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A Quick Assessment of the Mukhyamantri Saur Krishi Vahini Yojana (MSKVY) in Maharashtra

Institute of Rural Management Anand, Gujarat

Hippu Salk Kristle Nathan, Uday Shankar Saha,
Rajeev A, Sk Niyaj Mohammed

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About the Organizations

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Solar Irrigation for Agricultural Resilience

The Solar Irrigation for Agricultural Resilience in South Asia (SoLAR-SA) project aims to sustainably manage the water-energy and climate interlinkages in South Asia through the promotion of SIPs. The main goal of the project is to contribute to climate-resilient, gender-equitable, and socially inclusive agrarian livelihoods in Bangladesh, India, Nepal and Pakistan by supporting government efforts to promote solar irrigation. This project responds to government commitments to transition to clean energy pathways in agriculture. All countries in this project have NDC commitments to reduce GHG emissions and SIPs can play a significant role in reducing emissions in agriculture.

Swiss Agency for Development and Cooperation

The SoLAR -SA project is supported by the Swiss Agency for Development and Cooperation (SDC). SDC is the agency for international cooperation of the Federal Department of Foreign Affairs (FDFA). Swiss Agency for Development and Cooperation, which is an integral part of the Federal Council's foreign policy, aims to contribute to a world without poverty and in peace, for sustainable development. SDC, through its Global Programme Climate Change and Environment (GPCCE), helps find solutions to global challenges linked to climate change. It engages in global political dialogue and manages specific projects in the fields of energy, climate change adaptation, sustainable development of mountainous regions and prevention of natural hazards that are likely to influence regional and international policy.

The Institute of Rural Management Anand (IRMA) is driven by the dream of serving under-served segments of the economy through professional management. Founded in 1979, IRMA is focused on creating management professionals who can bring about sustainable, ecologically-friendly and equitable growth by applying their management acumen at the grassroots level and influencing the public policy narrative at the national and global levels. IRMA's synergy with Government and Non-Government Institutions as well as International Development Organizations provides the students with an ideal ecosystem for learning, research as well as implementation experience of real on-the-ground projects.

Contents

Executive Summary

India's rural electrification policy since independence has focused on energizing pump sets to provide irrigation for agriculture (Harish and Tongia 2014). Currently, agriculture consumes 24% of the country's power (PFC 2022). Power supply to agriculture is highly subsidized by the government to cover the cost-revenue gap since the average cost of supplying power is Indian Rupee (INR) 6.19/unit (United States Dollar (USD) 0.0755/unit) while the average revenue from agriculture is only INR 1.03/unit (USD 0.0126/unit) (PFC 2022). This high subsidy is a strain on the exchequer and detrimental to the financial health of power distribution companies (DISCOMs). This unlocks the scope to use solar photovoltaic (PV)-based power in agriculture.

The Maharashtra State Government's Mukhyamantri Saur Krishi Vahini Yojana (MSKVY) launched in June 2017 promotes tail end solar plants near substations. Solar plants under MSKVY are typically of 2-10 megawatt (MW) capacity at the feeder level. The scheme has a target of installed capacity 5000 MW by 2025, with the State generation and distribution utilities as implementation partners. The scheme is expected to benefit all stakeholders: Farmers can expect power in the daytime while continuing to use electric pump sets; DISCOM saves on the prohibitive cost of procuring power to supply to agriculture at a subsidized tariff as well as benefits from reduced transmission and distribution (T&D) losses. It is also expected to help DISCOM meet its renewable purchase obligation (RPO) targets. In short, while the Government benefits from a reduced subsidy burden, it opens up opportunities for private sector investment and the deployment of more solar energy.

Projects under the scheme are implemented either through bids or an agreement with Energy Efficiency Services Limited (EESL). Though bidding is the norm, an agreement with EESL was promoted to give initial momentum to the scheme. As on March 31, 2022, a total of 731 MW capacity had been commissioned under MSKVY, of which 372 MW were commissioned by 29 private players through the bidding route. The scheme's progress as well as private sector participation in it have so far been moderate.

This study assesses the progress made by MSKVY, its impacts on farmers and groundwater as well as its potential and roadblocks. The study relies on data from the government and other agencies, interactions with stakeholders (officials of distribution and generation utilities, collaborating agencies, solar developers and tail end operators and managers of substations), primary data from a farmers' survey, and interactions through focus group discussions (FGDs). A mix of purposive and convenience sampling was used to identify the district as well as solar units from six administrative divisions in Maharashtra and availability sampling was used to select 280 farmers.

The scheme faces challenges due to increasing import duty and Goods and Services Tax (GST) on solar energy, and the cost escalation due to the COVID pandemic, making the prevailing power tariff unviable. The tariff might need a hike considering COVID related uncertainties. Also, a raised tariff will boost domestic manufacturing which will help in the long run not only the MSKVY scheme, but also overall solar sector. Land availability is another bottleneck that the scheme needs to overcome. When the onus of finding land for solar deployment was on private players, it added to the project cost; and involved the additional responsibility of procuring land, which is not always easy. To facilitate land availability, the distribution utility introduced a land portal to encourage farmers to rent out their lands at INR 30,000/month (USD 366/month). While this is a promising initiative, it is too early to assess its feasibility and impact.

The farmers' survey conducted in the six administrative divisions in Maharashtra revealed that less than 5% of the sample lacked awareness about the scheme, underlining the need for Maharashtra State Electricity Distribution Company Limited (MSEDCL) to have an awareness drive for farmers. The survey also showed an overall increase in daytime power supply after the MSKVY scheme began; however, the district-wise results show no change in some cases and even a decrease. Feeder-level daily data since 2018 also indicated a reduction in the duration of daytime power supply, with farmer information on the same varying in three villages connected to the feeder. This could be due to the small sample size as well as the availability sampling used. While a consistent observation from farmers revealed a reduction in load shedding after MSKVY was implemented, this cannot conclusively be attributed to the scheme. The survey also indicated a marginal increase in the use of pump sets (2.5%) and a handful of farmers changing their cropping pattern post-MSKVY.

An interesting finding of the study was the improvement in voltage quality during daytime power supply with the advent of the scheme, fulfilling farmers' irrigation needs with less duration of supply. This finding matches the data on sole feeder level power supply which indicated that there was a reduction in the duration of power supply in the period after the MSKVY scheme when compared to a period before it.

Given that MSKVY projects can enable the greening of the power system, cater to the agriculture load, benefit the distribution utility by reducing T&D losses and meet RPO targets, the study recommends accelerating the scheme through a lease mode of land procurement, raising the tariff, encouraging implementation through EESL and rotation-based supply if the total agriculture load cannot be met. MSKVY also needs to be seen as an avenue to generate local jobs and help the local economy.

1. INTRODUCTION

1.1 Context of the Study

India has seen a burgeoning deployment of solar irrigation pumps (SIPs), from a couple of thousands in 2010-11 to 272,000 by the end of 2020 (MNRE 2021; Mali et al. 2022). Their use has been greater in water-stressed states in western India compared to water-abundant ones in eastern India (MNRE 2022a). This has largely been due to the attractive subsidy offered by state governments on the cost of SIP installation (Verma et al. 2019; Yashodha et al. 2021). State governments and power utilities find the promotion of SIPs attractive for two reasons: (i) they can save on future power subsidy if offered in lieu of grid power connections for irrigation pump sets (Yashodha et al. 2021) and (ii) they can quickly energize irrigation wells in off-grid areas without going through costly grid extensions.

However, a slew of emerging concerns dominates the debate on promoting SIPs. Primarily, since power demand for irrigation is limited to 100-150 days in a year, off-grid SIPs risk low/underutilization of assets (expensive solar panels) and a waste of capital. Secondly, the 7-9 hours/day of reliable and free daytime power provided may worsen groundwater depletion in water-stressed areas (Closas and Rap 2017; Verma et al. 2019; Yashodha et al. 2021). Lastly, given the unsustainable current levels of capital cost subsidy (Rajan and Verma 2017), making solarization of pump set irrigation cost effective calls for new business models.

Based on the Dhundi experiment of a solar farmers' co-operative, Gujarat piloted a State-wide Suryashakti Kisan Yojana (SKY) in which grid-connected tubewells are solarized and farmers are encouraged to sell the solar energy that is in surplus after meeting their irrigation needs, to DISCOMs; this gives farmers an additional income (Yashodha et al. 2021). The State of Maharashtra has followed a different path of solarizing agricultural feeders through a 2-10 MW tail end solar plant near substations through the MSKVY (Gambhir et al. 2021). Under this model, tail end solar plants are built and managed by entrepreneurs who are paid a Feed-in Tariff (FiT) on all solar power generated through long-term fixed price contracts with DISCOM and farmers get free or subsidized daytime power for irrigation and other uses (Gambhir et al. 2021). This has many benefits for DISCOMs: the reduced burden of providing centralized power to farmers at greater cost, avoiding high T&D losses, and meeting their RPOs by procuring power from these plants (MERC 2020a). The decentralized solar plants also free farmers from their dependence on unreliable night-time power (Gambhir and Dixit 2019). The government doesn't need to make a capital investment in solarizing irrigation and saves on future grid power subsidy. A key advantage of the model is its potential to rapidly scale up solar energy use in irrigation by inviting private capital. In addition, feeder level plants not only reduce T&D losses but also improve power quality at the tail end, thereby enhancing the functioning of equipment and overall efficiency of the power system (MERC 2018a).

The Government of India's Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyaan (PM-KUSUM) scheme incorporates lessons from both the Gujarat and Maharashtra models (MNRE 2019a). The INR 344,220 million (USD 4,198 billion) scheme supports solar feeders up to 2 MW in line with the Maharashtra model and supports off-grid SIPs and grid-connected SIPs based on the Gujarat model (MNRE 2019a). Given the huge potential of the solar feeder scheme in Maharashtra, the Government of India considered its replication across the country in December 2019, boosting the development of decentralized solar power plants of more than 2MW capacity connected to substation of 66/11 KV or higher and up to 2 MW capacity connected to substation of 33/11 KV or lower where project under PM-KUSUM has already been exhausted (MNRE 2019b).

While Gujarat's SKY pilot with a real-time monitoring system enables an assessment of the progress made, its financial impact and behavior change among farmers, no such information is available in the public domain on the MSKVY solar feeder model in Maharashtra. This study aims to fill this knowledge gap.

1.2 Agriculture-Power-Water Nexus in Maharashtra

Agriculture's share in MSEDCL's total sale of power in the financial year (FY) 2020 was 29.38% [108,707 Gigawatt hours (GWh)] (PFC 2022). The entire supply to agriculture and more than 85% of the supply in Maharashtra come from MSEDCL (Josey et al. 2021).[1] Its share of supply to agriculture is higher than the national average of 23.89% from all the state utilities put together (PFC 2022).

[1] The rest of the supply comes from three agencies: The Brihanmumbai Electric Supply & Transport Undertaking (BEST), Tata Power Company (TPC) and Adani Electricity Mumbai Limited (AEML) (Josey et al. 2021) which are limited to the city of Mumbai.

While agriculture sector's share in power consumption is high, this sector's share in revenue from power is comparatively less. Agriculture contributed 3.11% to MSEDCL's revenue in FY 2020 (PFC 2022).[2] Low share of revenue from sale of power to agriculture is because farmers get extremely cheap or highly subsidized power. In FY 2020, MSEDCL's average cost of power supply was INR 6.83/unit (0.0833 USD/unit) while the average revenue from agriculture was INR 0.63/unit (0.0077 USD/unit) (PFC 2022). The gap between cost and revenue was a whopping INR 198,020 million (USD 2,415 million). To bridge this gap, a power subsidy ranging between INR 100 billion (USD 122 million) and INR 120 billion (USD 143 million) per annum is provided for farm and allied sectors (Khapre 2020). The government subsidy to MSEDCL in FY 2020 was INR 100,220 million (USD 122 million) (PFC 2022). This subsidy has been increasing; the compound annual growth rate (CAGR) of the subsidy between FY 2016 and FY 2020 was 7% (PFC 2022). The subsidy creates a debt burden on DISCOMS as these subsidies remain underfunded by government (Sharma, 2021).

Another important channel to bridge the gap between cost and revenue is the cross-subsidization of agriculture from other sectors like commerce and industry. In FY 2020, MSEDCL's revenue from agriculture was INR 0.63/unit (USD 0.0077/unit), while that from commercial consumers, industrial users, and domestic users were INR 12.27/unit (USD 0.1496/unit), INR 8.34/unit (USD 0.1017/unit), and INR 7.42/unit (0.0905/unit), respectively (PFC 2022). Cross-subsidization is limited to 20% in Maharashtra, as determined by the Maharashtra Electricity Regulatory Commission (MERC) (MERC 2020a). It may be noted that these differences in revenue from agriculture and other sectors in Maharashtra are in sharp contrast to the all-India picture. For instance, while the revenue from agriculture from all the state utilities in the country in FY 2020 was INR 0.75/unit (USD 0.0091/unit), the corresponding figures for commercial consumers, industrial users, and domestic users were INR 8.09/unit (USD 0.0987/unit), INR 7.38/unit (0.0900/unit), and INR 4.50/unit (USD 0.0549/unit), respectively (PFC 2022). The higher rates for industrial users and commercial consumers in Maharashtra compared to many other states in India reduced the state's ability to attract investments.

[2] This share excludes the tariff subsidy billed by MSEDCL. Including the tariff subsidy billed results in agriculture's share in MSEDCL's revenue fall to 2.77% (PFC 2022).

Another unique factor in Maharashtra is the high density of pump sets. The state has 45.2 lakh electric pump sets (GoM 2022), which account for 20% of electric pump sets in India (Gambhir et al. 2021). This share is high considering that Maharashtra's share in the country's total farmers and farm land area are 10% and 13%, respectively (Ministry of Agriculture & Farmers Welfare 2019). This disproportionately large number of electric pump sets explains the high power consumption by agriculture in Maharashtra.

The financial deficit of the DISCOM utility in Maharashtra is chronic and high. Malik (2021) observes that agricultural pump sets in Maharashtra account for close to INR 500 billion (USD 6,098 million) in arrears to DISCOM, made worse by their very poor recovery rate of 3.1%. In short, cheap, subsidized and at times free power to agriculture is the main cause of DISCOM's financial woes.

