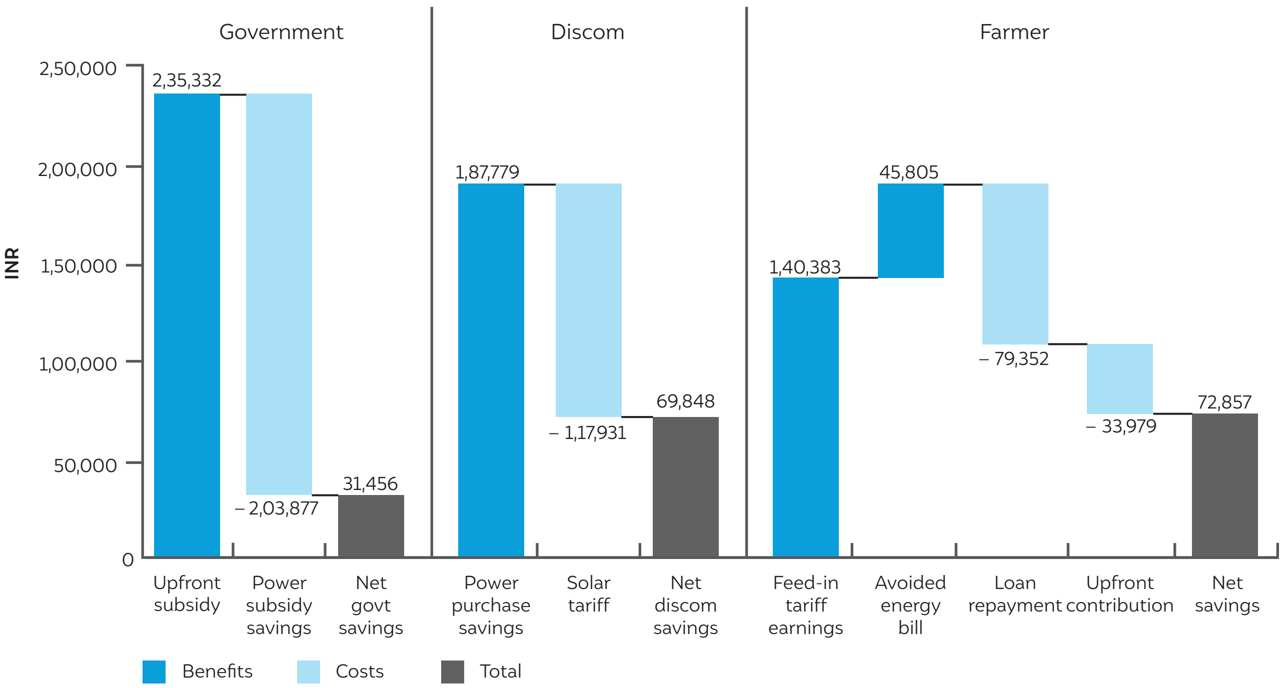
and the remaining 30 per cent as a loan from a scheduled commercial bank. The state government has the discretion to increase their share of subsidy to cover a part or full of the beneficiary contribution.

We did a cost-benefit analysis of the component to understand its economic viability for different stakeholders, viz. the government discom and farmers. We took the example of Gujarat, and analysed the net present value (NPV) of the cash flows for a representative pump of 5 HP capacity, assuming a 25-year life cycle. We assumed 1,000 hours of annual pump operation by the farmer (8 hours/day and 125 days/year) before and after the solarisation[5]. We also did a sensitivity analysis around these assumptions to cover various real-life scenarios. Other key assumptions are listed in Annexure II.

Accordingly, our analysis, summarised in Figure 4, suggests that for each 5 HP pump:

- The state government would realise net savings of ~INR 31,500 by substituting a recurring power subsidy over 25 years with a one-time capital subsidy.
- The discom would save ~INR 70,000 over 25 years by shifting a fraction of its power procurement from conventional sources to the solarised pump.
- The farmer would earn ~INR 73,000 over 25 years.

Figure 4 All three stakeholders would theoretically benefit from Component-C



Source: Authors' analysis (assumptions in Annexure II)[6]

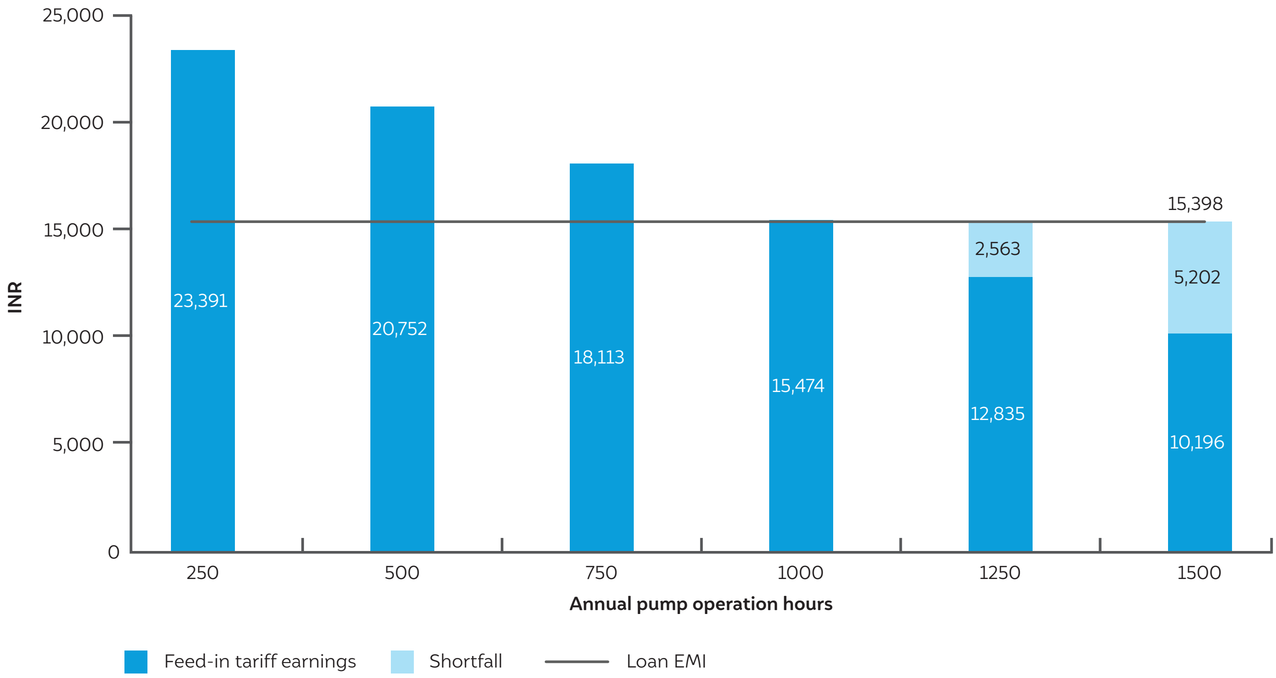
Under the assumed conditions, theoretically, all three stakeholders would benefit. However, a closer look at the numbers reveals potential challenges. Firstly, we note that the farmers' income from energy sale in the initial 10 years of the loan tenure is almost zero. This is because the FiT earnings for the farmer under the assumed conditions is barely sufficient to cover the loan repayment. A higher self-consumption (and, thus, a lower energy export) would mean that the farmers will have to contribute from their pockets to repay the equated

5 Due to the incoherent data on pump usage in different studies, we have based this assumption on two studies. As per a survey with 1.33 lakh farmers in Maharashtra, a majority of farmers practice irrigation for 100-150 days/year (MERC 2020). Further, average hours of power supply to farmers in 11 big states is about 8 hours (Dharmadhikary et al. 2018). Hence, we assume 8 hours and 125 days for our analysis. We have also done a sensitivity analysis of the outcomes based on other pump operation scenarios.

