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Enabling Policies for Solar-powered Micro-irrigation

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Given little scope to bring additional area under cultivation, the future growth in Indian agriculture has to come from technological change and institutional and policy innovations for efficient management of natural resources (i.e., land, water and energy). Agriculture accounts for 85% of the total consumption of water, 20% of the electricity, and 2% of the diesel. There is a strong nexus of water and energy in agriculture. Close to two-third of the irrigation demand is met from groundwater extracted using electricity and diesel. However, both the water and energy are becoming increasingly scarce.

For sustainable use of these resources, the Government of India has been promoting micro-irrigation and solar power in agriculture. Micro-irrigation enhances water-use efficiency and crop yields, reduces cost of production, and cushions against climatic shocks[1]. Solar power — the renewable source of energy — mitigates emission of greenhouse gases, and reduces fiscal burden of electricity subsidy and diesel imports[2]. In 2020-21, India spent Rs 724 billion on electricity subsidy for irrigation, and imported about 85% of the total diesel demand.

Despite a strong association between water and energy, there is a little, if any, synergy between micro-irrigation and solar power schemes. Micro-irrigation is promoted through Per Drop More Crop (PDMC) component of Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)[3] by the Ministry of Agriculture and Farmers Welfare (MoA&FW), and solar power through Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PMKUSUM) by the Ministry of New and Renewable Energy (MNRE). The lack of synergy leads to higher transaction and administrative costs to farmers as well as implementing agencies. In this brief note, we explore the possibility of convergence of PDMC and PMKUSUM, and the policy and institutional requirements to make this happen.

Potential of micro-irrigation and solar power use in agriculture

India has potential to irrigate 88.7 million hectares through micro-irrigation (Figure 1)[1]. Although there has been a significant increase in area under micro-irrigation, its potential has remained underexploited — only 17.6% of the potential could be exploited by 2023.

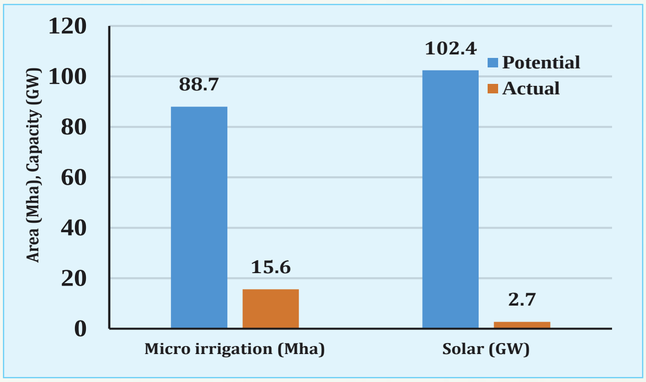

Figure 1. Potential of micro-irrigation and solar power use in agriculture, 2023

India is endowed with abundant solar energy. Official estimates of its potential for irrigation are not available. However, utilizing information on the number and horse power of pumps from 6th Minor Irrigation (MI) Census 2017-19 we have estimated it at 102 gigawatts (GW). Yet, only 2.6% of it has been exploited by 2023. Thus, there are huge prospects of substituting fossil energy by solar energy in agriculture. This will reduce the consumption of

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[1] Chand, S., Kishore, P., Kumar, S., and Srivastava, S.K. (2020). Potential, Adoption and Impact of Micro irrigation in Indian Agriculture. Policy Paper 36, ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi.

[2] Yashodha, Y., Sanjay, A., and Mukherji, A. (2021). Solar Irrigation in India: A Situation Analysis. International Water Management Institute, Colombo.

[3] Since 2022-23, PDMC is being implemented under Rashtriya Krishi Vikas Yojana (RKVY)

electricity and diesel; hence the subsidy burden as well as greenhouse gas emission.