Due to financial constraints and the nonavailability of power, DISCOM's power supply at night for agriculture is unreliable and fluctuates (Gambhir et al. 2021), causing inconvenience to farmers. Cheap power combined with its unreliable supply force farmers to keep irrigation pump sets switched on whenever power is available, without worrying about the excess energy used (Foster et al. 2007). This has resulted in the overexploitation of groundwater which is in limited supply (Foster et al. 2007). Maharashtra is one of the nine states overusing groundwater and this calls for an examination of the agriculture-power-water nexus in the state (Mukherji 2022).[3]

1.3 Scope of Solar Power

Given the financial hardship of DISCOMs and the highly subsidized low-cost power leading to the overexploitation of groundwater, solarization of agriculture seems to be the way out. Globally, solar PV-based power generation has become cheaper in recent years (Figure 1). Between 2010 and 2020, solar PV-based power cost fell by 85% (IRENA 2021). No other power generation technology matched this fall in cost (Sun 2019; IRENA 2021).

[3] The nine states overusing groundwater are Punjab, Andhra Pradesh, Karnataka, Haryana, Gujarat, Rajasthan, Madhya Pradesh, Maharashtra and Tamil Nadu (Mukherji 2022).

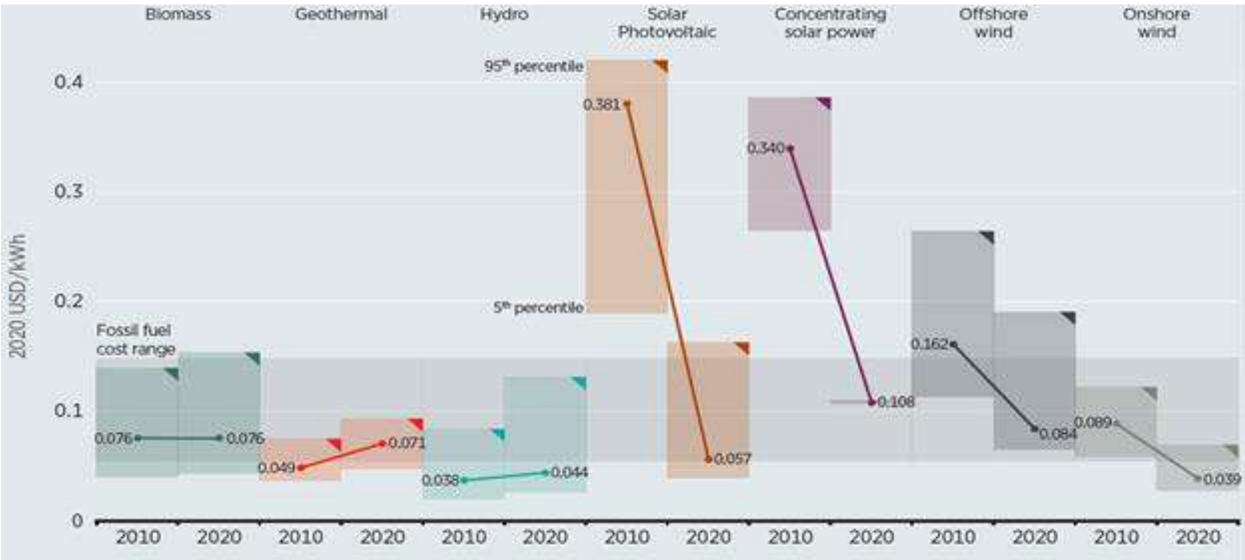


FIGURE 1. The cost of generating solar PV-based power compared to other technologies.

Note: USD stands for United States Dollar

Source: IRENA 2021.

India saw a fall in PV-based solar power tariff by about 70% between 2013-14 and 2020-21 (Figure 2).

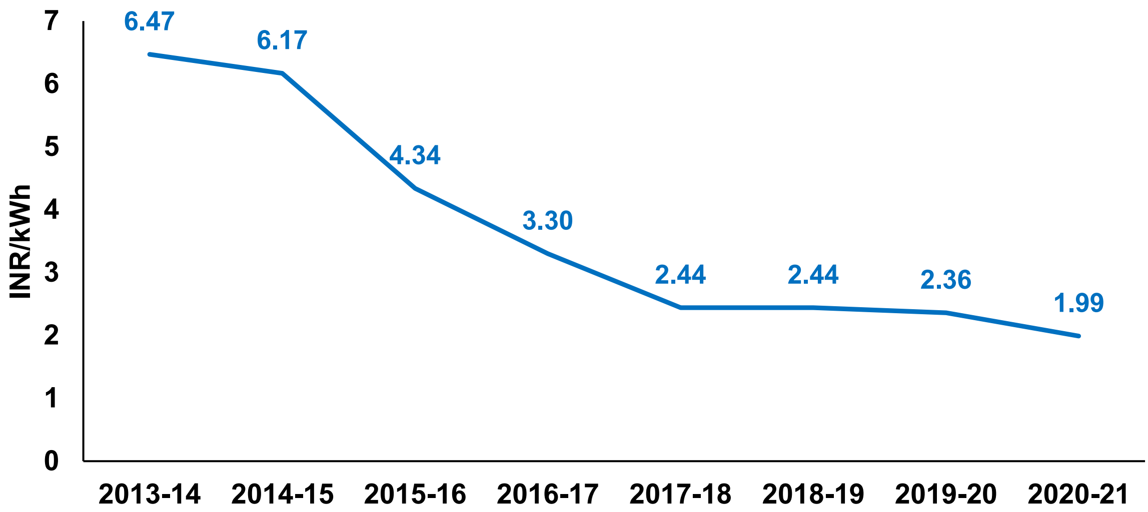
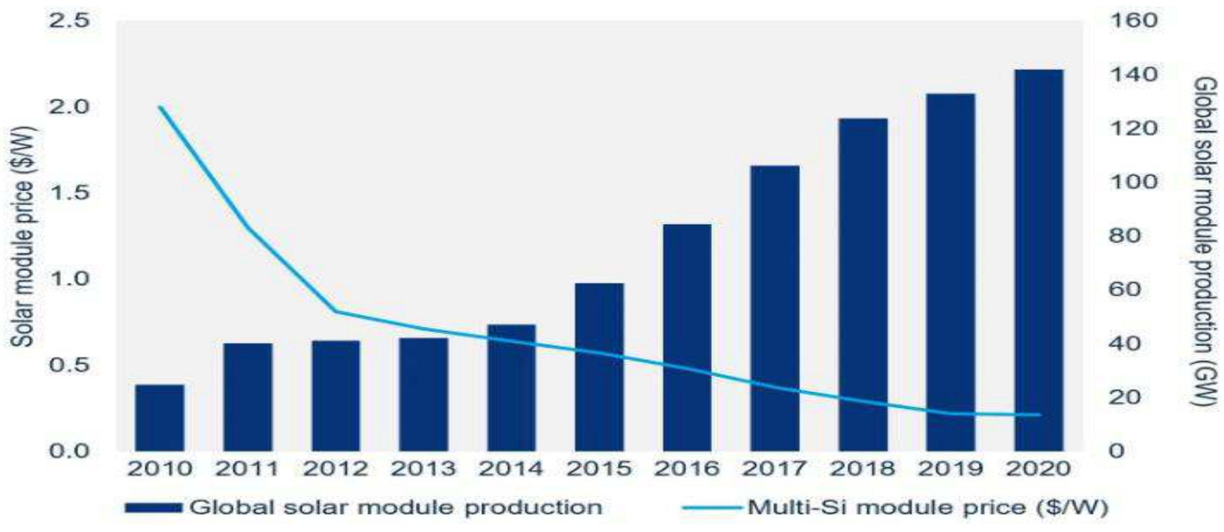


FIGURE 2. Average solar power tariff across India between 2013-14 and 2020-21.

Note: The exchange rate is 1 USD = 82 INR in 2023

Source: MNRE 2021.

This fall in tariff was primarily on account of a decline in the price of PV-based solar modules. Between 2010 and 2020, the global price of solar modules fell by 90%, accompanied by an increase in production (Figure 3).



Source: Sun 2019.

Note: $ stands for United States dollar, GW stands for gigawatt

FIGURE 3. Trends in the global price of PV-based solar modules and their production.

Solarization is an ideal solution since agriculture requires daytime irrigation that can be provided using power that is available from the sun from 8 am to 6 pm. This is in the farmers' interest as it will avoid the use of power in the night-time, prevent frequent power cuts, and avert irrigation pump set malfunction.

Promoting solarization in agriculture has multiple benefits for DISCOMs. They don't have to supply costly power at a cheap or highly subsidized rate, which in turn reduces the agriculture subsidy burden on them. It also reduces the cross-subsidy requirement from other sectors, making power supply to industry and commercial enterprises more attractive. It will improve the financial state of DISCOMs (as less working capital is required, there are no delays in subsidy and there is greater competitiveness of the utility); insulate them from exposure to fluctuating power procurement prices; allow them to meet RPOs and provide better supply to agriculture, thereby boosting farmers' trust in them.

From the government's point of view, solarization of agriculture has advantages. Solar power being cheaper, the government can avoid providing centralized costly power passing through a long transmission and distribution lines to agriculture. Solarization of agriculture also reduces government's subsidy burden. The government's power subsidy is to the tune of 1.2 lakh crores with a CAGR of 10%, accounting for approximately one-sixth of the DISCOMs' total revenue (PFC 2021; Gambhir et al. 2021a; Regy et al. 2021) (Figure 4).

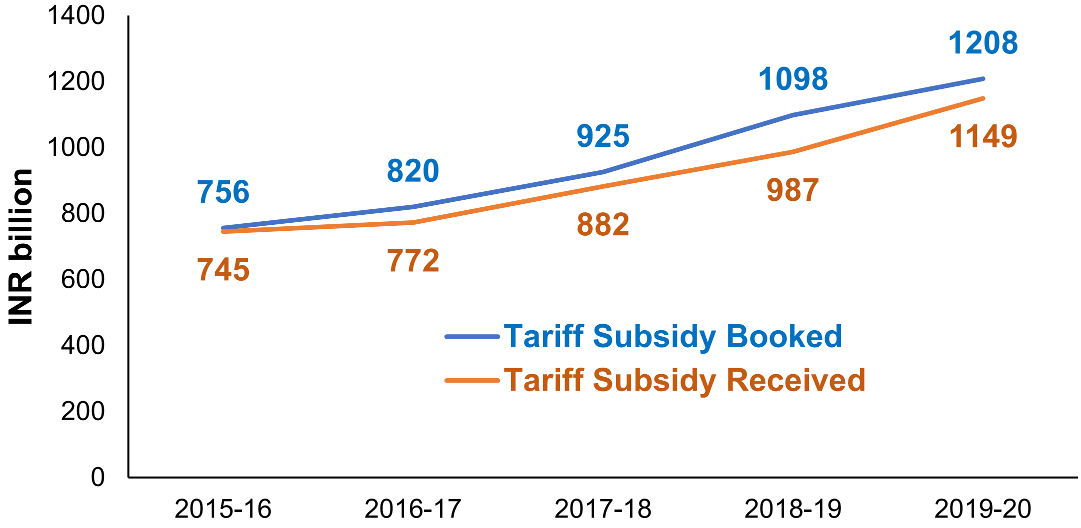


FIGURE 4. Tariff subsidy booked and received by DISCOMs in India from 2015-16 to 2019-20.

Source: PFC 2022.

Also, since solar generation is more local, it reduces T&D losses. The average 30% T&D losses in power fed through rural feeders (MNRE 2019b) can be reduced with local solar power generation.

Another rationale for solarization of agriculture has to do with benefits to the power system. When power generation happens at the tail end of the distribution network, it leads to greater grid balance (Nathan 2015). Since sunlight timings match that of the power demand from agriculture, the use of batteries, often considered the weakest link in solar power generation, is avoided. Also, improving the quality of power will improve the working of equipment connected to rural feeders and consequently improve energy efficiency (MNRE 2019b). So wherever there is a separation of domestic and agriculture feeders, solarization of agriculture is expected to be smooth and effective.

1.4 The Present Study

Solarization in agriculture can occur in three ways: (i) solarization of pump sets, which provides an off-grid solution; (ii) installation of solar plants on the farm and the use of electric pump sets and (iii) installation of solar plants at the feeder and the use of electric pump sets.

Of these, feeder-level solarization has some distinct advantages. Farmers can continue to use their existing electric pump sets. It does not require land on the farmer's farm, which would involve complicated and voluminous paperwork with individual farmers. More importantly, the farmer is not burdened with the responsibility of ensuring the safety and maintenance of the solar plant. In short, farmers derive benefits while maintaining status quo.

The Maharashtra Government's MSKVY scheme was launched on June 14, 2017 as a feeder level solar scheme. However, there are no studies on feeder level solar schemes in general and MSKVY to understand their impacts. For instance, Gujarat's state-wide SKY scheme encourages farmers to set up a grid-connected solar system in their fields and sell surplus solar energy to DISCOMs after meeting their irrigation needs. This provides them an additional income. Moreover, a real-time monitoring system enables an assessment of its progress, financial impact and behavior change among farmers. Given the dearth of such information on the MSKVY solar feeder model in the public domain, IRMA Water Centre (IWC) was mandated to undertake a quick assessment of the progress made in the solar feeder program, assess its impacts, and identify issues of policy relevance.

1.5 Objectives and Research Questions

The main objective of this exercise was to carry out a quick assessment of the progress made, performance and impact of MSKVY in Maharashtra from the perspective of DISCOMs, farmers and state and central governments. It attempts to answer the following questions:

Q1: What physical and financial progress has been made in implementing MSKVY?

Q2: To what extent have the original assumptions underlying the scheme design been validated? How successful has it been in attracting private investment in establishing tail end solar plants? What constraints and bottlenecks have there been? How difficult has it been to find/lease land near substations to build solar plants? What kind of management models have evolved for the operations and maintenance (O&M) of tail end solar plants?

Q3: What has been the experience of farmers benefiting from solar feeders? Are they satisfied with the amount and quality of power supplied? Have there been benefits in terms of improved cropping pattern, cropping intensity and crop yields? Are there benefits in terms of availability of power for nonfarm uses? Have distribution losses decreased?

Q4: How effective have solar pump sets been for farmers to lift irrigation water and to rent them out to other farmers? How sustainable is the utilization of groundwater? Are they overdrawing water resulting in high depletion of groundwater?