6 Under the stakeholder category 'Government', we have included both central and state governments.

monthly installments (EMI) of the loan. Only at lower self-consumption rates does the net annual income become positive for the farmer during the loan tenure. Figure 5 summarises the cash flows for the discom in the first year for different pump-usage conditions.

Figure 5 At higher self-consumption, feed-in tariff earnings for farmers would not be sufficient to repay the loan



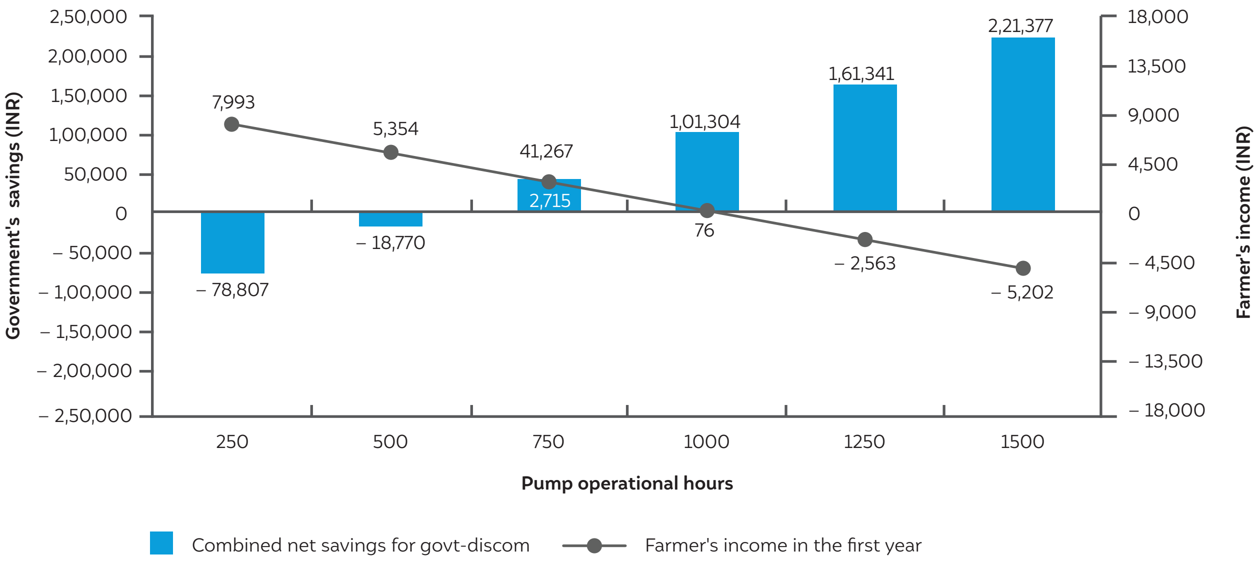
Source: Authors' analysis

To have no or negative income for the first 10 years, despite paying the upfront contribution, would be a very unattractive proposition for the farmers. They would either refuse to participate in the scheme, or look for alternative options to derive immediate returns from surplus power. This in turn would further reduce the quantum of energy fed into the grid, reducing the discoms' benefit from the component. However, it should also be noted that there are other critical costs and benefits which have not been captured in the analysis because of the difficulty in quantifying them. For instance, if the current quality of power supply is poor, the farmers may prioritise improvement in power quality over monetary benefits. It would be important to understand how the farmers perceive such factors by testing the model on ground before scaling up.

Impact of self-consumption

Several factors like water depth, type of crops and intensity of cropping influence the pump usage, due to which pumping hours can vary significantly across farmers. From Figure 5, it may appear that the model is feasible for farmers with low self-consumption, as they will have earnings even in the initial year. However, the combined net savings of the government and the discom would be negative if they target farmers with lower pumping needs as the avoided subsidy is much less (Figure 6). Thus, there is a strong trade-off between the state's economic benefit and a financing structure that would be acceptable to the farmers.

Figure 6 There is a strong negative correlation between farmer's income and combined net savings for the government and discom



Source: Authors' analysis

Challenges in financing Component-C

As per the discom respondents, notwithstanding the results from the cost-benefit analysis, realising the farmers' upfront contribution is a major hurdle for the discom in Component-C implementation. Owing to the availability of free power for agriculture connections, farmers are reluctant to pay the upfront contribution. Respondents from all the discoms consulted in the study mentioned that it would be difficult to get even a bare minimum contribution from the farmers.

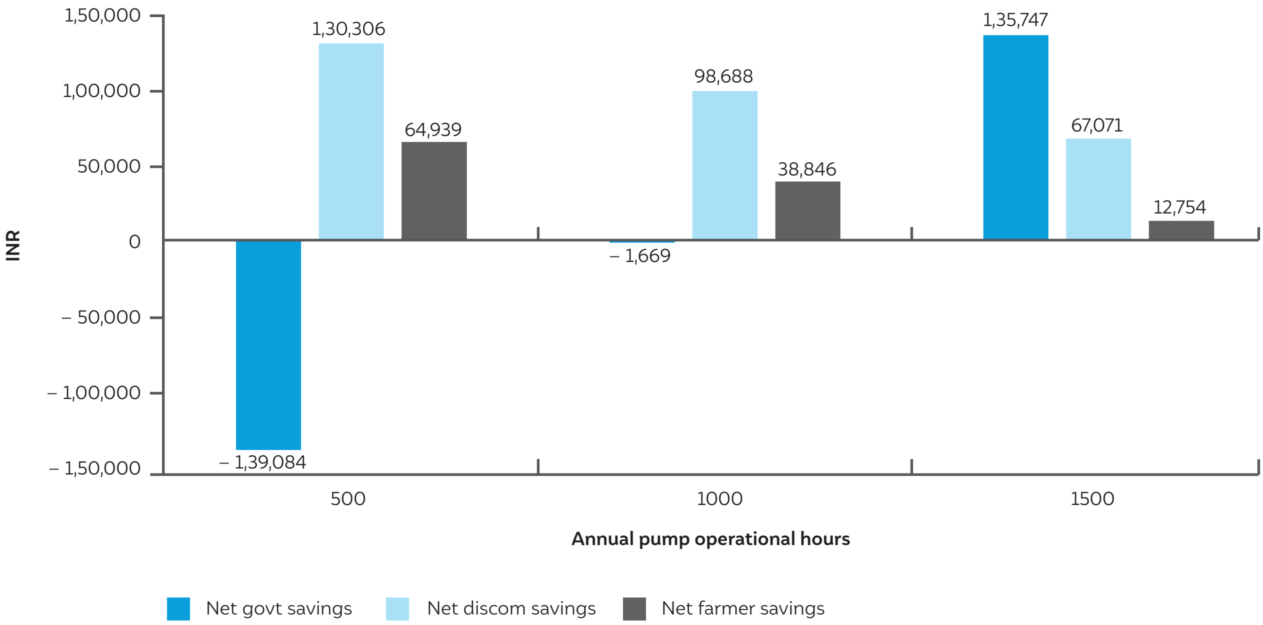
The pilot states experienced similar challenges. Karnataka's *Surya Raitha Scheme* initially envisaged a beneficiary contribution of 15 per cent of the project cost. However, farmers refused to make any contribution, and the portion was later converted into a discom-supported, interest-free loan. In Gujarat's SKY scheme, the discom earlier insisted that at least 90 per cent of the farmers in a target feeder participate in the scheme. However, many farmers refused to provide the initial contribution. The discom had to eventually relax this condition, as per the respondent from GUVNL. Hence, the discoms may have to find alternative financing models.