There exists a significant inter-state variation in their potentials (Table 1). Close to 80% of the area under micro-irrigation and also the solar pumps for irrigation are concentrated in a few states. Interestingly, states with higher adoption of micro-irrigation lag behind in adoption of solar energy and *vice-versa.* For instance, Chhattisgarh has the largest share of 23.8% in the total installed solar pumps but shares only 2.6% of the total area under micro-irrigation. Karnataka has the highest share of micro-irrigation (16.6%) but shares only 1.5% of the total installed solar pumps.

Coupling micro-irrigation and solar power

Micro-irrigation and solar power have a complementary relationship. Groundwater pumped out using solar power if applied as flood-irrigation can serve only a small area or falls short of crops' water requirement. Micro-irrigation by improving conveyance efficiency overcomes these shortcomings. Further, coupling micro-irrigation with solar pumps may reduce unintended consequences, if any, of the unrestricted access to solar energy on groundwater sustainability.

There are several benefits of coupling micro-irrigation with solar power.

- Micro-irrigation saves water; hence the energy for pumping out groundwater. The energy saved can be sold to power utilities through grid-connected solar pumps or used for other activities such as operating chaff cutter, flour mills, cold storages, driers, etc. through off-grid pumps with Universal Solar Power Controller (USPC).
- By reducing energy cost, the solar-powered micro-irrigation improves farm profits. Although farmers will incur 17-20% additional cost of coupling micro-irrigation with solar pumps but incremental benefits will significantly outweigh it. This will also reduce time lag in recovering capital costs of installing solar pumps.
- Our calculations indicate that solarization of a diesel pump can save 963 liters of diesel per annum[4]. Further, solarization of an electric or a diesel pump can reduce CO_2 emission by 2.1 ton per annum on an average[5]. Besides, it can improve water-use efficiency by 15-50%.
- Complete replacement of electric pumps with solar pumps will eliminate burden of electricity

Table 1. Potential and adoption of micro-irrigation and solar power in agriculture, 2023

State	Micro-irrigation				Solar power			
	Potential (lakh ha)	Actual (lakh ha)	% exploited	% share in total	Potential for irrigation (Megawatt)	Installed capacity (Megawatt)	% exploited	% share in total *
Uttar Pradesh	201.7	3.7	1.8	2.4	20685	218	1.1	8.3
Madhya Pradesh	118.1	7.1	6.0	4.5	7008	94	1.3	5.0
Rajasthan	92.8	22.9	24.6	14.7	10376	596	5.7	21.7
Gujarat	75.2	18.2	24.1	11.6	7416	54	0.7	2.6
Punjab	65.5	0.6	0.9	0.4	8699	81	0.9	3.3
Haryana	49.2	7.2	14.6	4.6	2484	488	19.7	8.4
Maharashtra	45.1	22.1	49.0	14.2	12011	288	2.4	9.8
Bihar	41.7	1.3	3.0	0.8	2283	21	0.9	0.6
Karnataka	38.6	26.0	67.3	16.6	5789	30	0.5	1.5
West Bengal	35.0	1.4	4.1	0.9	1701	13	0.8	0.1
Tamil Nadu	32.0	13.3	41.4	8.5	8203	66	0.8	1.6
Telangana	30.8	3.5	11.5	2.3	6853	9	0.1	0.1
Andhra Pradesh	25.2	20.1	80.0	12.9	5687	88	1.6	6.8
Chhattisgarh	14.1	4.1	28.8	2.6	1029	387	37.6	23.8
Odisha	7.0	2.0	28.4	1.3	876	28	3.2	2.1
Uttarakhand	4.4	0.3	7.8	0.22	264	14	5.5	0.1
Kerala	3.3	0.4	10.8	0.23	98	23	23.6	0.2
Assam	2.3	0.4	17.9	0.26	526	9	1.8	0.01
Jharkhand	1.9	0.5	28.5	0.35	311	50	15.9	2.7
India	886.7	155.9	17.59	100	102438	2704	2.64	100

*share of states in total 501673 solar pumps installed by 2023.
Source: Authors' estimates based on data from Directorate of Economics and Statistics (DES) and MNRE

4 Diesel saved (liter/well/annum) = Weighted average Hp (6.37) * Irrigation hours (605/annum) * unit diesel use (0.25 liter/Hp/hr).