2. MSKVY AND ITS ARCHITECTURE

The Government of Maharashtra launched the MSKVY scheme via a government resolution by the Industry, Energy and Labour Department (GoM 2017). The objectives of the scheme (GoM 2017; MERC 2018a; 2020b) are to:

- Electrify agricultural lines with solar power
- Reduce MSEDCL's revenue losses by avoiding the provision of costly and subsidized power for agriculture
- Conserve traditional power supply for other productive purposes
- Reduce cross-subsidy, thereby reducing tariffs for commercial and industrial buyers

- Provide daytime agricultural load to farmers
- Fulfil RPO targets
- Reduce T&D losses
- Ensure farmer satisfaction.

2.1 Features of MSKVY

The scheme is mandated to deploy 0.3 to 10 MW ground-mounted solar plants through Public-Private Partnership (PPP) mode within a 5 km area of substations at 11/22 (kilovolt) kV bus that have substantial agriculture load (AG load) (MERC 2019a; 2019b; 2020b). Initially, Maharashtra State Power Generation Company Limited (MSPGCL) was the main implementing partner; MSEDCL was roped in in March 2018 for flexibility and speedy implementation (GoM 2017; 2018). The initial maximum capacity of 10 MW per *taluk* (administrative unit) and 50 MW per district/circle envisioned under the scheme was revised to 20 MW per *taluk* and 100 MW per district/circle (MERC 2018b; 2018c).

The projects were to be developed by private players, EESL and MSPGCL and called for a long-term power sale agreement with MSEDCL (MERC 2020b). The evacuation of power would be MSEDCL's responsibility, for which funding support would come from Green Cess Fund from Maharashtra Energy Development Agency (MEDA) (MERC 2018a).

2.2 Architecture of MSKVY

The scheme has two implementing partners, namely MSEDCL and MSPGCL (Figure 5) and is implemented via two routes: competitive bidding and a Memorandum of understanding (MoU) with EESL. In the competitive bidding (initiated by the implementation partner) through reverse auction, both MSEDCL and MSPGCL have agreements with private players who own and commission the plants, and either run the same by themselves or outsource it to another private player. In the MoU route, both MSEDCL and MSPGCL have agreements with EESL who owns and commissions the plants, and has agreements with system integrators who deal with installation and O&M.

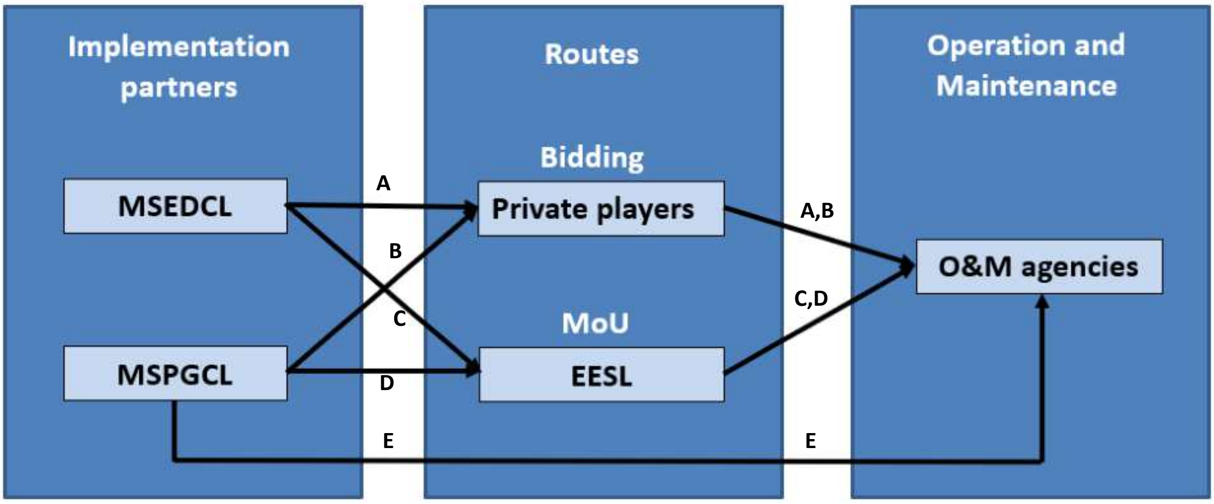


FIGURE 5. Architecture of MSKVY.

Source: Authors' creation.

Notes: [a] MSEDCL = Maharashtra State Electricity Distribution Company Limited; MSPGCL = Maharashtra State Power Generation Company Limited; [b] MoU = Memorandum of Understanding; EESL = Energy Efficiency Services Limited.

Competitive bidding is the default route or the norm. Though the MoU route was initially adopted to give momentum to the scheme, it cannot be taken as a precedent (MERC 2020b; Gambhir et al. 2021). There are five channels (refer to A, B, C, D, E in Figure 5) involved in the scheme implemented under MSKVY: MSEDCL and MSPGCL through private players, MSEDCL and MSPGCL through EESL and O&M agencies, and power generating agency MSPGCL directly owns some of the plants and may engage system integrators for installation and O&M (Figure 5).

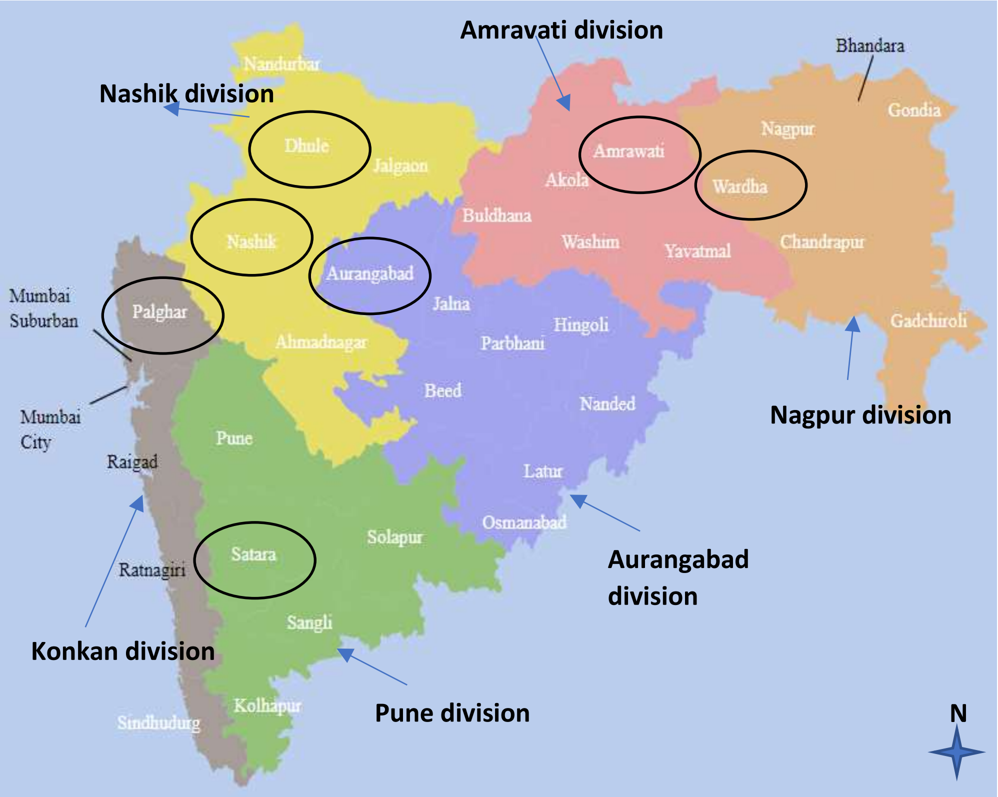
3. METHODOLOGY AND STUDY SITES

The study involved three steps. First, documents related to MSKVY from the government and other agencies involved in the scheme were studied, a significant source of which was the orders of the Maharashtra Electricity Regulatory Commission (MERC). Between January 2018 and May 2022, at least 23 orders relating to the MSKVY scheme were passed by MERC (MERC 2022a). The project team also accessed contracts/agreements between different players, apart from articles, webinars and other material published by Prayas Energy Group (PEG 2018).

The second step was gleaning information from stakeholder interactions. Telephonic and in person consultations were held with government officials of DISCOM (MSEDCL) and the generation agency (MSPGCL), EESL, private players, tail end operators and think tanks like Prayas Energy Group.

The third aspect of the methodology was a farmers' survey. A combination of purposive and convenience sampling was used to identify districts from six administrative divisions in Maharashtra: Konkan, Nashik, Pune, Aurangabad, Amravati and Nagpur (GoM 2022). Seven districts representing these administrative divisions were selected: Dhule, Nashik, Satara, Aurangabad, Wardha, Amravati and Palghar. One or two solar units from each district were selected. The choice of districts and solar units was based on their convenient location for the survey team, their representation of both the implementing partners (MSEDCL and MSPGCL) and routes of operationalization (bidding and MoU).

A total of 280 farmer beneficiaries of the solar units were surveyed, approximately 40 farmers from each district (Figure 6 and Table 1). Farmers were selected based on their availability and willingness to participate in the survey (availability sampling).



Map source: Adapted from Wikimedia commons (2011)

FIGURE 6. The study districts (circled) where the survey was conducted.

TABLE 1. Number of solar units and farmers surveyed in the study districts.

District	Division	Number of solar units	Number of farmers
Dhule	Nashik	1	40
Nashik	Nashik	2	40
Aurangabad	Aurangabad	2	40
Amravati	Amravati	2	39
Wardha	Nagpur	1	40
Palghar	Konkan	1	40
Satara	Pune	2	41
Total		11	280

Source: Authors' creation.

The farmers' survey data was triangulated through seven FGDs and interactions with village heads. Appendix 1 provides pictorial glimpses of the field survey.

4. PHYSICAL AND FINANCIAL PROGRESS OF MSKVY

This section corresponds to Q1: What physical and financial progress has been made in implementing MSKVY?

4.1 Overall Progress

The Government of Maharashtra set a target of installing a capacity of 5,000 MW under MSKVY by 2025 (GoM 2021; Josey et al. 2021). Interactions with stakeholders revealed that to date projects totalling 2500 MW capacity have been approved and those of 1500 MW capacity have been signed off. Publicly available government data shows that by March 2022, 737 MW of solar installations (one-seventh of the target and approximately half of the projects signed off) had been commissioned under MSKVY (MSEDCL 2022). The physical and financial progress made under the scheme is given in Table 2.

TABLE 2. Progress made under the MSKVY scheme.

Status	Capacity (MW)	Estimated investment[a] (INR million)	Share
Cabinet to decide by 2025	5,000	200,000	
Approved	2,500	100,000	50% of target
Signed	1,500	60,000	60% of approved (30% of target)
Commissioned	737	29,480	49.1% of signed (14.7% of target)

Note: [a] Estimated investment was calculated at the rate of INR 4 crores/MW (EESL 2017). The exchange rate assumed 1 USD = 82 INR in 2023

Source: Authors' interaction with stakeholders and (GoM 2021; Josey et al. 2021; MSEDCL 2022)

4.1.1 Progress Made Under the Five Channels

Five channels were used in the implementation of the MSKVY scheme (viz., channel A, B, C, D, and E as given in Figure 5). The channels are different based on the combination of factors like implementation partner, route of operation and ownership. Table 3 gives each channel's commissioned capacity.

TABLE 3. Capacity commissioned by different parties under MSKVY (as on March 2022).

Implementing partner	Ownership	Capacity (MW)
Maharashtra State Electricity Distribution Company Limited (MSEDCL)	Private players	345
	Energy Efficiency Services Limited (EESL)	186
Maharashtra State Power Generation Company Limited (MSPGCL)	MSPGCL	179
	Private players	27
	EESL	0
Total		737

Source: Authors' interaction with stakeholders and MSEDCL (2022)

Between the two implementing partners, MSEDCL with 518 MW of installations accounts for more than 70% of the commissioned projects. This is because it has spare land at the substation/feeder level. Moreover, its enthusiasm to roll out the projects stems from being the biggest beneficiary of MSKVY (demonstrated later in the Section 6). Josey et al. (2021) indicate that going forward, MSEDCL will add more capacity under MSKVY, given its potential savings and political commitment.

Also, between direct bidding with private players and an MoU with EESL, both have equal shares in terms of capacity installed as of now. However, the bidding route is expected to be more successful in the future for two reasons: (i) MSKVY's main objective is to deploy more solar power by engaging the private sector and (ii) both the implementation partners and MERC are aware of the initial reluctance of private players, due to which EESL was roped in. Quoting from MERC (2020b):

> "*To avoid the retendering process for solar power projects which involved time and cost, and to avoid further delays due to non-receipt of bids in implementation of these projects, MSPGCL approached EESL and requested to submit a proposal for the development of 100 MW projects....*"

"*…in order to break the logjam and to avoid any further delay after scrutiny of rates, the Commission has adopted the rate decided through MoU between MSPGCL and EESL. It is clarified that the Order shall not be treated as a precedent*."

4.1.2 Progress Made through the Bidding Route

Projects commissioned by MSEDCL (Figure 7) are concentrated in Nashik and Aurangabad divisions, and none have been commissioned in many districts/circles in other divisions. The geographical spread of MSPGCL projects (Figure 8) is more uniform across divisions. Stakeholder interactions revealed that since MSEDCL is a distribution company, having a good number of projects is essential for it to meet the AG load in order to provide daytime power supply. If the supply from solar plants is inadequate and can't cater to the entire AG load of the feeder area, the substation will refrain from supplying power to farmers of one area of the substation as this would mean relatively depriving farmers in another area of the same substation. This may lead to protests which the distribution company cannot afford to entertain. Therefore, it makes sense for MSEDCL to consolidate the MSKVY projects in specific districts/circles rather than spreading them across all the districts. MSPGCL does not face such a dilemma as it is a power generating agency.

4.1.3 Progress Made through the MoU Route

Table 4 shows the projects undertaken by EESL. In total, MoUs for a capacity of 800 MW were signed between 2018 and 2020, of which 500 MW are with MSEDCL and 300 MW are with MSPGCL.

TABLE 4. Projects under MSKVY undertaken by EESL through an MoU.