There are two options for the states to compensate for the farmer's upfront contribution – (i) increase the subsidy, and (ii) increase the loan component. Both will have implications on the economic outcomes discussed above. The pilot states also experimented with these variations. We extended the cost-benefit analysis to pilot projects in two states: Andhra Pradesh and Gujarat.

Full-subsidy model to solarise electric pumps (Andhra Pradesh's pilot)

In Andhra Pradesh, the discom bore the entire cost of the pilot project, with zero beneficiary contribution. The discom kept the FiT at a low INR 1.5/kWh to compensate for the high subsidy. If this model – with zero beneficiary contribution – has to be scaled up, the capital investment would have to come from the state government. Figure 7 shows the net outcome for each of the beneficiaries under different scenarios.

Figure 7 Government savings are highly sensitive to farmer's self-consumption in the full-subsidy model



Source: Authors' analysis (assumptions in Annexure II)

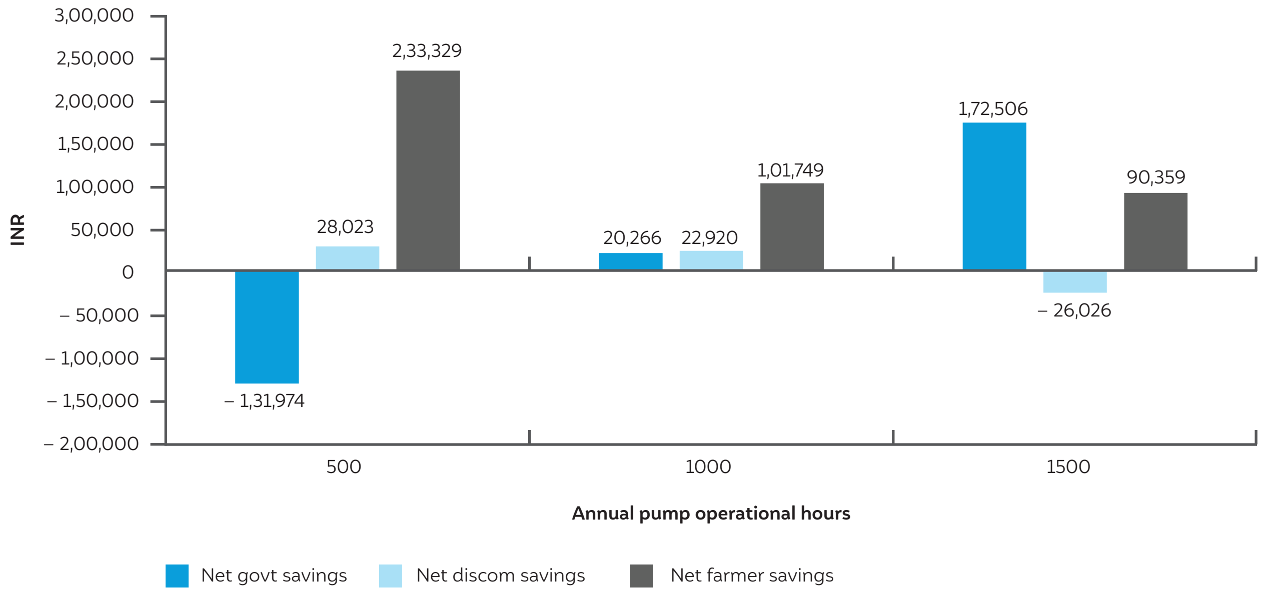
For farmer's self-consumption of 1,000 hours or less, the government stands to incur a loss. Only by targeting farmers with higher irrigation needs can the government gain from the scheme while providing 100 per cent capital subsidy. For farmers with 1,000 hours of pump operation, their annual income from selling surplus power would be INR ~5,000 in the first year. With the financial incentive in feeding power to the grid being so low, many farmers may find it more attractive to use the surplus power for alternative purposes like selling water to neighbours. A higher FiT may incentivise farmers to sell power to the discoms, but that would impact the scheme's viability for the latter. Further, the BLDC pumps used under the project cannot operate on grid power due to unidirectional metering (see Section 4.3.1 for details). Hence, the pump can operate only with solar power, which would restrict pumping during non-peak hours or overcast conditions. It would be important to test whether farmers will find this proposition reliable and attractive.

A loan-based model to solarise electric pumps (Gujarat's SKY scheme)

Under the SKY scheme in Gujarat, the beneficiary contribution is five per cent. Sixty-five per cent of the total cost gets financed through a National Bank for Agriculture and Rural Development (NABARD)[7] loan taken by the discom on behalf of the farmer, while the state government subsidises the remaining 30 per cent. The discom repays the loan by diverting a portion of its payment to the farmer against the energy procured. However, since the loan component is high, the amount from energy sale alone is insufficient for the discoms to service the debt. Hence, the state government provides an additional annual subsidy in the form of a 'generation incentive' of INR 3.5/kWh for the first seven years, over and above the FiT of INR 3.5/kWh. Figure 8 summarises the net benefits for each of the stakeholders under different scenarios.

7 NABARD, under its Rural Infrastructure Development Fund (RIDF), provides low interest-rate loans to state governments for rural and agricultural development. For the SKY scheme, NABARD provided the loan at a 5.5 per cent interest rate, much less than the weighted average interest rate of the discoms.

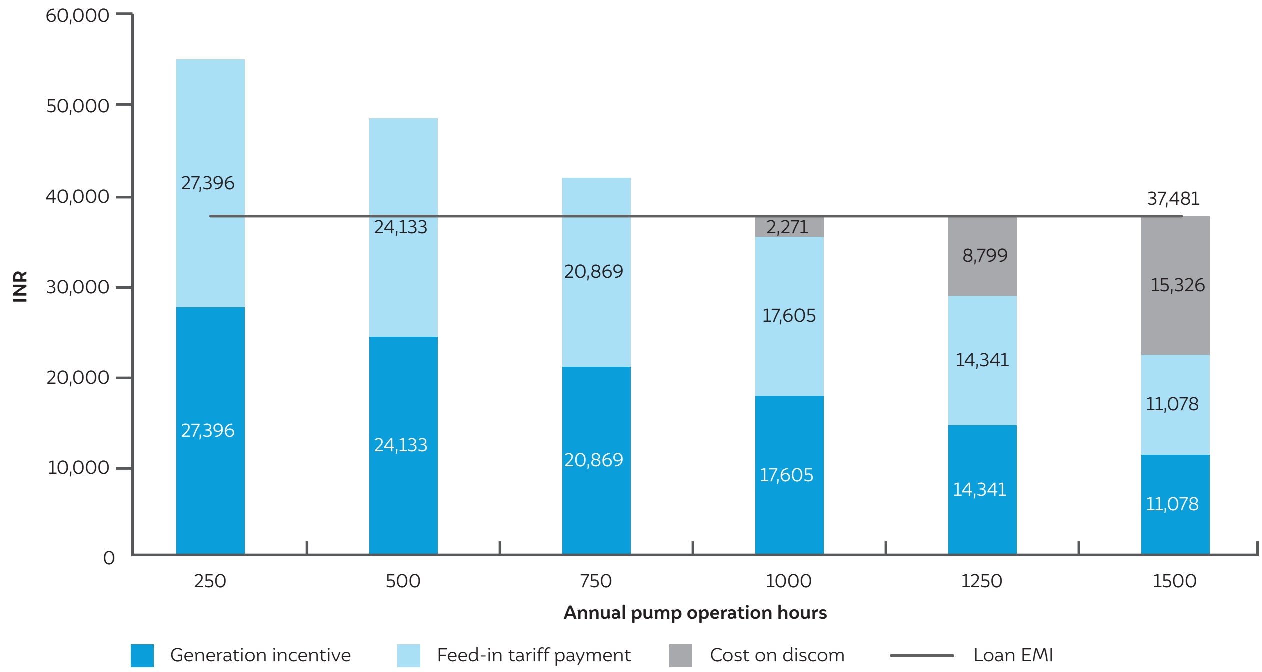
Figure 8 There is a strong trade-off between government's and farmer's income in Gujarat's SKY model