5 CO2 emission is estimated by applying emission factor of 0.715 (electric pumps) and 2.67 (for diesel pumps) to Hp-hours.

subsidy (e.g., Rs 724 billion in 2020-21)[6]. Besides, solarization of diesel pumps will reduce diesel import bill.

Techno-economic feasibility

Being dependent on sunshine, solar pumps often suffer from low pressure and result in an uneven flow of water throughout the day, while micro-irrigation (particularly sprinkler irrigation) requires high pressure and consistent flow of water. This technical challenge can be addressed by location-specific customization of the design and size of solar-powered micro-irrigation system. An additional 20-25 feet head can be added to the estimated size of solar pump for maintaining pressure. Under PMKUSUM solar pumps upto 10 Hp can be installed on individual farms, which can address problem of low water pressure. Further, system automation can ensure consistency in water flow.

Initial investment requirement for a solar-powered micro-irrigation system is quite high. The benchmark cost of a solar pump system (7.5 Hp pump without USPC) under PMKUSUM is fixed at Rs 3,49,566 and of a micro-irrigation system under PDMC at Rs 69,218 for a farm size of 1.08 ha (national average). After accounting for 60% subsidy on solar pumps and 45-55% on micro-irrigation, a farmer still has to bear Rs 1,70,974 to 1,77,896. Although financial institutions are supposed to provide loan upto 75% of the beneficiaries' contribution to the capital cost, farmers find it difficult to avail it on account of the collateral and other procedural requirements.

Finally, farmers' decision to install capital-intensive irrigation system depends on the returns on investment. Our calculations show substitution of a diesel pump with solar-powered micro-irrigation system is economically viable. At existing level of subsidy on micro-irrigation and solar pumps, the incremental cost can be covered in two years through diesel savings alone (Table 2). The payback period extends up to five years if there is no capital subsidy.

Substitution of an electric pump with a solar-based micro-irrigation system is not economically viable if only the savings in electricity cost at subsidized tariff are considered. If there is no subsidy on electricity tariff, it is possible to recover the capital cost in 11 years. However, an additional capital subsidy of 20% (over the current 60%) on solar pumps coupled with no subsidy on electricity tariff reduces the payback period to five years. It may be noted that in calculating IRR and payback period, we have not accounted for the gains in crop yields due to micro-irrigation. These findings suggest rationalization of power tariff and re-purposing electricity subsidy to the adoption of solar-powered micro-irrigation.

[6] Electricity subsidy for irrigation is estimated by factoring total subsidy received by power utilities with share of irrigation in the total revenue loss on account of subsidized electricity.

Table 2. Payback period for solar-based micro-irrigation system

Capital subsidy regime	Electricity subsidy				Diesel pumps	
	No power subsidy[#]		Subsidized power*			
	IRR (%)	Payback period (years)	IRR (%)	Payback period (years)	IRR (%)	Payback period (years)
No subsidy	4	-	-1	-	23	~5
60% on solar+ 45% on micro-irrigation	14	11	6	-	55	<2
60% on solar+ 55% on micro-irrigation	15	10	7	-	57	<2
60% on solar+ 90% on micro-irrigation	18	7	9	18	67	<2
80% on solar+ 45% on micro-irrigation	24	5	13	14	91	<2
80% on solar+ 55% on micro-irrigation	26	5	14	12	97	<2
80% on solar+ 90% on micro-irrigation	34	4	19	7	128	<1

Notes:
[#]Electricity tariff (Rs 6.30/unit) +fixed charge (Rs 50/Hp/month).
*Electricity tariff (Rs 2.87/unit) +fixed charge (Rs 50/Hp/month).
Internal Rate of Return (IRR) is estimated assuming life of a solar pump of 25 years, and of a micro-irrigation system of 7 years. Discount rate was assumed at 6%.