Year	Contracted capacity (MW)	Status	Contracted party	Power tariff (INR)
2018 (Phase I)	200	170 MW commissioned	MSEDCL	3.00
2019 (Phase II)	300	On hold	MSEDCL	3.11

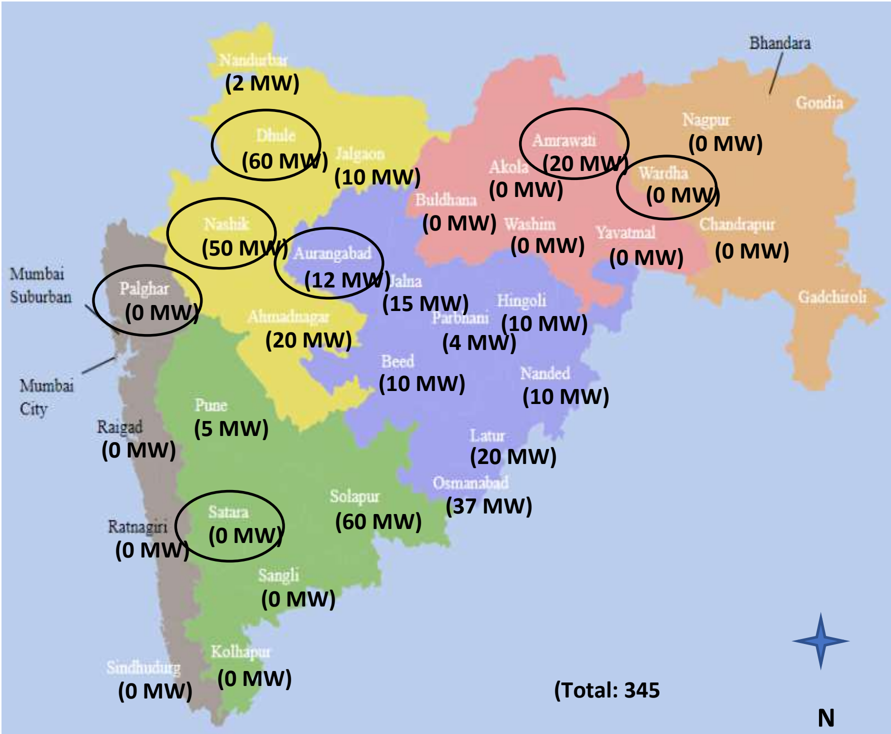
Year	Contracted capacity (MW)	Status	Contracted party	Power tariff (INR)
2019 (Phase III)	200	In progress	MSPGCL	3.11
2020 (Phase IV)	100	On hold	MSPGCL	3.11

Note: The exchange rate is 1 USD = 82 INR in 2023

Source: Authors' interaction with EESL

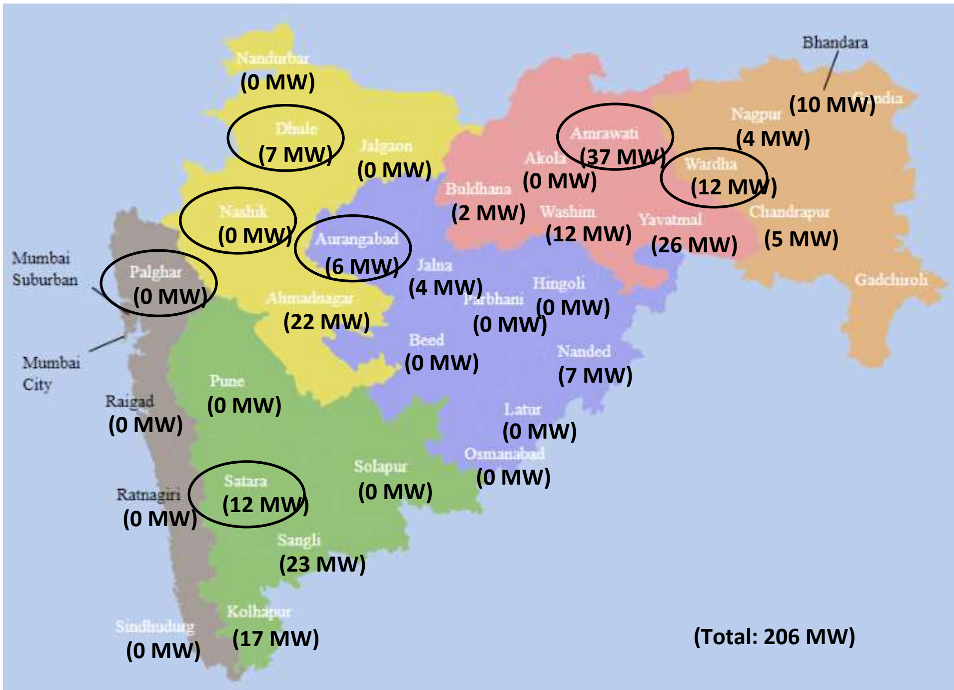
In the first phase, of the 200 MW contracted projects with MSEDCL, approximately 170 MW were commissioned. The second phase's projects were kept on hold because the supply chain of solar modules, particularly from China, was disrupted in the last two years due to the COVID pandemic. In addition, land was not easily available, unlike in the first phase when MSEDCL could spare its own unused land to install plants.

Of the 300 MW contracted projects with MSPGCL, the first phase's projects are in progress. By March 31, 2022 no project was commissioned. The second phase's projects are on hold because of internal issues with EESL. It was revealed that EESL strategically kept the second phase's projects on hold in order to focus first in making headway with projects agreed to earlier.



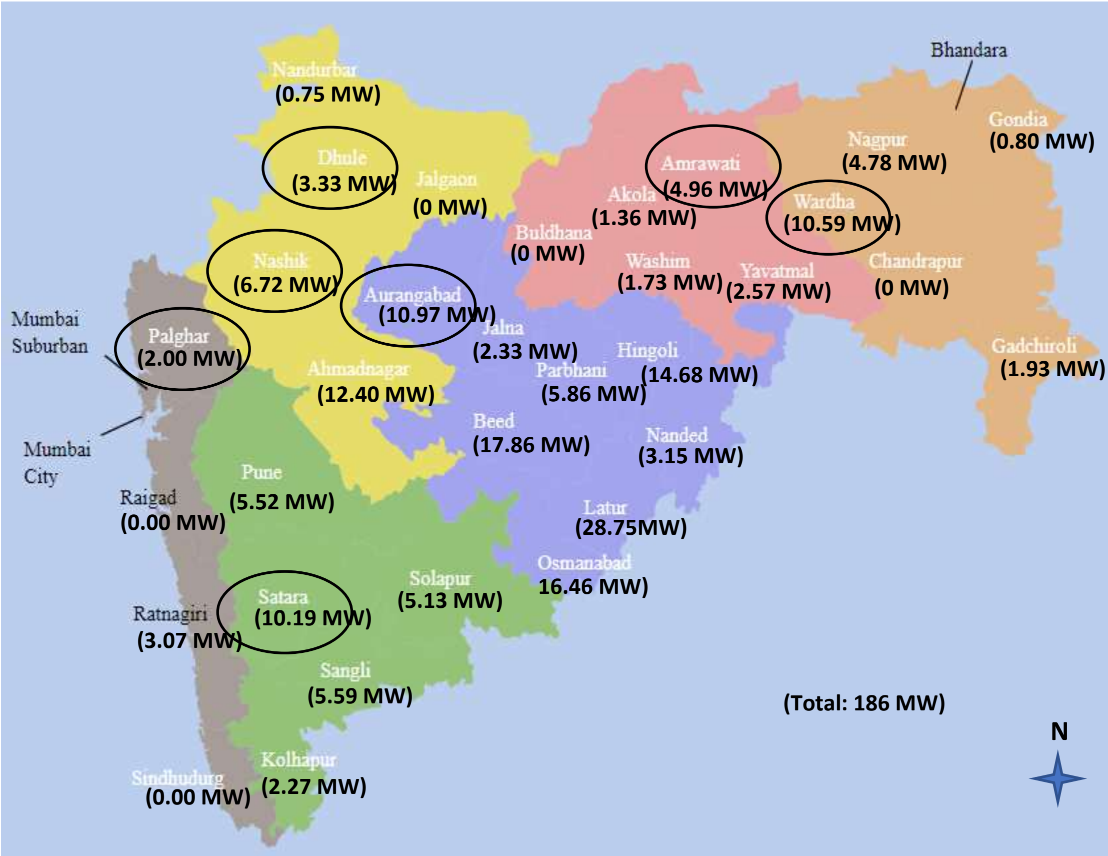
Map source: Adapted from Wikimedia commons (2011)

FIGURE 7. Location of solar power plants (circled) implemented by MSEDCL and commissioned under MSKVY through a bidding route.



Map source: Adapted from Wikimedia commons (2011)

FIGURE 8. Location of solar power plants (circled) implemented by MSPGCL (including those owned by it) and commissioned under MSKVY through a bidding route.



Map source: Adapted from Wikimedia commons (2011)

FIGURE 9. Location of solar power plants (circled) commissioned through EESL via an MoU route.

The regional distribution of EESL projects as of March 31, 2022 is given in Figure 9. The projects are more or less distributed across different regions. It may be noted that EESL projects have two tariffs of INR 3.00/unit (USD 0.0366/unit) and INR 3.11/unit (USD 0.0379/unit) which is extremely competitive (MERC 2018a; MERC 2020c; Gambhir et al. 2021). The competitiveness of the tariff is discussed in section 4.2.

4.1.4 Progress of MSKVY Projects in the Study Districts

Figure 10 gives details of the projects commissioned under MSKVY through private players, EESL and MSPGCL. Private players had a greater role in commissioning solar units in Dhule, Nashik, Amravati, and Aurangabad. In the districts of Satara, Wardha, and Palghar, there are EESL and MSPGCL solar units, but no private units.

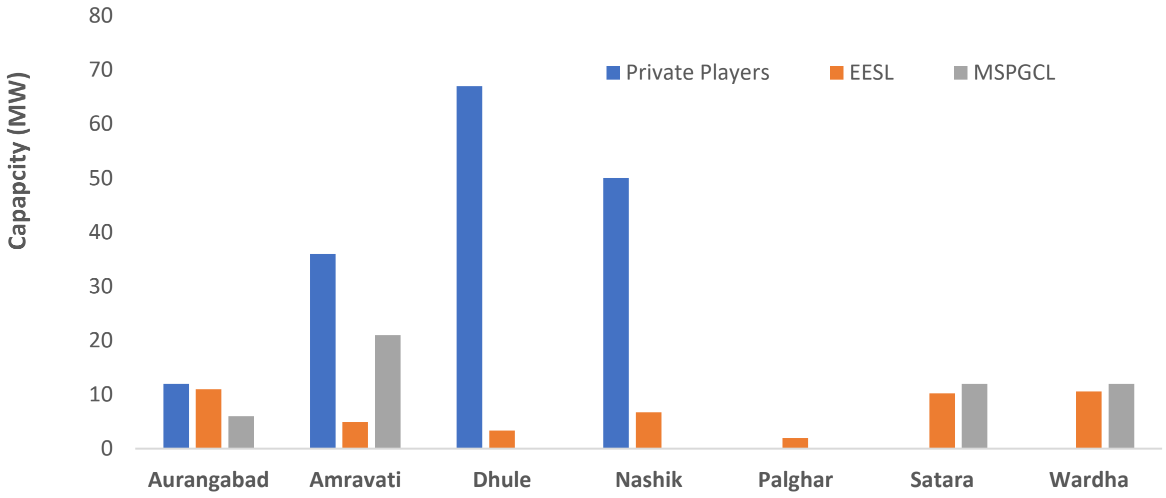
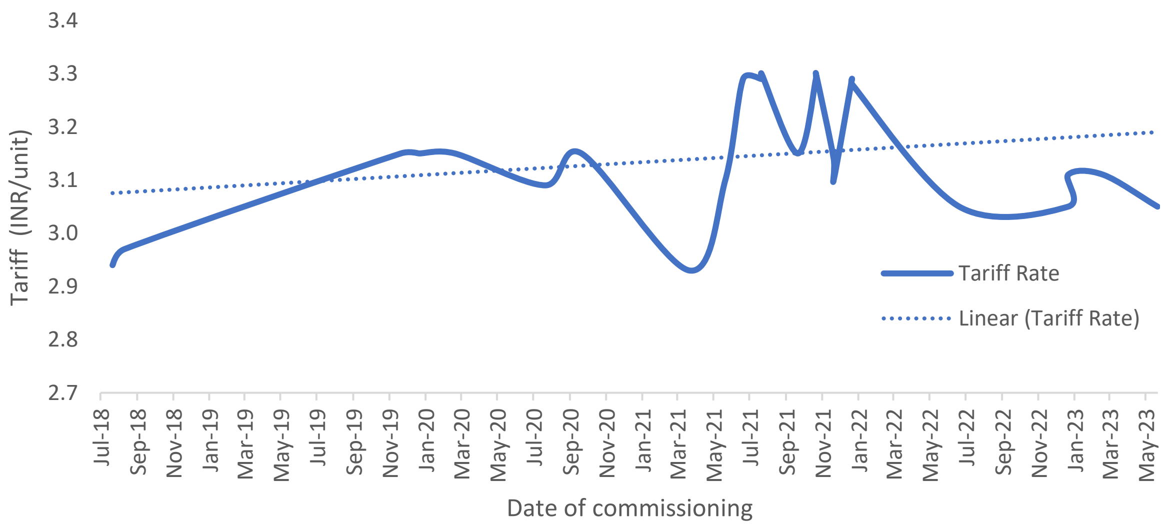


FIGURE 10. Projects commissioned under MSKVY developed by private players, EESL and MSPGCL in the study districts.

Source: Authors' interaction with stakeholders and MSEDCL (2022)

4.2 Power Tariff

The power tariff in MSKVY projects varied from INR 2.94/unit (USD 0.0359/unit) to INR 3.30/unit (USD 0.0402/unit) (MSEDCL, 2022) (Fig. 11). The tariff for projects commissioned in FY 2021 were higher compared to the rest of the period mainly because the cost of solar modules increased during the peak of the COVID-19 pandemic.



Data source: MSEDCL (2022)

Note: The exchange rate is 1 USD = 82 INR in 2023

FIGURE 11. Power tariff in MSKVY projects commissioned from July 2018 to May 2023.

It may be noted that the power tariff in MSKVY projects are competitive. The tariff discovered by MSEDCL to procure power from large-scale solar projects under solar parks is at INR 2.5/unit (USD 0.0305/unit) (Ranjan 2021). Since the MSKVY projects are small scale and distributed, any tariff around INR 3.00/unit (USD 0.0366/unit) can be considered competitive. The tariff of INR 3.00/unit (USD 0.0366/unit) negotiated between MSEDCL and EESL has been termed 'a very competitive rate' for the following reasons (MERC 2018a):

(i) MERC's generic tariff for solar PV plant FY 2017-18 was INR 5.13/unit (USD 0.0626/unit).