Source: Authors' analysis (assumption in Annexure II)

While the net benefits largely follow the same pattern as the other two models, a major difference is in the discom's savings. Due to high FiT, the power-purchase savings are less for the discom in this model. More importantly, the net benefits turn negative when pump operation hours are higher. Unlike the Component-C model, the loan in the *SKY* scheme is taken by the discoms on behalf of the farmers and is to be repaid by them by diverting FiT payments due to the farmer. When the farmer feeds less power into the grid, the discom ends up paying from its own pocket to cover the shortfall (Figure 9).

Figure 9 In the SKY model, the discom may incur an additional cost for repaying the loans



Source: Authors' analysis

The cost-benefit analysis shows that, on paper, there might be an ideal sweet spot of hours of usage and farmers' expected behaviour to feed surplus energy back to the grid, even with no returns in the initial years. However, in practice, it is difficult to realise such a sweet spot and expect the farmers to keep feeding energy back to the grid without any immediate (short-term) return or gratification. We'd like to stress again that the cost-benefit analysis may not be capturing all the economic factors that determine the outcome. It is important to test these models on the ground in various agroeconomic contexts. In the subsequent sections, we discuss other key challenges beyond economic constraints highlighted by various stakeholders.

Lack of a standardised methodology for tariff determination is leading to wide variations in FiT across states

4.2 Regulatory challenges

As evident from the economic analysis, the FiT is a critical determinant of Component-C viability. The tariff should be viable for the discoms and attractive enough for the farmers to encourage them to export surplus power. It has been a challenge for most states to strike that balance while arriving at a FiT.

In India, SERCs approve the tariffs for all new capacity additions. For regular capacity additions, SERCs consider different commercial aspects of the project. But in the case of Component-C, the states do not have a standard methodology to arrive at a justifiable tariff. This fact is evident from the SERC filings of different states, summarised in Table 5.

Table 4 Tariff determination methodology varies between different states

State	Logic followed in determining tariff	Final tariff
Rajasthan	• The feed-in-tariff should be remunerative so that farmers invest in the scheme • The current marginal variable cost of power for the discoms is INR 3.44/kWh. Power purchase from the consumer end at a cost equal to or less than the variable cost is bound to reduce average power purchase • If the tariff for Component-A is taken and adjusted for 11 kV losses @8.8%, the rate of purchase works out to be approximately INR 3.44/kWh	INR 3.44/kWh
Punjab	• The levelised cost calculation considering the farmer's contribution as the capital cost gives a value of INR 2.278 • However, as a special dispensation to encourage farmers to take part in the scheme, it can be revised upwards • The minimum power purchase cost from solar power outside the state is INR 2.66/kWh at the 400/220 kV level. Any cost less than this is beneficial for the discoms	INR 2.60/kWh
Gujarat	• The generic tariff determined for small-scale solar projects is INR 2.83/kWh	INR 2.83/kWh

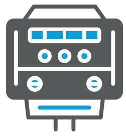
Source: Authors' compilation based on SERC orders and government notifications

It is evident that a lack of standard methodology is leading to wide variation in FiT across states with little or no consideration of the farmers' opportunity cost of exporting the power to the grid. To guide the SERCs in tariff determination, the MNRE, in consultation with the Forum of Regulators (FOR), must formulate a framework that accounts for different factors discussed above.

4.3 Technical considerations

There are two primary technical considerations for the discoms regarding the Component-C design. First, the metering modalities of the solarised pump, and, second, concerns about pump replacement.

Metering modality



Although unidirectional meter configuration is favoured by discoms, farmers' buy-in would be difficult for it

A solarised grid-connected pump is designed to export power to the grid, which can happen through either unidirectional or bidirectional metering with varied implications.

Unidirectional configuration allows a farmer to feed surplus solar power to the grid but not import power from the grid. The pump runs exclusively on solar power. This configuration is particularly suitable for DC pumps, which cannot run on grid power without an AC-DC converter. Among the pilot states, Karnataka and Andhra Pradesh had opted for unidirectional metering. The discom respondents from these states said that unidirectional metering is beneficial for the discoms. It relieves the discom of the responsibility to supply power to the concerned pump in the future. For the farmers, the acceptability of the model depends on the current power-supply scenario. For example, in the Andhra Pradesh pilot, despite the farmers getting the solar pump for free, they were initially reluctant to join the project, as they were getting good daytime power. Similarly, the respondents from the Chhattisgarh discom and SNA mentioned that they are not considering a unidirectional metering modality since the state already provides upwards of 14 hours of daily power supply to the farmer. As the unidirectional metering would mean a considerable reduction in the power available to farmers, it would be difficult to get farmers' buy-in.

Bidirectional configuration, adopted for Gujarat's SKY scheme, allows power to flow both ways. Excess power can be sold to the grid, and the pump can intake grid power when solar generation is inadequate. This is an attractive option since the configuration ensures maximum availability of power. However, farmers may also draw grid power during non-peak generation hours (when the sun is not shining), which could pose a significant financial and technical challenge for the discoms.

Under Component-C, states can select any of the two metering modalities. Different states' choice of the metering modality seems to be guided by the economics and current availability of subsidised power. Respondents from multiple discoms mentioned that unidirectional metering is the ideal choice. However, when there is a farmers' contribution to the scheme, states are reluctant to adopt unidirectional metering, as it can reduce the scheme's attractiveness. This is why Gujarat and Rajasthan, which have mandated some beneficiary contribution, have adopted bidirectional metering. States that have not mandated any beneficiary contribution should not adopt bidirectional metering as it will further decrease the scheme's viability. Moreover, as seen earlier, the lack of beneficiary contribution leads to a low FiT. With low tariffs, bidirectional metering may perversely incentivise the farmer to exploit surplus grid power.

The metering configuration also has implications for the pump's operational aspects, as revealed by the respondents.

- **Intentional islanding:** Off-the-shelf, grid-connected inverter controllers come with anti-islanding features that shut off the internal circuit in the absence of grid power. It is a safety feature to avoid accidents. However, this feature is not ideal for solar pumps, as agriculture feeders are prone to frequent faults, and farmers cannot operate the pump when the grid is not live. In areas where the discoms cannot ensure grid reliability, the lack of an option to run pumps on solar power might dampen farmers' interest in the scheme. To combat this issue, pump controllers should incorporate the intentional islanding feature. Intentional islanding is a technology to keep the internal circuit alive safely when grid power is unavailable, allowing pump operation even if the grid is not live. In Andhra Pradesh's pilot project, the discom had to work with multiple controller manufacturers to develop suitable electronics. According to an interview with one controller manufacturer, controllers of only DC pumps available in the market are equipped with intentional islanding features. The states opting for AC pumps will have to address this challenge by working with controller manufacturers.

