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HIGHLIGHT

Solar Irrigation Pumps and India's Energy-Irrigation Nexus:

Rejoinder to Sahasranaman et al. (2018). Solar Irrigation Cooperatives: Creating the Frankenstein's Monster for India's Groundwater. Economic and Political Weekly, 53 (21): 65-68.

Shilp Verma,
Neha Durga and
Tushaar Shah

In their article, "Solar Irrigation Cooperatives: Creating the Frankenstein's Monster for India's Groundwater", Sahasranaman *et al.* (2018) erroneously conclude that, "*the Dhundi pilot... is an experiment that has gone terribly wrong*". While the article is full of miscalculations and internal inconsistencies, as fellow researchers, we welcome their critique. In the first half of this rejoinder, we offer clarifications so that readers can make a proper assessment of the Dhundi experiment. In the second half, we reiterate our vision of the critical role that solar irrigation pumps (SIPs) can play in India's agriculture future by projecting likely consequences of alternate policy scenarios.

Solar Irrigation Pumps and India's Energy-Irrigation Nexus[#*†]

Rejoinder to Sahasranaman et al. (2018). Solar Irrigation Cooperatives: Creating the Frankenstein's Monster for India's Groundwater. Economic and Political Weekly, 53 (21): 65-68.

Research highlight based on a paper with the same title

1. Introduction

India's groundwater economy is stuck in a perverse nexus between electricity subsidies and groundwater depletion. From Punjab down to Tamilnadu, free power to farmers has been the cause of rampant groundwater over-exploitation and deteriorating finances of electricity utilities (see, for instance, Kumar 2005; Kumar and Singh 2007; Kumar *et al.* 2011). The situation can be salvaged if irrigation tubewells are metered and farmers charged for power consumed in irrigation. But this will have political risks that leaders will be unwilling to accept for much time to come. Solar Irrigation Pumps (SIPs), considered unviable, are being aggressively promoted with high investment subsidies by governments and DISCOMs to reduce farm power subsidy burden. Since 2014, SIP numbers have grown at CAGR of 65 per cent/year; at this rate, India will have 12 million SIPs by 2025. In Shah *et al*. 2017, we had argued that, when it comes to groundwater overdraft, SIPs may be worse than free grid power because solar energy is available during day-time, is uninterrupted and free. Shah *et al*. (2017) argued that one way to reverse this perverse outcome is to promote Solar Power as Remunerative Crop (SPaRC) among farmers by: [a] using SIPs to replace grid-connected electric tubewells; [b] by offering SIP owners a buy-back guarantee for their surplus solar energy at a remunerative price. Such a policy would create incentive for farmers to conserve energy and water, curtail grid power subsidies that burden DISCOMs, reduce carbon-foot print of irrigation and offer farmers a new risk-free income source. Gujarat DISCOMs accepted the proposition but felt challenged by the logistical hassle of buying small amounts of power from numerous farmers. The *Dhundi Saur Urja Utpadak Sahkari Mandali* (DSUUSM) – the world's first solar irrigation cooperative – was created to demonstrate an institutional pathway to meet this challenge.

2. Solar Pumps are too expensive to be viable

Using Dhundi costs, Sahasranaman *et al*. (2018) argue that solarising tubewells will be prohibitively costly. Table 1 presents the detailed break-up of the initial capital investment in Dhundi. The cost of the SIP for the 6 initial farmers amounts to ₹62 per watt-peak. However, the total cost is much higher, at ₹89.8 per watt-peak. The difference is because Dhundi did not have an agricultural grid and all farmers were using diesel pumps. Constructing a new micro-grid only for 6 farmers meant that the high costs were divided over a small base. However, when the experiment is scaled up – as is being done under the recently announced Government of Gujarat scheme SKY *(Suryashakti Kisan Yojana)* – the 2018 benchmark cost for SIPs are projected to be around ₹50/watt-peak.

Table 1: Break-up of capital cost in Dhundi pilot

Particulars	Quantity/Capacity	Amount	Cost/watt-peak
SOLAR IRRIGATION PUMPS		₹ 34,99,400	₹ 62.0
Solar Panel Modules	56.4 kWp	₹ 20,30,400	₹ 36.0
Inverters	6	₹ 5,10,000	₹ 9.0
Pump + Variable Frequency Drive (VFD)	6	₹ 4,20,000	₹ 7.4
Mounting Structures	6	₹ 3,15,000	₹ 5.6
Switches, Panels, Meters and Wiring	Lump sum	₹ 1,34,000	₹ 2.4
Solar Pump Installation Cost	6	₹ 90,000	₹ 1.6
MICROGRID AND OTHER PERIPHERALS		₹ 15,65,600	₹ 27.7
Microgrid: Supplies	2.8 km	₹ 11,42,600	₹ 20.3
Microgrid: Installation Cost		₹ 1,90,000	₹ 3.4
BOS		₹ 50,000	₹ 7.4
Dedicated 100 kVa Transformer	100 kVa	₹ 1,83,000	₹ 5.6
GRAND TOTAL		₹ 50,65,000	₹ 89.8