Policy suggestions for promotion of solar-powered micro-irrigation

Evolve mechanism for convergence at central government level: Operational guidelines for PDMC and PMKUSUM explicitly mention the complementarity between micro-irrigation and solar pumps and suggest their joint implementation. Yet, these are silent on institutional mechanisms for their convergence. For instance, the National Stewardship Council (NSC), the apex committee for providing strategic directions for implementation of PDMC, does not have any representative from the MNRE. So is in case of PMKUSUM. For effective convergence, the apex committees should have representatives from the concerned ministries.

Make joint implementation of schemes mandatory at sub-national level: In most states, PDMC and PMKUSUM are separately implemented by different agencies or departments, except in Rajasthan where the Department of Horticulture is the designated nodal agency. A single window approach is essential for all processes beginning from beneficiary registration to the installation of solar-based micro-irrigation system. The other option is to promote Special Purpose Vehicles (SPVs) for implementing these schemes in tandem. This mechanism has been found effective in promoting micro-irrigation in Andhra Pradesh and Gujarat; and can be adopted by other states.

Re-purpose electricity subsidy: To improve economic viability of the grid-connected solar-powered micro-irrigation, electricity subsidy must be re-purposed to the adoption of solar-powered micro-irrigation system, and if required additional subsidy can be provided for the purpose.

Learnings from the states

- In Rajasthan, Department of Horticulture is the nodal agency for implementation of PDMC and PMKUSUM, and for farmers to avail subsidy on solar pumps it is mandatory to adopt micro-irrigation.
- Recently, Uttar Pradesh has started an Accelerator Programme called "Uttar Pradesh Micro Irrigation Project (UPMIP)" in technical collaboration with World Bank and Gujarat Green Revolution Company Ltd. for implementing PDMC scheme. Given the complementarity between micro-irrigation and solar pumps, PMKUSUM can be brought under the ambit of UPMIP.
- In Uttar Pradesh, farm-ponds are constructed with mandatory installation of micro-irrigation under sub-component "other interventions" of PDMC, which are implemented jointly by the Department of Agriculture, and the Department of Horticulture. PMKUSUM can also be dovetailed in this framework.

Evolve innovative financing mechanism: Convergence of schemes should be supported by a single package of finance for solar-powered micro-irrigation system to reduce transaction and administrative costs to the financial institutions and farmers.

Prioritization and targeting at sub-national level: Uttar Pradesh, Bihar, West Bengal, Odisha, Jharkhand, Assam and Uttarakhand have larger shares in area under horticultural crops, lower levels of groundwater extraction and a larger shares of diesel pumps, but have lower penetration of micro-irrigation. These states should emphasize on adoption of solar-powered micro-irrigation system.

Promote solar-powered micro-irrigation for high-value crops: Micro-irrigation is most suited for cultivation of fruits and vegetables, which generate significantly higher returns compared to widely-grown staple food crops. The initial investment in solar-based micro-irrigation system can be recovered in a shorter period if high-value crops are targeted for implementation of the system.

Water-budget based regulation of groundwater: Improvement in farm-level efficiency in water use from the adoption of solar-powered micro-irrigation system need not necessarily lead to the savings in groundwater at basin-level because of farmers' behavioural responses in term of switching over to water-intensive crops, and bringing more area under irrigation, besides its increasing demand in non-farm activities (i.e. domestic and industrial). Hence, it is imperative to budget and regulate groundwater use within its replenishable limits.

Encourage community-based adoption: To improve efficiency, sustainability and inclusiveness for solar-powered micro-irrigation system, community-based approaches for its adoption should be incentivized.

Strengthen industry-academia collaboration: There is a need for industry and academia to come together and collaborate for developing and testing bundled approaches to natural resource management, and assessing institutional and policy requirements of their implementation.

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