Pump replacement

States can benefit from replacing inefficient pumps with efficient ones by designing the scheme appropriately

Studies show that replacing old agricultural pumps with energy-efficient pumps can reduce the energy required for irrigation by as much as 37 per cent (HESCOM 2014). Many farmers operate old, inefficient pumps. Among the pilot projects, only Andhra Pradesh carried out pump replacement. However, under Component-C, the cost of pump replacement is not eligible for central financial assistance. States like Gujarat and Rajasthan have chosen not to offer pump replacement under Component-C because of the additional financial burden, as per respondents from the respective discoms.

For Component-C, there are two possible approaches for pump replacement:

1. Replace the existing pumps with efficient pumps of the same capacity. The panel capacity will remain the same, but the pump's operational hours will reduce and energy export will increase. However, the system cost will increase due to the additional pump cost.
2. Replace with an efficient pump of lower capacity. The panel size is also correspondingly decreased. Pump operational hours will remain the same, but the overall cost of the system reduces.

We extended the cost-benefit analysis to the two scenarios. We found that the combined savings of the government and the discom reduces in the first scenario. In the second approach, efficiency gains of even 10 per cent increase the combined savings. Adopting the second approach for replacement could be financially attractive for the government.

Often farmers operate irrigation pumps of capacity higher than their sanctioned load – a common trend in areas with dropping groundwater levels or increasing irrigation requirements. These observations were shared by a system integrator and respondent from GUVNL. For this reason, under the *SKY* scheme, farmers were allowed a one-time opportunity to upgrade their sanctioned load. However, farmers had to bear the cost of upgrading, due to which there were few takers. Replacing pumps through the second approach can help farmers mitigate the need for upgrading their sanctioned load.

Both inefficient and oversized pumps diminish the component's attractiveness for the farmer by causing sub-optimal output (in unidirectional metering) and reduction in surplus power (in both types of metering). Hence, the MNRE should seriously consider including pump replacement under PM-KUSUM.

4.4 Challenges to groundwater regulation

One major attraction for the states in Component-C is the purported incentive for water conservation built in the design. If farmers get more income from selling surplus energy, they will use power and water judiciously. In reality, the realisation of this benefit is highly context-dependent. Farmers with a solarised grid-connected pump can treat the surplus power in three ways:

Export energy: As envisaged in the scheme, farmers can export the excess energy to the grid.

Sell water: They can use the surplus power to take out more water and sell it to others during the irrigation seasons, typically neighbours.

Intensify cultivation: They can also increase water usage for their cultivation either by increasing the intensity of cultivation or shifting to more water-consuming crops.

The experience from the pilot projects gives a sense of how different factors impact farmers' choice (Table 4). Under the *Surya Raitha Scheme*, as mentioned earlier, farmers got a FiT of effectively INR 1/kWh during the loan-repayment period. However, many farmers chose to sell water to their neighbours instead of feeding-in power (Institute of Social and Economic Change 2018). The exact price of water varies a lot between regions. Based on one study, INR 40 per hour is a going rate in Karnataka (Yashodha 2020). The corresponding income for a 5 HP solar pump (with 5 kW panel) from selling of power even at its peak is INR 5 per hour. This gives us a sense of the opportunity cost for the farmer in selling power.

Farmers have multiple options with surplus power and would choose what is most beneficial for them

The outcome from Gujarat's SKY scheme has been different for different discoms in the state. As per the respondent from GUVNL, the quantity of energy exported by the consumers of three of the four discoms were mostly along expected lines. The farmers in the area catered by these discoms usually cultivate two crops a year and have continued with the same cropping pattern. However, in Dakshin Gujarat Vij Company Ltd (DGVCL), the power exported by many farmers was much lower than the expected quantity. In some cases, the income from energy procured by the discoms is not even sufficient to cover the loan repayment. According to the respondent from GUVNL, the area catered by the discom is a sugarcane-growing belt. Sugarcane is a water-intensive but high-value crop. The respondent assesses that the farmers took advantage of the increased power supply and consumed more electricity from the grid to extract more water to increase their production.

As per the respondent, the Gujarat government has recognised this shortcoming and is considering solutions to put an upper limit of eight hours to the time available for drawing power from the grid. Under Component-C, Gujarat's discoms are mulling over a technological solution (automatic transfer switch) to control the net-meter so that the grid remains energised during the daytime to enable power export, but the power import is limited to daytime eight hours (Gujarat Energy Department 2020).

Table 5 Exporting energy is not always preferred by the farmer

Discom	Context	Farmer preference with excess power
BESCOM (Karnataka)	Low feed-in-tariff (during loan repayment period), plenty of farmers without connections	Selling water to neighbours
DGVCL (Gujarat)	Belt of intensive sugarcane cultivation	Intensifying cultivation
UGVCL, MGVCL, PGVCL (Gujarat)	Target farmers cultivate two crops in a year	Farmers exported power to the grid as expected

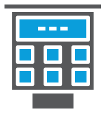
Source: Authors' compilation based on stakeholder consultations

The main takeaway from the pilots is that the environmental and economic sustainability of Component-C is highly contextual. Current cropping patterns and farmers' attitude towards adopting new cropping systems are critical determinants. However, there aren't enough studies dealing with these aspects at scale. Hence, the states should implement pilots at scale combined with robust monitoring mechanisms to assess the outcomes and farmer behaviours under different conditions before scaling up the model.

4.5 Operational issues

We identify three main operational challenges in the implementation of Component-C.

Metering and billing



Smart-meter solutions are scalable, but discoms must complement them with farmer engagement to gain their trust

Most agricultural connections in India are unmetered due to two key reasons. Firstly, for most discoms, metering and monitoring a large number of dispersed agricultural connections would require significant investments and staff capacity, with limited avenues for cost recovery. Secondly, farmers have strongly resisted any attempts at metering in the past, as they see it as a step towards removing power subsidy. In this milieu of distrust, metering agricultural connections even to implement Component-C has been a significant challenge for discoms.

The three pilot states adopted different strategies to overcome this challenge, as discussed below:

1. **Community-supported meter reading:** In the pilot projects of Andhra Pradesh and Karnataka, cooperatives/committees of participant farmers had a central role to play. In Andhra Pradesh, a team of three people – including a representative each from the discom, the cooperative, and the farmers – together carried out the meter reading. Karnataka envisaged a similar arrangement between the discom and the cooperative. As per the respondent from APEPDCL, the strategy was effective primarily because of consistent engagement with the farmers. The discom was able to carry out meter reading without fail. In Karnataka, however, an impact study showed that the cooperative was not functioning properly, due to which the famers had not received any payment. A majority of the farmers were not even aware of the amount they were supposed to receive from the discom (Institute of Social and Economic Change 2018) .
2. **Smart-metering:** Gujarat introduced a remote billing system by installing smart energy meters and the IT infrastructure for reading the energy flow remotely. As per the respondent from GUVNL, this approach has worked well with a few minor challenges. The implementing discoms have tried to infuse transparency by creating a mobile application through which farmers can see their real-time energy generation. Due to these measures, the annual bill settlement has mostly been smooth. But in locations where the self-consumption was quite substantial, the farmers were not happy with the bills generated (with little or no FiT earnings) and alleged faults in the metering.