(ii) Short-term bids floated by MSEDCL for 100 MW solar power between November 2017 and October 2018 with a ceiling tariff of INR 3.00/unit (USD 0.0366/unit) had no takers.

(iii) Long-term bids for 200 MW solar power (cumulative capacity in Vidarbha, Marathwada, Western Maharashtra, and North Maharashtra) resulted in a tariff of INR 3.15/unit (USD 0.0384/unit).

(iv) The Solar Energy Corporation of India Limited's bidding process tariff discovered for Maharashtra was INR 4.42/unit (USD 0.0540/unit) for 50 MW in December 2016 and INR 4.43/unit (USD 0.0540/unit) for 450 MW in September 2016.

4.3 Compensation Protocol

A Power Purchase Agreement (PPA) between MSEDCL and power generation agencies (private players, EESL or MSPGCL) provides for compensation by both parties if either delivers below expectations. MSEDCL compensates the generating agency if it is unable to evacuate power beyond a certain time period. MSEDCL's connected grid needs to be live for power evacuation. If the availability of the distribution/transmission line after the interconnection point to evacuate power (from 8 am to 6 pm) falls below 98%, i.e., line non-availability is more than 2% of the time [i.e., approximately 175 hours (2% × 365 days × 24 hours) in a year], and power is not evacuated for reasons not related to the generating agency, then the generation loss is offset by a compensation of 75% of the PPA tariff (MERC 2019b).

Generation loss is a product of the average generation per hour during the contract year and the excess hours of grid outage (MERC 2019b).

Similarly, if there is a shortfall in generation considering a 17.5 Capacity Utilization Factor (CUF), the generating agency compensates MSEDCL for it at a rate corresponding to solar Renewable Energy Certificate (REC) (MERC 2018a). On the contrary, any excess generation above the maximum declared CUF is purchased at 75% of the tariff (MERC 2018a).

5. ENGAGEMENT OF PRIVATE PLAYERS AND RELATED CHALLENGES

This section corresponds to Q2: To what extent have the original assumptions underlying the scheme design been validated? How successful has it been in attracting private investment in establishing tail end solar plants? What constraints and bottlenecks have there been? How difficult has it been to find/lease land near substations to build solar plants? What kind of management models have evolved for the operations and maintenance (O&M) of tail end solar plants?

5.1 Solar Deployment

It was assumed that the MSKVY scheme will attract a lot of private players and that deployment of solar power will be scaled up. Projects under MSKVY are reasonably attractive to private players. It gives them a long term contract (25 years) with MSEDCL at a competitive price, with the responsibility of power evacuation and compensation if evacuation falls below 98% being MSEDCL's. Also, unlike farmer-level micro projects, private players neither suffer from lack of scale, nor do they need to go through enormous paperwork with each farmer. Moreover, in some cases, land is provided by MSEDCL/MSPGCL or other government agencies, or the provision of community land is facilitated by government agencies, saving them the bother of finding land and bearing its cost.

As of March 2022, barring the EESL projects, there were 50 solar power units with a capacity of 372 MW (MSEDCL - 345 MW and MSPGCL - 27 MW) commissioned by 29 private players (Appendix 2, Table A1) (MSEDCL 2022). Of these, 27 units are of 10 MW, 2 units of 17 MW, 2 units of 5 MW and 1 unit of each 7 MW, 15 MW, 16 MW and 20 MW. Of the 29 private players, 15 have a capacity of 2 MW under MSKVY, 2 have 5 MW capacity, 1 has 7 MW capacity, 3 have 10 MW capacity, 1 has 15 MW capacity, 3 have 20 MW capacity, 1 has 30MW capacity, 1 has 50 MW capacity and 2 have the maximum capacity of 70 MW.

The involvement of private players has so far been a mixed bag of success and failure. In the initial rounds of bidding, they showed very little interest because of the low tariff, timeline challenges, and difficult to comply guidelines (Josey et al. 2021). Over time, the tariff increased from INR 2.94/unit (USD 0.0359/unit) to INR 3.30/unit (USD 0.0402/unit) in some cases. As of February 2021, Josey et al. (2021) report that 3,654 MW are at various stages of procurement; they will cover a fifth of the state's total power sale to agriculture and 40% of the RPO of MSEDCL.

5.2 Constraints Faced by Private Players

Discussions at MERC hearings have dwelt on the inadequate response of private players (MERC 2020b; 2020c). As stated in MERC (2020c):

> "*Even after enormous efforts during last 2-3 years, MSEDCL was able to contract only 527 MW against 1873 MW of bids received through competitive bidding processes conducted for total capacity of 6500 MW under MSKVY. Further, all of five tenders totaling to 6500 MW floated under MSKVY were under subscribed.*"

Similarly, with respect to tenders of MSPGCL, MERC (2020b) states:

> "*The Commission notes that MSPGCL has taken efforts to discover tariff through transparent process of competitive bidding for procurement of solar power. However, even after re-tendering and repeated extension of bid deadlines, it had to cancel the tender for two regions as there was no response.*"

This poor response from private players has mainly been on account of the nonviable tariff and issues related to land.

5.2.1 Nonviable Tariff

A study of the MERC case documents and interaction with stakeholders reveal that private players found it difficult to meet the tariff for the following reasons:

(i) The falling price of solar modules from USD 2.649/Wp in 2010 to USD 0.192/Wp in July 2020 was instrumental in making solar energy cheaper. The price rose by 38% in the last 20 months on account of the pandemic (JMKRA 2022). Since solar panels constitute approximately 65% of the project cost (JMKRA 2022) it raised the cost of the entire system.

(ii) The basic customs duty on solar modules increased to 40% and on cell imported from China and Malaysia to 25% from April 2022 (Prasad and Bhaskar 2021a). This duty replaces the safeguard duty which was at 15% (Prasad and Bhaskar 2021a; 2021b). Initially, a 25% safeguard duty was imposed in August 2018 but was reduced to 20% in July 2019 and to 15% in January 2020, giving a boost to solar deployment (Prasad and Bhaskar 2021b). However, the basic customs duty which was introduced to make domestic manufacturing more attractive, has made solar PV costly.

(iii) The GST on solar PV module which stood at 5% when GST was introduced in India in 2017, was increased to 12% in October 2021 (Sinha 2021). Also, when solar system are provided to customer as a complete solution it invites a GST rate of 5%, whereas when it is unbundled and provided component wise, it invites a GST rate of 18% (Kabeer 2018). Delays in GST reimbursement and confusion around GST have also affected solar developers (Kabeer 2018). The increased GST has made solar power costlier and the power tariff unviable.

Together these changes increased the cost of installation from INR 40 million/MW (USD 0.4878 million/MW) (EESL 2017) to INR 47 million/MW (USD 0.5732 million/MW) under MSKVY.

5.2.2 Land Issues

Availability of land has remained a hindrance to the growth of solar power under MSKVY (MERC 2020c; 2022b). Initially, the land requirement relating to MSKVY was to be made available from spare land at the MSEDCL substation (GoM 2017; 2018). Of the 3257 substations of MSEDCL, 300 of them each had 10,000 m^2 of land to house small units (up to 1 MW), from which an estimated 200 MW solar capacity was developed (MERC 2018a).

Also, MSPGCL was entrusted with finding government land within 2 to 3 km of substation (or even 5 to 10 km) to be leased by the implementing partner from the Revenue department for 30 years for a nominal rent of INR 1 (USD 0.0122) (GoM 2017; 2018). Village land can be obtained on lease with permission from the Gram Sabha and District Magistrate for a mutually agreed rent (GoM 2018). The same rent is passed on to the private developer. The registration of such village land would happen freely by MEDA and the land can be continued to be designated an agriculture land (MERC 2018c). A feasibility report on the use of the land produced by one of the implementation partners (MSPGCL or MSEDCL) and the other implementation partner and Maharashtra State Electricity Transmission Company Limited (MSETCL) provide their feedback (GoM 2018), and if all go well actual development of the land would be undertaken. If the land is barren, non-fertile non-agricultural, a sum of INR 500,000/MW (USD 6098/MW) is added to the cost, and the tariff increases by INR 0.012/unit (USD 0.015 cents/unit) (MERC 2019c).

Challenge of land availability is a major reason for the undersubscription of the MSKVY scheme (MERC 2020c). Wherever land is not available to MSEDCL/MSPGCL, private solar developers may come forward to develop the project on their own land and factor the costs in tariff bids (MERC 2018c). The land cost adds 5% to the total project cost. The power tariff depends on whether land is provided by MSEDCL/MSPGCL or is obtained by the private player. For instance, when land is provided by MSEDCL, the tariff ceiling is INR 3.11/unit (USD 0.0379/unit); if not, it is INR 3.30 /unit (USD 0.0402/unit) (MERC 2020c).

To facilitate land availability, MSEDCL created a land bank portal where farmers can offer their land on lease for 26 to 30 years at INR 30,000/acre/year (USD 366/acre/year) (1 acre = 0.404685642 hectares) with a 3% annual increase. MSEDCL provides the farmer rent after deducting the power generation payment given to the developer. All the tax and other statutory liabilities with respect to the land lease are borne by the developer (MERC 2022b). This provision insulates farmers from private players. Where MSEDCL provides land to private developers through the portal, they need to commission the plant within nine months (MERC 2020c).

5.3 Other Assumptions of the MSKVY Scheme

The major objective of solarizing the power sector was to reduce the gap between average cost of supply (ACS) and average revenue realized (ARR)/kWh. This gap has been widening from 2017-2018 to 2019-2020 (Table 5) owing to rising oil prices and inflation associated with it. This reinforces the relevance of solar power considering the reduction in power purchase cost.

TABLE 5. The average cost of power supplied and average revenue realized by DISCOM.

Year	Average cost of supply (INR/kWh)	Average revenue realized (INR/kWh)	Gap (INR/kWh)
2019-20	6.83	6.30	0.53
2018-19	6.15	6.31	0.16
2017-18	5.40	5.10	0.31

Note: The exchange rate is 1 USD = 82 INR in 2023

Another major benefit expected from local solar power generation is the reduction in losses from long distance T&D. The national average of T&D losses stands at 20.66% (CEA 2021). Since solar power is generated and consumed through local distribution systems, the implementation of MSKVY projects is expected to reduce losses by up to 6% (MERC 2018a). Reduction in loss due to solarization through MSKVY, considering the planned 5000 MW, will be around 300 MW per year (assuming 6% savings). MSEDCL is currently undertaking a study to assess the impact of solar power on T&D losses. However, given only 724 MW of installation, the saving in total T&D losses is approximately equivalent to 0.1% of the total capacity of the state.[4]

Meeting RPO targets for MSEDCL was another major objective of the scheme. These targets for solar power purchase have been increasing from 2016-17 to 2024-2025 from 1% to 13.5% of the total energy purchased (Table 6). The trend is reflected across states to support the renewable energy targets set by the central government (MNRE 2022b). The total power consumption in Maharashtra during 2019-20 was 108,707 gigawatt-hours (GWh) (PFC 2022). Since the installed capacity through MSKVY had reached only 737 MW till March 2022, assuming a 17% CUF, MSKVY's contribution will be approximately 1100 GWh, which is only

[4] This is calculated taking into account a 6% saving and that the total installed power capacity of the state is approximately 44 GW (CEA 2022)

1% of the total sales and insufficient to meet the RPO target. Once the installed capacity reaches the planned 5000 MW, more visible contributions to reducing T&D losses and solar RPO targets are likely in the future.

TABLE 6. Year-wise renewable purchase obligation (RPO) targets.

Year	Solar renewable purchase obligation (%)
2016-17	1.00
2017-18	2.00
2018-19	2.75
2019-20	3.50
2020-21	4.50
2021-22	6.00
2022-23	8.00
2023-24	10.50
2024-25	13.50

Source: MERC 2018a; 2020a.

6. CASE STUDY: EVALUATING THE OPERATIONAL AND FINANCIAL VIABILITY OF THE SYSTEM INTEGRATOR/O&M PARTNER, EESL AND MSEDCL IN PALGHAR DISTRICT

A detailed study was conducted on the setting up and O&M of a 1995.2 kilowatt peak (kWp or ~2 MW) solar plant at Dapchari village in Palghar district, Maharashtra, installed through EESL. The plant commissioned on June 23, 2020 was installed and managed by Mundra Solar PV Limited (a subsidiary of Adani Solar) as system integrator and O&M contractor. Implementing agency MSPGCL opted for the MoU route with EESL, which in turn opted for a bid, resulting in Adani Solar being given the task of installing the plant.

FIGURE 12. The Adani Solar plant at Dapchari village in Palghar district, Maharashtra.

The plant was set up on a fenced five-acre plot. It has 6200 polycrystalline modules installed in 310 boxes of solar modules, with each box consisting of 20 modules (Figure 12) The modules are of different capacities: 315 Watts (W), 320 W, 325 W and 330 W. Each module has details of its specifications (Figures 13 and 14). The power generated from the plant between January 2021 and January 2022 is given in Table 7. The power generated differed due to variations in solar intensity, with generation being higher from March to May due to the steady availability of sunlight. The plant has a small office. The plant provides power for its maintenance.

TABLE 7. Solar power generated from January 2021 to January 2022.

Month	Export readings (kWh)	Import readings (kWh)	Grid outage (hours:minutes)
January 2021	223,720	1,300	19:00
February 2021	231,900	1,040	27:49
March 2021	270,548	1,104	35:50
April 2021	284,544	1,088	9:57
May 2021	172,802	782	114:38
June 2021	198,352	932	21:58

Month			
	Export readings (kWh)	Import readings (kWh)	Grid outage (hours:minutes)
July 2021	133,250	1,104	80:23
August 2021	137,970	1,136	43:28
September 2021	135,278	1,298	46:29
October 2021	227,278	1,298	46:29
November 2021	188,384	1,386	55:14
December 2021	213,140	1,680	24:07
January 2022	236,684	1,676	29:29

FIGURE 13. Taking a picture of module specification

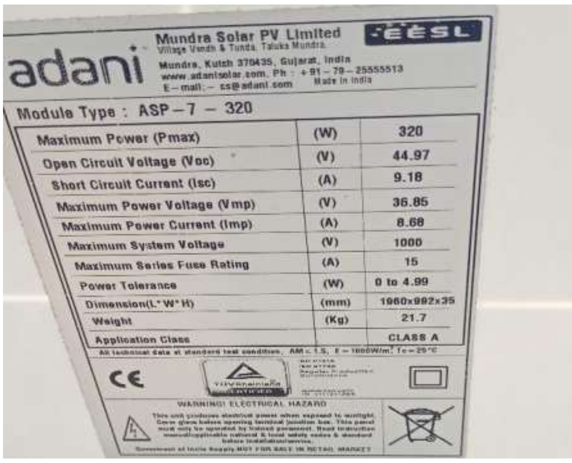


FIGURE 14. Specifications of each module.