Community-supported meter-reading is very time and effort consuming and is not a scalable approach for a state-wide scheme. Moreover, the engagement of additional staffing for meter reading comes with additional costs. Smart-meter solutions appear promising and scalable but need to be complemented by close engagement with farmers and a robust ecosystem for data collection. Table 6 summarises these findings.

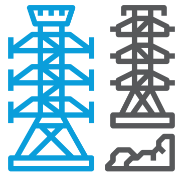
Table 6 Smart-meter solutions are comparatively more effective and scalable strategy for metering and billing challenges

Strategies for meter-reading and billing	Effectiveness	Farmer's acceptance	Scalability	Cost of implementation
Community-based meter-reading	Medium	High	Low	Medium
Smart-meter	High	Medium	High	Medium

Source: Authors' analysis based on consultation with stakeholders from the discoms

Free-rider problem

In a feeder targeted under Component-C, all farmers need to participate, otherwise the scheme's administration can be challenging for the discom. For the participating farmers, the grid has to be energised throughout the day to enable the export of power. However, this also enables reliable day-time supply for the non-participating, essentially gaining better supply reliability without investing in the solar asset. The non-participating farmer can free-ride and exploit the increased availability of cheap or free power.



Discoms should adopt technological solutions to curb free-riding

In the three pilot projects, the respective implementing agencies adopted different strategies to combat this challenge.

1. **Ensure 100 per cent participation in a feeder:** In Andhra Pradesh, the discom ensured that all farmers in the target feeder participated in the project. This strategy would free up the discom from taking additional measures to curb the power supply to non-participating farmers. However, the approach is highly time- and effort-intensive. In Andhra Pradesh, for instance, the discom had to delay the project for two years to get buy-in from all the farmers. The respondent from the discom mentioned that it took them multiple rounds of individual-level and group-level engagements to convince the farmers.
2. **Community-based monitoring:** In Karnataka, the discom constituted a farmers' committee to monitor the usage by non-participating farmers. However, as per the discom respondent, this has been a non-starter, and the non-participants rampantly misused the increased supply hours.
3. **Technology-based solution:** In Gujarat, the discom developed an accessory for the transformer called a 'watchdog device', which can remotely monitor and control the transformer's power supply. This device was installed on all the transformers supplying non-participating farmers to regulate their power supply schedule. Gujarat had initially envisaged 100 per cent participation of farmers in a feeder but later relaxed it to a minimum of 70 per cent due to lack of interest. As per a discom representative, Karnataka also tested a mini-SCADA system to monitor energy usage but could not effectively curtail free-riding due to network issues.

Respondents from all the discoms concurred that it is ideal to have all the farmers in a feeder solarised for the scheme. But it is evident from the pilot projects that getting farmers' buy-in requires considerable engagement efforts from the discom. A technological solution like a watchdog transformer is costly but could be viable at scale. Discoms should strategise to get maximum farmers' participation, while adopting technological solutions for non-participating farmers.

Table 7 Among the different strategies, technology-based monitoring is the most scalable solution to tackle the free-rider problem

Strategies	Effectiveness	Scalability	Cost of implementation
Ensure 100% participation in a feeder	High	Low	Low
Community-based solution	Low	Medium	Low
Technology-based solution	Medium	High	Medium

Source: Authors' analysis based on consultations with stakeholders from the discoms

Infrastructure challenges

One prerequisite for the implementation of Component-C is the segregation of the feeder. It is not a bottleneck for Component-C in most states, but some states will have to invest in feeder segregation in the long term. In the short term, however, the condition of existing segregated agriculture feeders is a concern in many states.

The last-mile infrastructure is critical but often overlooked in the scheme's planning. The agricultural feeder networks are often poorly maintained. In the maintenance and upkeep of the grid, the discoms give the least priority to these networks since revenue recovery is too low (Dharmadhikary et al. 2018). As per the respondents from multiple stakeholders, issues like power leakages and the use of non-standard wires are pretty common.

Discoms should ideally lead Component C's implementation, aided by other agencies

The actual cost for the discom implementation of the scheme should, therefore, factor in the additional costs to upgrade the infrastructure. According to multiple discom respondents, a comprehensive assessment of the feeder is a must before implementing this component in a feeder. The assessment should capture the connected pump capacities in use, the status of grid infrastructure, and sources of other commercial losses before implementing the component in any feeder. The states should adequately study the cost of infrastructure upgrades through pilots before scaling up Component-C.

4.6 Choice of implementing agency

The implementing agency for Component-C for any state is to be decided by the respective state administration. So far, out of the 15 states which notified the scheme, nine have designated their respective SNAs as the implementing agencies, which may not be ideal for the scheme's smooth implementation.

As evident from the discussion so far, planning the scheme's rollout requires a good understanding of power supply operations and the discoms' relationship with agricultural consumers. Overcoming the multiple implementation challenges requires engagement with farmers before and after the installation to build an atmosphere of trust. Only the discoms are best placed for this role. The respondents from the discoms of Rajasthan and Chhattisgarh mentioned that choosing SNA as the implementing agency carries the risk of constant roadblocks in aspects like billing and payment.

A case attesting to this point was evident in the proceedings for approval of tariff in Haryana, where the SNA is the implementing agency. In Haryana, the SNA proposed a bidirectional-metering modality under Component-C to the SERC. The discom contested it and submitted that it was not feasible to provide net-metering options to agricultural connections.

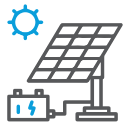
By its design, Component-C accords a pre-eminent role to the discom in its implementation. Hence, states should select discoms as implementing agencies unless there are compelling reasoning to do otherwise. The discoms can undoubtedly benefit from the expertise of SNAs in decentralised solar projects. States should set up a dedicated PM-KUSUM cell with representatives from all concerned departments to facilitate coordination with multiple actors.

For PM-KUSUM to succeed, we need to ensure farmers' participation and ownership of the solar-powered irrigation.

Image: Anas Rahman

5. Conclusion

The PM-KUSUM scheme has been running since early 2019. However, the progress of the scheme, particularly on the two novel approaches that it introduced, components A and C, has been marginal, at best. These components intend to support farmers with additional incomes, improve power quality for irrigation, reduce agriculture power subsidies, and further clean-energy transition in the agriculture sector. However, the planning and implementation challenges at the state level are significant and need immediate attention to materially yield outcomes against these components of PM-KUSUM.



MNRE must prepare a model framework for tariff determination and study the impact of recently introduced basic customs duty on distributed solar plants

For Component-A, most of the discoms are enthusiastic. However, they are concerned about the short-term disruption in their finances. The concern stems from the fact that many discoms across the country already have surplus contracted capacity. With existing PPAs to honour, the room for additional procurement under Component-A is limited, even though it makes economic sense in the medium- to long-term. Modifying the scheme timelines and converging them with state-level power procurement planning would allow the discoms to leverage this model to meet future energy demand in a planned manner.

Further, the current ceiling tariffs finalised by many states are not finding traction among developers. Relatively higher capital and overhead costs for small-scale power plants, poorer grid availability at the distribution substation, and counterparty risks increase the cost of power under Component-A as compared to utility-scale solar plants. The MNRE must prepare a model framework, in consultation with the Forum of Regulators, to guide the SERCs in using a standardised approach in determining viable ceiling tariffs for projects under Component-A. The impact of recently introduced basic customs duty on solar modules and cells should also be assessed thoroughly as they disproportionately impact the capital cost of plants under Component-A.

Beyond the economics of the component for the discoms and the developers, the implementation challenges such as restrictions and delays in leasing or conversion of agricultural land and lack of interdepartmental coordination must be addressed on priority. A steering committee for PM-KUSUM consisting of representatives from all concerned state departments could go a long way in enabling smoother coordination for the scheme's implementation.

Finally, farmers aiming to invest under Component-A are facing difficulties in accessing institutional finance. Innovative models such as farmer and developer SPVs can help unlock financing for farmers.

For Component-C, we focused on the grid-connected solar-pump model. Most discoms anticipate significant challenges in getting farmers' buy-in for the model. In states with highly subsidised agricultural tariff, the discoms expect a lack of interest among farmers in making a monetary contribution to solarise their connection. We found that the model is economically viable for farmers, the discoms and the government only in very specific contexts. Low FiTs means limited incentives for farmers to feed surplus power back to the grid, while a high tariff would mean a net loss for the government/discoms. Current experiences at the state level suggest a cautious way forward: careful design of the scheme financing model, limited pilot roll-outs under different agroeconomic contexts, observation of farmers' behaviour in the initial years, and finally scaling up the model only in suitable contexts.

For farmers, there could be high opportunity costs associated with the export of power. In certain scenarios, farmers may prefer to sell water or grow more crops instead of exporting surplus power, which can put pressure on groundwater in water-stressed areas . We propose that the SERCs be aware of these factors while determining the FiT for the scheme. Similar to our suggestion for Component-A, the MNRE should prepare a framework to guide SERCs in determining viable FiT for Component-C.

Beyond economic viability, operational challenges related to metering and billing, the non-participating farmers in a feeder, and the poor state of agriculture distribution infrastructure are worth noting. Employing technologies like smart devices in conjunction with community-engagement efforts can help the discoms bridge the trust deficit with farmers. Alongside, comprehensive feeder-level assessments are imperative to address infrastructure gaps.

Having said that, unless measures are taken to reform the larger issues of agriculture power subsidy and its administration, the individual solarisation of agricultural pumps may not fly with the discoms and farmers at large. While the government should address the challenges we outline to fast track implementation of PM-KUSUM, it must not lose sight of the fact that a perfect solution in an imperfect environment may not succeed.

Unless measures are taken to reform the larger issues of agriculture power subsidy and its administration, the individual solarisation of agricultural pumps may not fly with the discoms and farmers at large

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Annexures

Annexure I: Cost-benefit analysis of Component-A under VGRS framework

Table A1 summarises the key assumptions used for the cost-benefit analysis for the state of Karnataka. Table A2 illustrates the formulae used to estimate various cost and benefit components under the VGRS framework.

Table A 1 Key assumptions used for cost-benefit analysis of Component-A

Parameters	Value	Unit	Remarks/Source
Plant capacity	1000	kW	
Transmission loss	3.13%		KERC tariff order FY 2020-21
Distribution loss down to 11 kV substation	6.00%		KERC tariff order FY 2020-21
System coincidence factor	15.00%		The AGCC depends on the contribution of solar power during the discom's peak demand. System coincidence factor quantifies this contribution.
Fixed capacity cost	3,529.13	INR/kW	KERC tariff order FY 2020-21
Fixed transmission charges	2,861.00	INR/kW	KERC tariff order FY 2020-21
Variable cost of power	2.86	INR/kWh	KERC tariff order FY 2020-21
Feed-in-tariff	3.08	INR/kWh	KERC general tariff for small solar plants 2018
Capacity utilisation factor	16.00%		
Degradation rate	0.50%		
REC unit cost	1.00	INR/kWh	https://www.iexindia.com/marketdata/recdata.aspx
PBI rate	0.4	INR/kWh	PM-KUSUM guidelines
Discount rate	14%		Weighted average cost of capital KERC tariff order FY 2020-21

Source: Authors' compilation

Table A 2 Formulae used for estimating cost and benefit component under VGRS framework

Parameter	Formula
Avoided generation capacity cost (AGCC)	$\frac{(\text{Power plant capacity} \times \text{System Coincidence Factor} \times \text{Fixed Capacity Charges} \times (\text{1-Degradation rate})^{(\text{Year-1})}}{(\text{1-Transmission loss})}$
Avoided transmission capacity cost (ATCC)	$\frac{(\text{Power plant capacity} \times \text{System Coincidence Factor} \times \text{Fixed Transmission Charges} \times (\text{1-Degradation rate})^{(\text{Year-1})}}{(\text{1-Transmission loss})}$
Avoided power purchase cost (APCC)	$\frac{(\text{Power plant capacity} \times \text{CUF} \times 24 \times 365 \times (\text{1-Degradation rate})^{(\text{Year-1})} \times \text{Variable cost of power})}{(\text{1-Transmission loss})(\text{1-Distribution loss down to 11 kV})}$

Parameter	Formula
Avoided REC purchase cost (ARPC)	Power plant capacity × CUF × 24 × 365 × REC unit cost
Performance-based incentive (PBI)	Power plant capacity × CUF × 24 × 365 × PBI rate
Tariff payments	Power plant capacity × CUF × 24 × 365 × Tariff rate

Source: Kuldeep et al. 2019

Annexure II: Cost-benefit analysis of grid-connected solar pump schemes of Andhra Pradesh and Gujarat

Table A3 summarises the assumptions used for the cost-benefit analysis of the grid-connected solar pump pilot projects of Andhra Pradesh and Gujarat. Table A4 lists the formulae to calculate the different costs and benefit components.