During grid outage, the solar plant stops supplying power to the grid. This is equivalent to a lost opportunity for the power generation company. To minimize this loss, a compensation agreement for a minimum level of service was made with the distribution company. If grid outage exceeds 72 hours in any month, the plant is compensated by the distribution company to the amount proportionate to the loss incurred. Table 7 provides details on the monthly outage for 2021. As per the contract, for outages exceeding 72 hours in May and July 2021, the distribution company has to compensate EESL in case the outage is not related to the generating plant.

Two electric meters installed in the premises measure the export and import of power. The 'main meter' (Figure 15) measures the total units of power generated (exported). The 'check meter' (Figure 16) measures the power imported, which is used for lighting, to run the water pump sets, CC TV camera and other electrical fixtures in the office room. Every day the meter is manually assessed. An automatic mobile tracking app called "I- Solar Cloud" (Figure 17) tracks the energy produced during the day. There are 20 inverters installed to convert DC power generated to AC power, which is supplied to the grid. The inverter specifications are given in Figure 18.

FIGURE 15. The main meter.


FIGURE 16. The check meter.

FIGURE 17. Solar Cloud app.

FIGURE 18. Specification of the inverter.

The plant is run with the help of an engineer who stays on the premises and a technician, who have a contractual work agreement with Mundra Solar through an HR consultancy and get paid INR 23,000 (USD 280) and INR 12,000 (USD 146), respectively.

FIGURE 19. Solar panels being cleaned.

To ensure the efficient functioning of solar panels, they are washed thrice a month by three workers hired on a daily wage of INR 400 (USD 4.88). The washing takes four days. Hence 12 days or 36 human-days a month are spent on the cleaning activity. The panels are sprayed with water sourced from a tap installed in the center of each row of panels and washed using a hand-made mop (Figure 19). The 6-hour cleaning is split into three hours in the early morning and three hours in the late evening. The company is spending INR 14,400 (USD 176) a month on contract labor for cleaning the panels. For security purposes, two 360˚ cameras installed on the premises monitor the plant; this is done by the engineer who stays in the office house. The total direct monthly labor cost on operations and maintenance is INR 49,400 (USD 602) (excluding power and other costs). The management of the plant has been smooth, and the employees have not been facing any difficulty in operating and maintaining the plant in the last two years of installation.

6.1 Financial Analysis

The establishment cost of the 2 MW solar plant was around INR 80,000,000 (USD 975,610) (MNRE benchmark cost), with 60% of the payment done in advance for material procurement, 30% of it after the plant was set up and 10% paid annually for the next 25 years. Project funding was obtained through green funds from the Asian Development Bank (ADB) and KfW Bank. A total of 2,403,018 units of power was exported from the plant to the grid in 2021. The agreement with DISCOM is to purchase power at INR 3.00/unit (USD 0.0366/unit); so, the total revenue from DISCOM through power sales is approximately INR 7.2 million (USD 87.8 thousand). EESL pays the O&M partner an annual maintenance fee of INR 1.1 million (USD 13.4 thousand) to ensure the facility's upkeep and power supply at 17.5% CUF throughout the year. Any shortfall in power supply must be compensated by the O&M partner at INR 3.45/unit (USD 0.0421/unit). As per the agreement with EESL and Mundra Solar, a mandated 17.5% CUF will be reduced by 0.9% every year owing to a decline in module efficiency. For May and July, grid outage exceeded the 72-hour monthly limit (Figure 20).

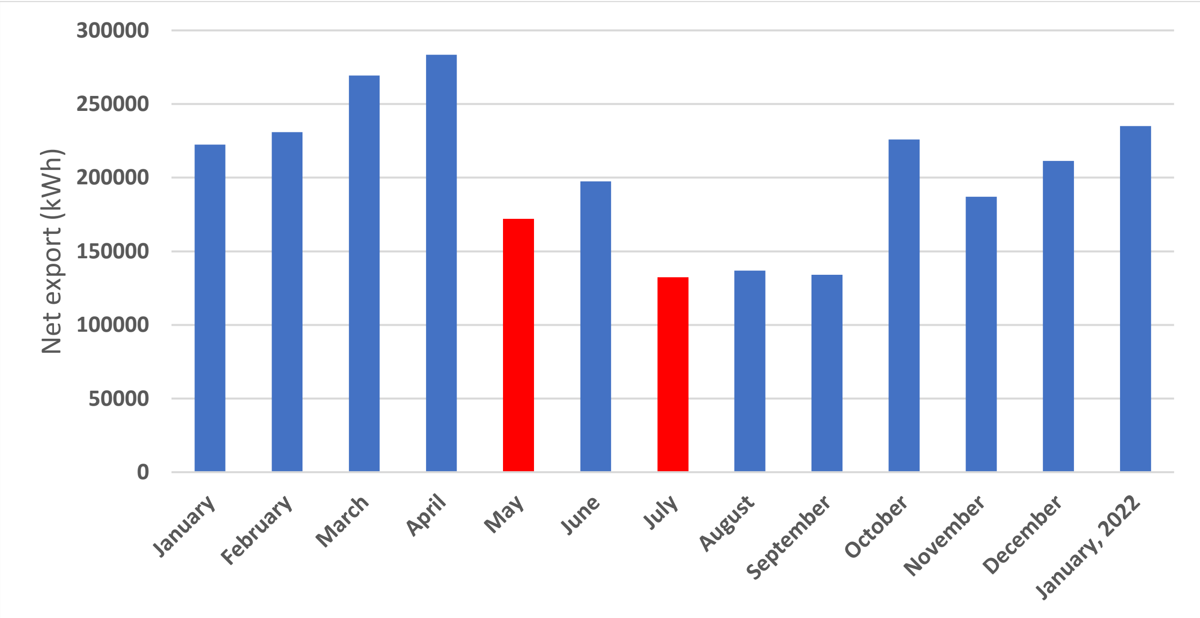


FIGURE 20. Monthly solar power export from the Dapchari plant in Palghar.

Source: Authors' creation (from the data obtained from the plant site).

The financial implications for different agencies is discussed below.

6.1.1 Financial Implications for EESL

For the year 2021, power produced at 17.5% CUF amounts to 3,066,000 units and an ideal revenue of INR 9.198 million (USD 112 thousand). Since the total power produced fell short by 662,982 units, the O&M operator must pay a compensation of INR 2.287 million (USD 28 thousand) to EESL. If this payment is made promptly, EESL's revenue for 2021 will be close to INR 9.5 million (USD 116 thousand). The net profit after paying an annual maintenance fee to the O&M operator will amount to approximately INR 8.4 million (USD 102 thousand). Net returns assuming prompt payment of penalty will translate into an internal rate of return (IRR) of around 5.8%.

According to officials, EESL is currently not stressing on penalty payments due to operational uncertainties and the difficulty in calculating and collecting them. In the event of their non-collection, net returns for EESL will be 2.4% (IRR) over the next 25 years. Details on project funding and exchange rate risk can provide more clarity on the viability of the project for EESL. Overall, the project seems to be viable if EESL can ensure operational efficiency at 17.5% CUF.

6.1.2 Financial Implications for the System Integrator/O&M Partner

For Mundra Solar, the revenue as system integrator and O&M partner will be INR 80 million (USD 976 thousand) for setting up and INR 1.1 million (USD 13 thousand) of annual payment to keep it operational for 25 years. In the event of maintaining a 17.5% CUF over 25 years, the maximum net returns will be around 1.2 crores net present value (NPV), assuming a 10% margin on setting up and INR 0.7 million (USD 8.5 thousand) of annual expenses on maintenance. Given the power generation in 2021, if the penalty payment is made on the shortfall in production, net returns from the project falls to INR 6 million (USD 73 thousand) (assuming similar production levels over 25 years). This calculation does not include material and instrument replacement expenses that may be incurred over time. The cost for replacing modules and inverters may further reduce net returns. A more detailed analysis of the operational aspects of the plant can provide clarity on the additional expenses and variation in O&M expenses over location, size and contractor efficiency over time.

6.1.3 Financial Implications for MSEDCL

DISCOM eliminated the risk of cost variations in power procurement by entering into a long-term agreement for INR 3.00/unit (USD 0.0366/unit) with EESL. Hence DISCOM has no investment risk and reduced ownership, maintenance and management expenses. Considering the average power procurement cost of INR 5.4/unit (USD 0.0659/unit), with this agreement, DISCOM makes a profit of INR 2.4/unit (USD 0.02927/unit). Since the power is generated and utilized locally, the aggregate technical & commercial (AT&C) losses are minimal. With actual production levels, DISCOM's net profit through this project for 2021 amounted to INR 5.767 million (USD 703 thousand). If the system outage is limited to 72 hours/month, the maximum profit at 17.5% CUF will generate a maximum annual cost saving of INR 7.358 million (USD 90 thousand) for DISCOM. If DISCOM can achieve a similar performance across projects, the maximum cost saving from the 5000 MW MSKVY can reach INR 18 billion (USD 220 million) annually. Details of the saving on AT&C losses will be clear once the project generates a sizable production.

7. IMPACT ON FARMERS

(This corresponds to Q3: What has been the experience of farmers benefiting from solar feeders? Are they satisfied with the amount and quality of power supplied? Have there been benefits in terms of improved cropping pattern, cropping intensity and crop yields? Are there benefits in terms of availability of power for nonfarm uses? Have distribution losses decreased?)

7.1 Farmers' Survey

Using availability sampling, a total of 280 farmers were selected from 2-3 villages in each of the seven districts covering all the administrative divisions of Maharashtra. Data was collected using structured questionnaires (including open-ended questions for greater clarity) from an average of 40 samples per district. The survey was representative of the following five farmer categories (as indicated by the Government of India based on the size of land holdings): marginal farmer (31%, land holding < 1 ha), small farmer (28%, land holding of 1 - 2 ha), semi-medium farmer (22%, land holding of 2-4 ha), medium farmer (15%, land holding of 4 -10 ha) and large farmer (4%, land holding > 10 ha) (Figure 21) (PIB,2019).

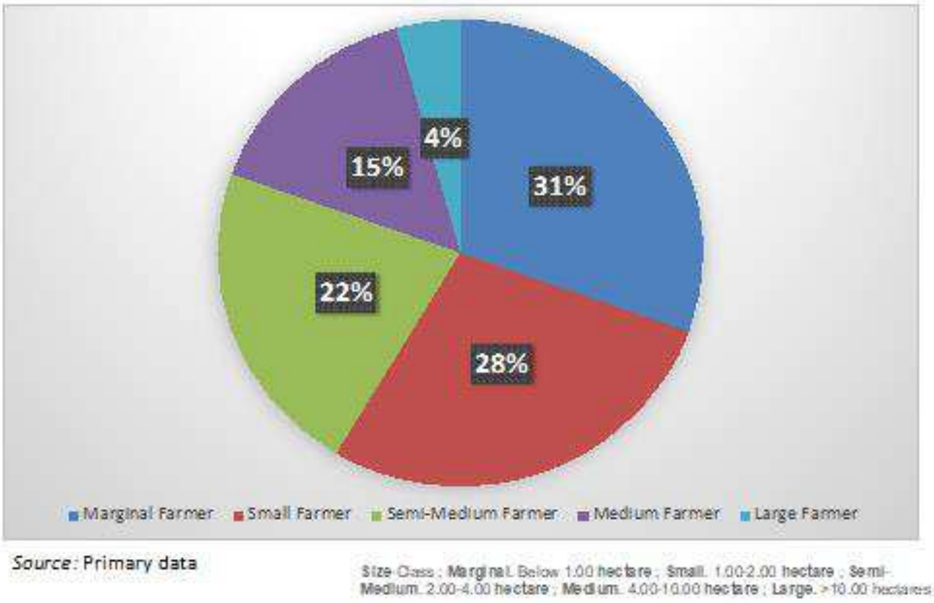


FIGURE 21. Profile of farmers based on their land holding size.

Source: Primary data.

7.2 Awareness About the Solar Unit

The farmers were asked if they are aware about the MSKVY scheme under which solar plants are installed at the feeder level that supplies power to the substation for better supply of power during the daytime. Of the 280 farmers, 96.4% did not know about the scheme even when told the month and year of installation. Only ten farmers were aware of the unit. This is unexpected given that the main purpose of the MSKVY scheme is to provide reliable daytime power to farmers.

This shows the flip side of feeder-level projects compared to micro projects at the farmers' level. In the feeder-level project, farmers are expected to continue irrigation relying on the same supply of power. Since there is no significant improvement in daytime availability of power (discussed in the next sub-section) farmers have no clue about solar plants installed at the feeder level to provide them with reliable power in the daytime.

7.3 Daytime Availability of Power (8 Hours a Day)

Farmers require regular daytime power supply for irrigation. The MSKVY was created to fulfil this objective. As per the survey, daytime availability of power was 7.40 hours (with standard deviation of 1.597) prior to MSKVY project. Availability after the MSKVY project was 8.01 hours (with standard deviation of 1.453), demonstrating an improvement. All the farmers surveyed responded to the question.