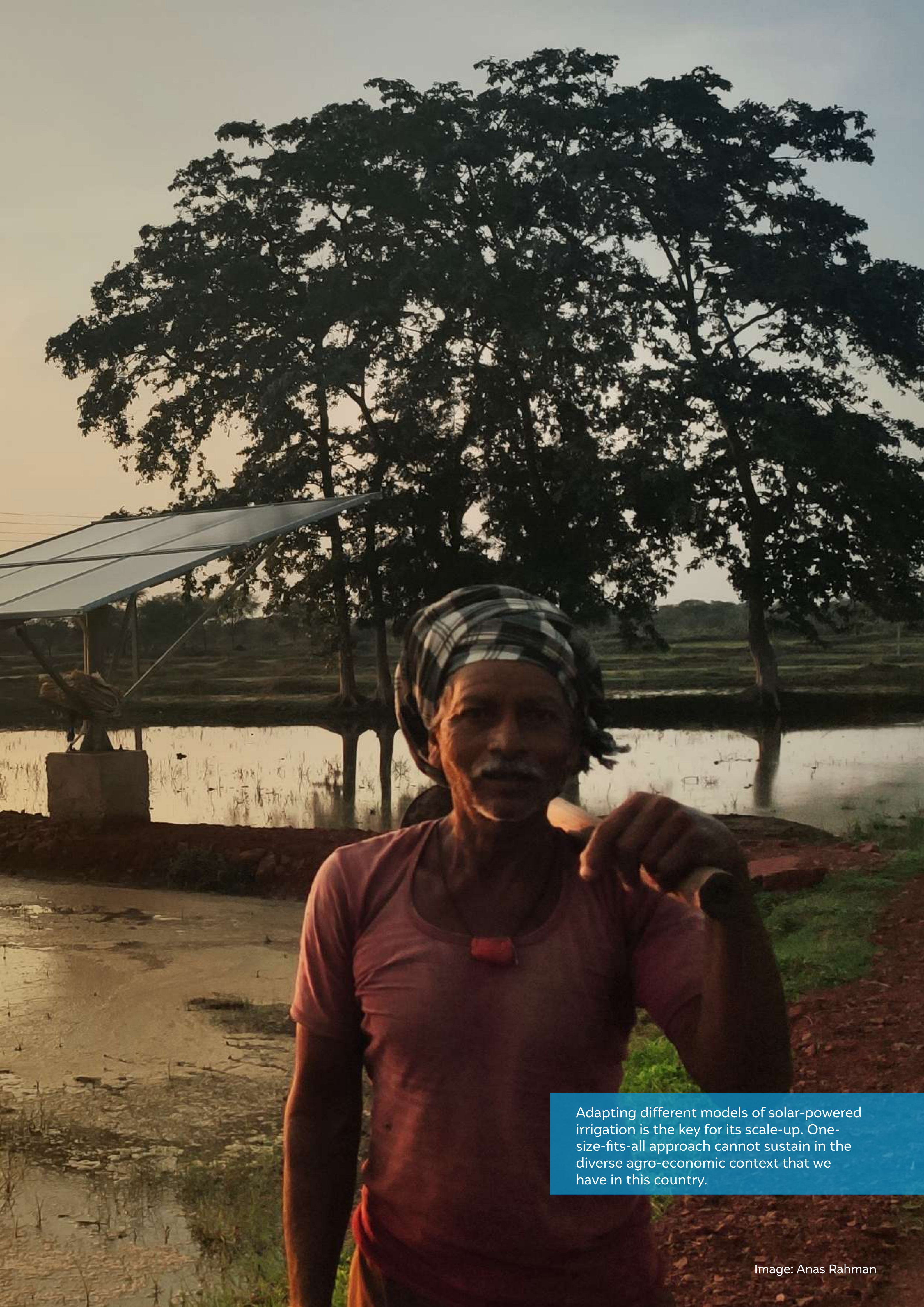
Table A 3 Key assumptions for cost-benefit analysis of grid-connected pump schemes

	Parameters	Andhra Pradesh	Gujarat (SKY)	Gujarat (PM-KUSUM)	Remarks
Generation related	Pump size (HP)	5	5	5	
	Panel size (kW)	5	6.25	6.56	Andhra Pradesh mandated solar panel capacity (in kWp) equivalent to the contracted load in HP. Gujarat allowed 1.25 times oversizing
	CUF	16%	16%	16%	
	Annual pump operational hours (hours)	1000	1000	1000	
	Self-consumption %	53%	43%	43%	Calculated based on the assumed CUF
	Feed-in-Tariff (INR/kWh)	1.50	3.50	2.83	
	Government tariff support (INR/kWh)	-	3.5		
	Farmer tariff rate (INR/kWh)	0	1.18	1.18	Tariff order FY 2020-21
	Average cost of power supply (INR/kWh)	6.61	6.84	6.84	Tariff order FY 2020-21
	Current cost of power purchase (INR/kWh)	4.71	3.67	3.67	Tariff order FY 2020-21
	Annual degradation	1%	1%	1%	Based on the standard panel quality prescription for solar pumps
	Transmission loss	3.00%	3.00%	3.00%	Tariff order FY 2020-21
	Distribution loss (down to 11kV substation)	5.97%	4.71%	4.71%	Tariff order FY 2020-21
	Distribution loss (below 11kV substation)	7.20%	4.71%	4.71%	Tariff order FY 2020-21
	System coincidence factor	15%	15%	15%	
	Generation capacity cost (INR/kW)	8056	6450	6450	Tariff order FY 2020-21
	Transmission capacity cost (INR/kW)	1848	2900	2900	Tariff order FY 2020-21
	Variable cost of power (INR/kWh)	3.54	2.68	2.68	Tariff order FY 2020-21
	Years till current generation capacity is sufficient	1	1	1	

	Parameters	Andhra Pradesh	Gujarat (SKY)	Gujarat (PM-KUSUM)	Remarks
Finance-related	System cost (INR)	2,76,500	3,27,700	3,39,800	For Andhra Pradesh (pump replacement included): Benchmark price of 5 HP off-grid system + 40,000 for grid-tie inverter For Gujarat SKY (no pump replacement): Benchmark cost of 6.25 HP off-grid system + 60,000 for grid-tie inverter – 30,000 for pump For Gujarat PM-KUSUM (no pump replacement): Benchmark cost of 6.56 HP off-grid system + 60,000 for grid-tie inverter – 30,000 for pump
	Farmer upfront contribution (INR)		16,875	33,979	For AP: 0% For Gujarat (SKY): 5% For Gujarat (PM-KUSUM): 10%
	Subsidy amount (INR)	2,76,500	98,310	2,03,877	For AP: 100% For Gujarat: 30%
	Loan (INR)		2,13,005 (by discom)	1,01,938 (by farmer)	For AP: 0% For Gujarat: 65%
	Interest rate		8.30%	8.30%	SBI MCLR (3 years) + 1%
	EMI (INR per year)		38,602	15,398	
	Loan period (Years)		7	10	Gujarat (PM-KUSUM) based on Bank of Baroda notification
	Weighted average cost of debt		9.29%	9.29%	Tariff order FY 2020-21
	EMI @ normal interest rate (INR per year)		37,481	15,398	
	Discount rate (govt)	7.50%	7.50%	7.50%	Long-term bond rate
	Discount rate (farmer)	8.3%	8.3%	8.3%	Base rate of SBI + 100 basis points
	Discount rate (discom)	11.6%	10.7%	10.7%	WACC of FY 2020 (average of two discoms)

Table A 4 Formulae used for different cost and benefit components of grid-connected pump schemes

Government	
Upfront govt. subsidy	*Govt. subsidy share × Cost of the system*
Generation incentive	*Panel capacity × CUF × 24 × 365 × (1-Self consumption) × Government tariff support*
Power subsidy savings	*Panel capacity × CUF × 24 × 365 × Self consumption × (Actual cost of service-Farmer tariff rate)*
Interest subsidy	*Normal EMI-EMI for the scheme*
Discom	
Loan repayment	*EMI*
Solar tariff	*Panel capacity × CUF × 24 × 365 × (1-Self consumption) × Feed-in tariff*
Avoided generation capacity cost (AGCC)	$\frac{(\text{Power plant capacity} \times \text{System Coincidence Factor} \times \text{Fixed Capacity Charges} \times (1-\text{Degradation rate})^{(Year-1)}}{(1-\text{Transmission loss})}$
Avoided transmission capacity cost (ATCC)	$\frac{(\text{Power plant capacity} \times \text{System Coincidence Factor} \times \text{Fixed Transmission Charges} \times (1-\text{Degradation rate})^{(Year-1)}}{(1-\text{Transmission loss})}$
Avoided power purchase cost (APCC)	*Panel capacity × CUF × 24 × 365 × (1-Self consumption) × Variable cost of power*
Power purchase savings	AGCC + APCC + ATCC
Farmer	
Upfront contribution	*Farmer subsidy share × Cost of the system*
Annual income	*Panel capacity × CUF × 24 × 365 × (1-Self consumption) × Feed-in tariff*



Adapting different models of solar-powered irrigation is the key for its scale-up. One-size-fits-all approach cannot sustain in the diverse agro-economic context that we have in this country.

Image: Anas Rahman

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