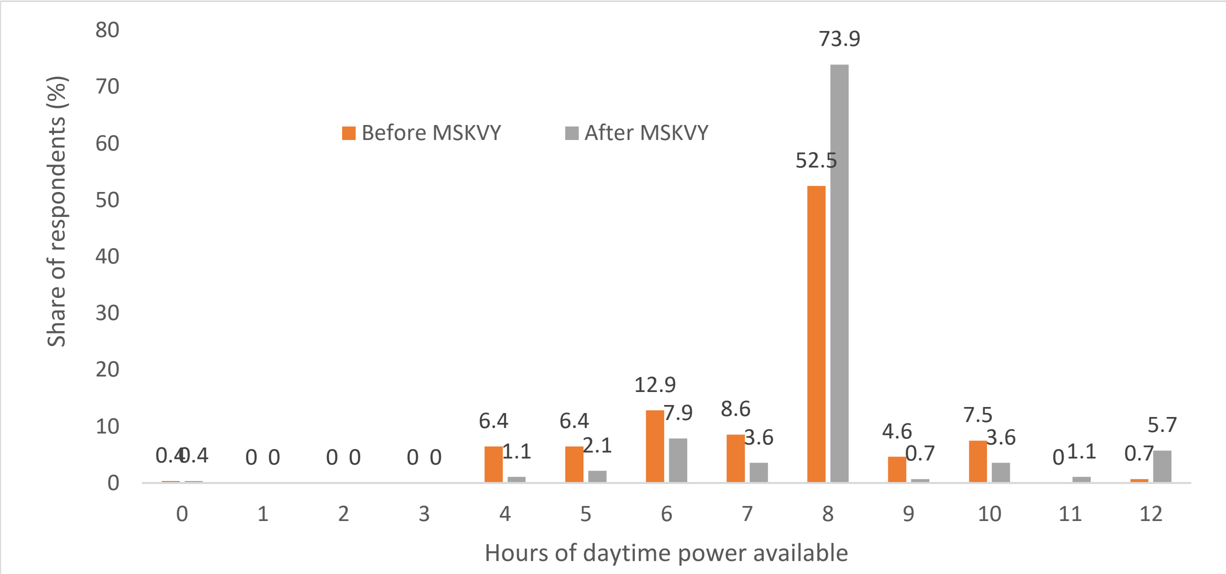


FIGURE 22. Hour-wise availability of daytime power across the districts before and after MSKVY.

Source: Authors' creation

Figure 22 shows that the hour-wise availability of power during the daytime varied from 4 hours to 12 hours in the study area (barring one respondent in Dapchari who reported no availability). In the pre-MSKVY period, around 65% of the respondents reported that at least 8 hours of power was availability compared to nearly 85% reported in the post-MSKVY period. Though this may indicate a commitment to supply 8 hours of power, it does not apply to all the districts. Table 8 shows the district-wise availability of daytime power as obtained from the farmers' survey.

TABLE 8. A district-wise comparison of the availability of daytime power before and after the project based on the survey.

District	Hours of daytime power supply (before MSKVY)[a]	Hours of daytime power supply (after MSKVY)[a]	Change (%)
Amravati	7.77 (39, 0.485)	7.90 (39, 0.852)	1.65
Aurangabad	5.53 (40, 0.751)	7.58 (40, 0.844)	37.10
Dhule	7.78 (40, 0.423)	7.70 (40, 1.067)	-0.96
Nashik	6.80 (40, 2.503)	6.93 (40, 1.185)	1.84
Palghar	8.75 (40, 1.904)	10.00 (40, 2.353)	14.29
Satara	7.22 (41, 0.908)	7.98 (41, 0.156)	10.47
Wardha	8.00 (40, 0.000)	8.00 (40, 0.000)	0.00
Average of 7 districts	7.40 (280, 1.597)	8.01 (280, 1.453)	8.20

Source: Primary data.

Notes: [a] Numbers in parentheses are number of observations and standard deviation.

It may be observed that the change in daytime power availability in all the districts was not uniform across districts. Wardha district showed 8 hours of daytime power availability both pre- and post-MSKVY supply, demonstrating that this district was already meeting the 8-hour daytime supply commitment to agriculture even before the MSKVY initiative. Dhule district showed close to 8 hours of daytime supply both before and after the MSKVY scheme. Aurangabad district showed a remarkable improvement in daytime supply of power from an average of 5.53 hours before MSKVY to 7.58 hours post-MSKVY. Palghar showed an interesting trend, with 8.75 hours before MSKVY to 10 hours after the scheme (the observations showed high standard deviation). There was a reasonable improvement in Satara post-MSKVY, with supply available for close to 8 hours. There was hardly any improvement in Nashik where the installed solar plant may not be able to cater to the AG load.

To corroborate the data from farmers' survey, the study collected daily data at the feeder level. The case of Ganeshpur substation feeder is given below.

7.3.1 Supply at the Feeder Level

Compared to the farmers' survey (which has limitations of recollection bias for data in the pre-MSKVY period and a small sample size), one of the better and more objective ways to obtain data on daytime supply is to explore information at the feeder level. We could access data for only a 10 MW solar project that was commissioned on January 7, 2020 by Nisagra Renewable Energy Pvt. Ltd under MSKVY (MSEDCL 2022). The output of the plant is connected to the Ganeshpur substation agriculture feeder located in Sakri taluk in Dhule district. The substation provides AG power to the three villages of Kasare (population - 8417), Ganeshpur (1537), and Sayane (678) (Census of India 2011).

To know the change in daily daytime supply, data was collected for both the periods before MSKVY (May 2018 to December 2019) and after (April 2021 to May 2022). Data showed that daily average daytime availability of power was 6.37 hours in the pre-MSKVY period; this fell to 5.43 hours in the post-MSKVY period. Our farmers' survey had an interesting observation. In Kasare village, 9 out of 23 farmers surveyed indicated an improvement in the availability of daytime power from 7 hours (pre-MSKVY period) to 8 hours (post-MSKVY period). In Ganeshpur, 9 farmers surveyed revealed that pre-MSKVY power availability was 8 hours; 3 of the 9 farmers said post-MSKVY availability was reduced to 4 hours. In Sayane, all the 8 farmers surveyed reported consistent supply of 8 hours per day during both periods. We understand that the sample size of farmers in our study is too small to draw any definite conclusions.

While it is worth noting that feeder level data is a more accurate source to assess changes in daytime availability of power, information on more feeders could not be accessed. However, feeder data showing a reduction in the duration of daytime supply with the MSKVY scheme could have three explanations. Insights from interactions with MSEDCL revealed that at the feeder level, the decision to supply power to the AG feeders is based on the availability of supply. If the supply is insufficient to cater to the full AG load, then the supply is not given to AG load to avoid protest from farmers who remain deprived of power to their agriculture knowing well that farmers of other location in same substation area are supplied with. Second, while interacting with the substation, it was revealed that with the advent of the MSKVY scheme improved voltage levels have been reported because of which fewer hours of supply can cater to the need of farmers. The third explanation is that post-MSKVY, the non-payment of bills by a section of farmers may have led to reduced supply.

The farmers' survey showed on an average improvement in daytime supply of power post-MSKVY, though not uniformly in all the districts. Since MSKVY is in its early years of implementation (with only 15% of the target commissioned), it may be too early to draw a concrete inference about its success. Moreover, the farmers' sample size is not large enough. However, it is clear that the observations at the feeder level contradict the overall increasing trend in daytime power supply, which calls for a detailed study with larger feeder level data from more substations and a larger sample size of farmers for surveys.

7.4 Load Shedding

The study also examined the quality of power availability, i.e., load shedding and voltage fluctuations which lead to damage pump sets.

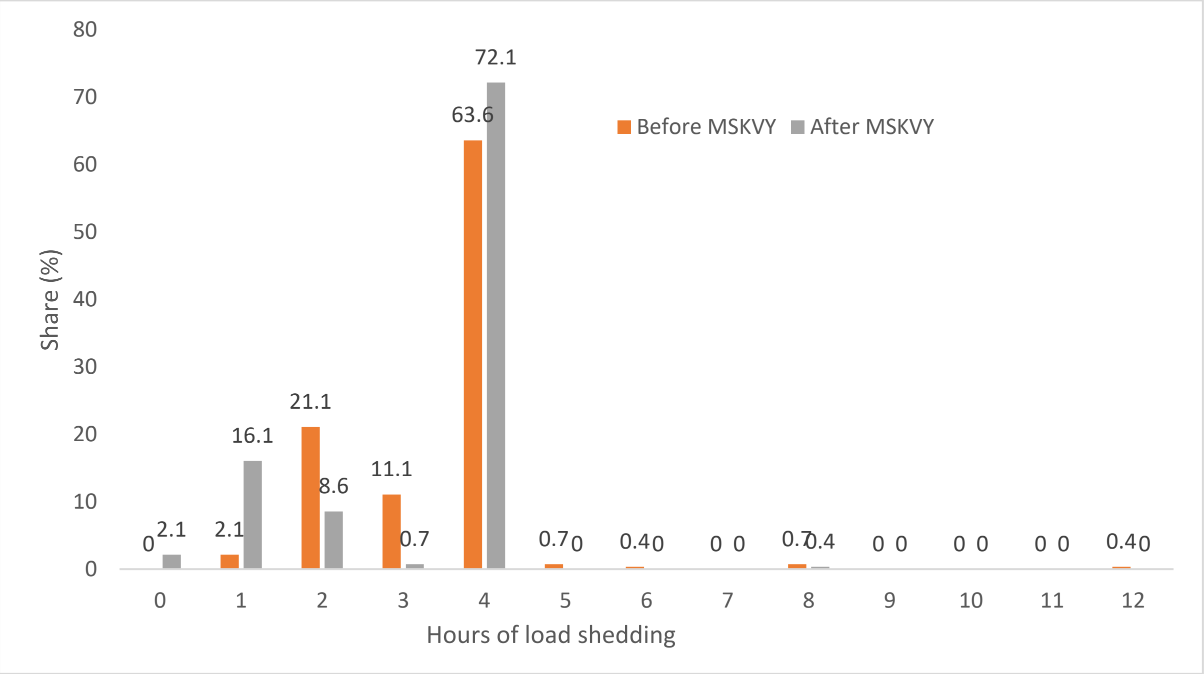


FIGURE 23. Changes in scheduled load shedding before and after MSKVY

Source: Authors' creation

Figure 23 shows farmers' responses to the pattern of hourly load shedding in seven districts. Load shedding seems to have improved from the pre-MSKVY to the post-MSKVY period. Overall considering 280 respondents on an average the daily load shedding has decreased from 3.475 hours before MSKVY to 3.268 hours after the scheme. It is interesting to note that no respondent reported 24 hours of supply pre-MSKVY; however, 6 of them reported 24-hour power supply post-MSKVY. The share of respondents reporting 5 or more hours of load shedding decreased from 2.1% in the pre-MSKVY period to 0.4% in the post-MSKVY period.

An analysis of responses on district-wise load shedding (Table 9) showed a positive change (reduced load shedding) in four districts (Aurangabad, Dhule, Nashik and Palghar), no change in two districts (Satara and Wardha) and an increase in load shedding in Amravati.

TABLE 9. District-wise change in hours of load shedding.

District	Average before the scheme[a]	Average after the scheme[a]	Change (%)
Amravati	3.82 (39, 0.389)	4.00 (39, 0.000)	4.70%
Aurangabad	2.13 (40, 0.607)	1.50 (40, 0.877)	-29.41%
Dhule	4.10 (40, 0.632)	4.00 (40, 0.906)	-2.44%
Nashik	2.76 (40, 0.891)	1.38 (40, 0.838)	-50.45%
Palghar	4.00 (40, 0.000)	3.70 (40, 4.177)	-7.50%
Satara	4.00 (41, 0.000)	4.00 (41, 0.000)	0.00%
Wardha	4.00 (40, 0.000)	4.00 (40, 0.000)	0.00%
Average of 7 districts	3.475 (280, 1.113)	3.268 (280, 1.291)	-5.96%

Source: Primary data.

Notes: [a] Number of observation and standard deviation are given in parentheses.

7.5 Voltage fluctuations

The study aimed to understand the quality of power supply in terms of frequency of daily voltage fluctuations during the pre- and post-MSKVY periods (Figure 24).

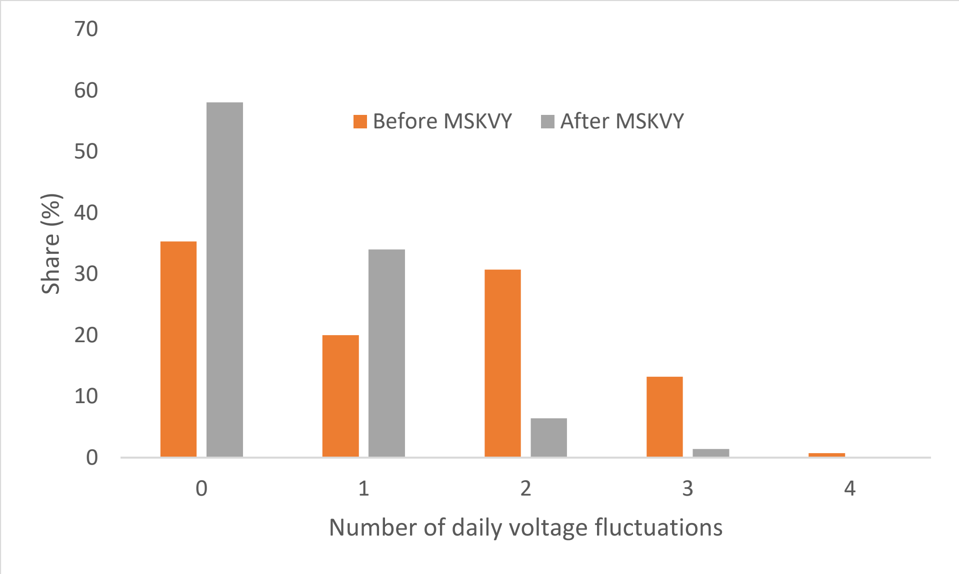


FIGURE 24. Change in frequency of voltage fluctuation.

Source: Authors' creation.

The figure clearly shows an improvement in voltage quality after the scheme was implemented compared to before its launch. Currently, close to 60% of the respondents reported that there is no voltage fluctuation; it was approximately 35% in the pre-MSKVY period.

District-wise voltage fluctuations (Table 10) show that all the districts barring Wardha have shown marked improvement.

TABLE 10. Change in the frequency of daytime voltage fluctuation**.**

District	Average before the scheme[a]	Average after the scheme[a]	Change (%)
Amravati	0.36 (39, 0.778)	0.15 (39, 0.366)	-57.14%
Aurangabad	1.95 (40, 0.552)	0.60 (40, 0.672)	-69.23%
Dhule	2.38 (40, 0.774)	1.05 (40, 0.846)	-55.79%
Nashik	1.65 (40, 0.622)	1.23 (39, 0.536)	-25.41%
Palghar	0.70 (40, 0.464)	0.28 (40, 0.452)	-60.71%
Satara	1.49 (41, 1.381)	0.12 (41, 0.331)	-91.80%
Wardha	0.13 (40, 0.335)	0.18 (40, 0.385)	40.00%
Average of 7 districts	1.24 (280, 1.096)	0.51 (279, 0.683)	-58.64%

Source: Primary data.

Notes: [a] Number of observations and standard deviation are given in parentheses.

7.6 Change in Cropping Pattern and Yield of Crops

The farmers were asked if there had been any change in land requirement for each crop after the scheme and if they had changed their farming strategy after the scheme. A marginal change in farming strategy and practices before and after the MSKVY initiative were observed. Only 5-6 of the 280 respondents gave positive answers. They all belonged to Palghar district and had begun rose, chilli and vegetable cultivation that enabled them to have a summer crop and increase their yield and income. However, this study does not claim this change can be attributed to the MSKVY initiative. The survey revealed that a large majority of the farmers had not changed their cropping pattern after the scheme.

FIGURE 25. Interaction with the farmer of Palghar near to Daphari solar plant

FIGURE 26. Chilli cultivation at the farm of the farmer

7.7 Change in Income

Income increase was determined by asking the respondents about their income from farming in the pre- and post-MSKVY periods. Only 2% of the farmers said their earnings had increased but it could not be established if this was on account of the MSKVY scheme, and this could have been due to other factors.

7.8 Solar Power Use in Nonfarm Activities

The study tried to capture the use of solar power in non-farm activities, such as in small industries, including processing activities. All the respondents responded in the negative indicating no use of solar power of MSKVY scheme in non-farm activities.

8. IMPACT ON PUMP SETS AND GROUNDWATER

(This corresponds to Q4: How effective have solar pump sets been for farmers to lift irrigation water and to rent them out to other farmers? How sustainable is the utilization of groundwater? Are they overdrawing water resulting in high depletion of groundwater?)

8.1 Use of Pump Sets in Agriculture

A total of 240 respondents of the 280 farmers reported the use of pump sets. A 5% increase was observed in the number of hours (294.41 to 310.37) pump sets were used to draw water during *kharif* (autumn season, India) from before the MSKVY started. There was also a marginal change in the use of pump sets during *rabi* (spring season, India); it increased by 2.5% (603.54 hours to 619.11 hours) compared to before the MSKVY scheme. Though a marginal increase in both the seasons was observed, it may be premature to infer that such changes were on account of the MSKVY initiative.

8.2 Impact on Irrigation Pump Sets

Farmers have experienced irrigation pump sets burning out due to the poor quality of power supply. Before the scheme, farmers used to face pump sets burning out due to low voltage and frequent load shedding. Based on the observations of the respondents, 0.69 pump sets were burning out annually before the scheme; this number declined by 60% to 0.27 annually after the scheme.

8.3 Use of Solar Units for Irrigation and Change in Groundwater Level

Since the hours of pump sets working increased in both the *kharif* and *rabi* seasons, we examined what happened to groundwater at two points, i.e., in 2017 for the pre-project period and in 2022 for the post-project period. The data showed that there were no changes in the groundwater table (Table 11) in any of the sampled districts during 2017 and 2020, as per the Central Ground Water Board (CGWB) for Maharashtra.

TABLE 11. Changes in the groundwater table in the districts**.**

District	Taluk	2017	2020
Palghar	Dahanu	Safe	Safe
Dhule	Sakri	Safe	Safe
Aurangabad	Aurangabad	Semi-critical	Semi-critical
Aurangabad	Gangapur	Semi-critical	Semi-critical
Amravati	Warud	Overexploited	Overexploited
Wardha	Wardha	Safe	Safe
Nashik	Sinnar	Critical	Critical
Satara	Wai	Semi-critical	Semi-critical

Source: CGWB (2023).

8.4 Water Market

The study also aimed to find out if a water market had been developed or strengthened during the period. It was observed that farmers were not selling water to other farmers. However, such a possibility can be studied as more projects are operational and people start reaping more benefits from solar power.

8.5 Sustainability of Using Solar Power for Agriculture

A question that we sought to answer was whether more and continuous daytime power supply poses a risk to the sustainability of groundwater utilization. Our observations from the survey and from CGWB data sources did not show any such evidence. Although a 5% increase in pump set utilization was observed in *kharif* season, it cannot be concluded that groundwater utilization is unsustainable. It may be too early to come to conclusions on this aspect of the sustainability of solar power in the MSKVY scheme. A deeper penetration of solar projects to the village level may give people greater confidence that there is an assured source of solar energy, continuous supply of power; this may lead to behavior change among farmers and stop them from drawing excess water by the random and continuous running of pump sets.

9. CONCLUSIONS AND RECOMMENDATIONS

The MSKVY scheme is based on solarization at the feeder level and the provision of solar power for agriculture load during the daytime. This study by IRMA and supported by IWMI was undertaken to understand the architecture of the MSKVY scheme and assess its physical progress through an analysis of documents from the government and other agencies, stakeholder interactions, and farmers' survey. The study also aimed to explore factors that may be hindering the scheme from attaining its full potential.

The study shows the scheme's moderate physical progress (15% of target and 60% of approved capacity already signed). Of its two implementation partners, MSEDCL accounts for a greater share of projects (70%). Going forward it is also expected that MSEDCL will add more capacity. The study has showed that MSEDCL benefited from the scheme in two ways: the cost saved from the cheaper procurement rate of solar power compared to the cost of power obtained from distant suppliers as well as from reduced T&D losses.

The study found that similar progress was made both in MSKVY projects implemented through an MoU with EESL and through bids invited from private players, as far as commissioned projects were concerned. Though the MoU route was taken only to give an impetus to the projects, it was found equally promising for two reasons. First, EESL has access to low interest finance from international funding organizations where no funding of the Government of Maharashtra is involved. Second, EESL invests in these plants and implements them through a system of integrators (i.e., private players) who install and manage the plants.

The participation of private players through the bidding route was moderate, with 29 private players commissioning 50 solar units of 372 MW capacity until March 31, 2022. This involved MSEDCL having a long-term PPA with the solar generating agency (EESL, MSPGCL or private solar developer) and being responsible for evacuating power and compensating the agency in case evacuation falls below 98%. The extremely competitive tariff of MSKVY projects varied between INR 2.94/unit (USD 0.0359/unit) and INR 3.30/unit (USD 0.0402/unit). However, in recent years, the tariff failed to attract many private players due to the increasing import duties on solar modules and cells together with the cost escalation due to the pandemic. Overall, with only 15% of the target commissioned, MSKVY's impact on fulfilling RPO targets and reducing T&D losses was marginal.

A major finding of the study was that although MSKVY was meant to provide farmers reliable daytime power, the farmers themselves were quite unaware of the scheme. Though daytime availability of power for 8 hours appears to have been achieved based on the small sample in the survey (280 farmers spread across seven districts), it is in contrast with one feeder level data (Ganeshpur, Dhule). Stakeholder interactions show that lesser supply can be justified as farmers were able to fulfil their irrigation needs in a shorter time given the substantial improvement in voltage reliability. Additionally, MSKVY may be instrumental in improving the quality of power in terms of reduction load shedding (by 8.6%). The survey revealed greater use of pump sets (by 2.5%) post the MSKVY scheme, however it could not be inferred that such change was on account of the scheme. While it indicated that there had been a change in the cropping pattern and yield of a handful of farmers, this can't be conclusively attributed to the scheme. The study shows the scheme had little impact on ground water situation.

Though initially MSKVY did not encounter much problems relating to land availability as it was available with MSEDCL at the feeder level, it may not be the case going forward. To overcome this challenge, MSEDCL has created an online land bank on which farmers can offer their land at a rate of INR 30,000/acre/year (INR 74,132/hectre/year or USD 904/hectre/year) for 26-30 years, with an incremental increase of 3% per year. This way, farmers do not lose ownership of their land to private players and at the same time earn a rental on it.

Further, MSKVY may have constraints from the unviable tariff and taxation norms (GST and customs duties). The tariff might need a rise considering the cost escalation because of COVID and recent increase in both GST and customs duty for solar modules and cells. Encouraging the domestic manufacture of these at a favorable price could aid in implementing the scheme in the long run and in meeting the state's target.

To realize the full potential of MSKVY, it is imperative to take the following steps:

(i) MSEDCL must launch an awareness drive for farmers to make them understand about the purpose of the scheme that includes provision of reliable daytime power to farmers for agriculture.

(ii) MSEDCL must direct all the substations to develop a rotation schedule for AG feeders in the event of solar generation falls short of full AG load of all the feeders in the area. Farmers must be informed of this in advance. This will build greater trust between DISCOM and the farmers and prevent skirmishes when supply is not regular.

(iii) The MoU (with EESL) route of implementing MSKVY projects must not be downplayed. It may be more attractive to small private players considering they don't have to make huge capital investments (and wait for payments from MSEDCL for their power sales). With EESL playing the intermediary between government utilities and private players, the overall trust improves. This explains why solar power developers participate in the bidding initiated by EESL rather than by MSEDCL or MSPGCL.

(iv) Promoting the lease model of land procurement will leave land ownership with farmers and provide them rent as well.

(v) A revision in the cost of installation and higher tariff may be examined under MSKVY. It need not be in competition with large utilities, as the latter have a huge advantage of scale. MSKVY are decentralized systems of 2 to 20 MW meant to provide farmers with a steady source of power and create local jobs that help the local economy. Considering increased customs duties, taxes, cost of (leased) land and other conditionalities that will affect capital costs, raising the tariff to about INR 4.00/unit (USD 0.0488/unit) or more may heighten interest among solar developers.

10. THE ROAD AHEAD

Though this exploratory study succeeded in understanding the overall landscape of the scheme, many issues require an in depth analysis. A difference has been observed in the quality and availability of power post-MSKVY implementation. The gaping difference in farmers' responses and feeder-level data on daytime power availability restricted us from making conclusive observations on their impact on farmers. A detailed analysis of a more number of feeder level data and a larger sample can provide more insights into the impact of decentralized solar power plants on rural power distribution.

The actual income benefit to farmers, changes in cropping pattern and use of pump sets for irrigation in this study cannot be directly attributed to solar power given the current small sample size. A larger study with a control can throw light on the impact of the scheme on farmers.

The profitability of private players is another major issue which requires further study. There was moderate participation by private players in the installation of solar units and O&M contract. Also, in this scheme, government expenditure is not involved except in the projects which were commissioned by MSPGCL and the evacuation of power by MSEDCL. It would be interesting to know how the operational projects under MSKVY are functioning commissioned by different implementation partners and different routes. The O&M contract appears to be a win-win model. However, the revised duties/taxes and cost of materials (on account of COVID) have put a question mark on the profitability of private players. A detailed study is needed on these aspects to assess the risks and returns from the project for all the stakeholders as well as one on operational expenses and best practices in O&M.

Land availability to set up solar plants was a constraint observed in the study, limiting private player participation in the scheme. A study on current land availability for ongoing and new projects, land issues faced by private bidders and on how far the online land bank is solving the problem and benefitting farmers will throw more light on this constraint.

This study could not conclusively assess the scheme's impact on agriculture and sustainable groundwater use by solar pump sets and impact on yield on account of the short period of execution, small dataset and lack of a control for a comparative yield assessment. This calls for a longer duration study with a larger study sample involving both the study and control groups.

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Appendix 1

Glimpses of field team conducting interaction with and data collection from different stakeholders in the study area. The photo credits goes to 'IRMA'.


20MWp/16MW SOLAR PV PLAN
WAACOX ENERGY LTD.













Appendix 2

TABLE A1: Solar projects commissioned by private players under MSKVY.

Private player	District and locations (number of units in parentheses)	Capacity (MW)	Capacity breakup
M/s. Atnu Solar Private Limited	Aurangabad: Nanded (1), Jalna (1), Beed (1), Aurangabad (1) Pune: Solapur (1) Nashik: Ahmednagar (1+1)	70	10×7
Aurinko Solar Private Limited	Pune: Solapur (1)	10	10×1
Juniper Green Energy Private Limited	Nashik: Nashik (3)	30	10×3
Nisagra Renewable Energy Private Limited	Nashik: Nashik (2), Jalgaon (1), Dhule (4)	70	10×7
TEPSOL RESCO Three Private Limited	Aurangabad: Osmanbad (2), Hingoli (1) Amravati: Amravati (2)	50	10×5
Kiran Renewables Private Limited	Pune: Pune	5	5×1
Vijay M Mankari, proprietor, Mankari Petroleum	Aurangabad: Latur	2	2×1
Ramesh N Amberkhane, proprietor, Ganesh Dall Industries	Aurangabad: Latur	2	2×1
Dinesh D Mane, partner, Satya Saibaba Construction	Aurangabad: Latur	2	2×1
Ask Green Energy Private Limited	Aurangabad: Latur	2	2×1
Laxman N More, proprietor, Ganga Mauli Solar Energy	Aurangabad: Latur	2	2×1
Harikishan R Malu, proprietor, Shrihari Traders	Aurangabad: Latur	2	2×1
Vivek M Reddy, proprietor, Reddy Construction	Aurangabad: Latur	2	2×1
Padamkumar J Ajmera, partner, Jai Sai Construction	Aurangabad: Osmanabad	2	2×1

Private player	District and locations (number of units in parentheses)	Capacity (MW)	Capacity breakup
Ashok A Kakade	Aurangabad: Parbhani	2	2×1
Ramprasad B Ghodke, partner, R B Ghodke	Aurangabad: Parbhani	2	2×1
Ajit Kantilalji Sisodiya, Kalika Ginning & Pressing Private Limited	Aurangabad: Aurangabad	2	2×1
Nature International Private Limited	Pune: Solapur	10	10×1
Chandrakant Bastesing Raghuvanshi	Nashik: Nandurbar	2	2×1
Waacox[a]	Ahmednagar, Yavatmal, Amravati	20	2×1, 2×1, 16×1
Gro Solar[a]	Dhule	7	7×1
Venkat M Garje, proprietor, Garje Steel Industries	Latur	2	2×1
Ramesh N Amberkhane, proprietor, Ganesh Dall Industries	Latur	2	2×1
Kosol Energie Private Limited	Dhule (2)	20	10×2
Kailash S Agarwal, partner, Shubhlaxmi Foods	Latur	2	2×1
Eirene Naval Systems Private Limited	Osmanabad	15	15×1
Sunfree Paschim Private Limited	Solapur	20	20×1
Eirene Naval Systems Private Limited	Solapur	10	10×1
Greak Infra Environs Private Limited	Jalna	5	5×1

Source: MSEDCL (2022)

Notes: [a] With MSPGCL. The rest are with MSEDCL.

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Submitted to

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