[#] Forthcoming in *Economic and Political Weekly*
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[†] Corresponding author: Shilp Verma [shilpv@gmail.com]

Under SKY, there will be no need for new micro-grid infrastructure for promoting solar irrigation cooperatives as the existing grid can be easily re-wired, especially since all or most farmers on a feeder agree to shift to solar as the scheme demands. At these costs, SKY proposes a feed-in-tariff (FiT) of ₹3.50/kWh and a capital subsidy of only 30 per cent (₹15/watt-peak). Farmers will contribute 5 per cent of the capital costs upfront (₹2.5/watt-peak) and will be offered a preferential-rate loan of 65 per cent (₹32.5/watt-peak) to be repaid through earnings from selling surplus power against a FiT of ₹3.50/kWh and an Evacuation Based Incentive (EBI) of ₹3.50/kWh; the EBI will be available to the farmers only for the period of loan repayment, projected to be 7 years.

Even if capital costs do not decline any further (which is highly unlikely), solarizing India's 15 million electric pumps will cost the exchequer only ₹2.92 lakh crore (assuming an average size of 6.5 HP[1]); not the ₹9 lakh crore estimated by Sahasranaman *et al*. (2018). Thus by spending the equivalent of 3.65 years of farm power subsidy, the annual dead weight of farm subsidies, and the perverse incentives that they create, can be eliminated.

3. Who will produce food for the nation?

On the one hand, the Sahasranaman *et al.* (2018) critique argues that with a high FiT, farmers will resort to only producing energy, seriously endangering India's food security – "*what will happen to food security if farmers no longer need to produce food required by the country to survive?*". At the same time, they also argue that despite inflated tariffs in excess of ₹7/kWh, farmers in Dhundi have been reported to have sold irrigation service to neighbours. Surprisingly, they also argue that with FiTs, water buyers will "*no longer be incentivised to use water prudently and adopt efficient cropping patterns*".

Ignoring the internal inconsistency in the Sahasranaman *et al*. (2018) argument, they think we imply that farmers enjoying free solar power "*will continue to pump out water… even at the cost of damaging their crops and flooding fields*". We did not imply this but that farmers enjoying free power would, ceteris paribus, pump more water per acre and per tubewell than farmers paying the full cost of energy. Were this not the case, the average energy use per hectare in western India offering free farm power would not be 3 times than diesel-dominated eastern India; nor would average annual tubewell utilization much higher for free-power electric tubewells compared to diesel tubewells[2].

A simple analyses of data from the fifth Minor Irrigation Census (GoI 2017) and performance report of state power utilities (PFC 2015) shows that an average electric pump in central Gujarat consumes 830 kWh/HP/year[3]. Against this, the consumption of member farmers of the Dhundi solar cooperative is only 446 kWh/HP/year[4]. This shows that they are consuming about 45 per cent less energy than they would have if they had equivalent capacity electric pumps with subsidized farm power. Given that the groundwater situation and water levels are comparable in central Gujarat and that their crop yields are comparable to those of electric pumps owners, this is the best proxy indicator for efficient pumping behaviour and groundwater use in agriculture.

Sahasranaman *et al*. (2018) also suggest that farmers will stop growing food if they are paid a high tariff for selling surplus solar energy, implying a backward sloping demand curve for household income. This is theoretically plausible but all evidence so far suggests that farmers will continue to grow crops and will also evacuate surplus energy when offered attractive FiTs/EBIs based incentives. Dhundi farmers have enjoyed a FiT higher than any that future solar irrigators are likely to be offered; yet there is no sign that they are reducing their agricultural production. It is far more likely that reliable irrigation and improved income security will help them grow more crops.

4. Who will buy power from farmers?

At present, a part of the losses from supplying power to farmers is recovered through cross-subsidization, by charging much higher than the cost-to-serve to commercial and industrial customers. In Gujarat, commercial users pay close to ₹9/kWh. If, through SKY, farmers can be converted into net energy producers, the DISCOMs will be able to service the

[1] This is based on data from the Fifth Minor Irrigation Census, 2013-14 (GoI 2017)

[2] The confusion stems partly from a misinterpretation of marginal cost and marginal returns in irrigation. The first irrigation in any crop will yield high marginal returns on energy use, let's say ₹100/kWh. This is because the first irrigation generally provides the highest increment to crop yield, compared to a completely rain-fed crop. However, as the farmer keeps irrigating, the marginal returns from each additional irrigation will decline. By the third irrigation, marginal returns might be down to ₹20/kWh and for the fifth irrigation, the marginal returns might be ₹7/kWh. When the farmer gets free or subsidized power at ₹1/kWh, it makes economic sense for him/her to irrigate a sixth time because marginal cost is ₹1/kWh while marginal return is ₹7/kWh. In fact, he will continue irrigating till marginal returns fall below the marginal cost of pumping. However, this behaviour is neither efficient nor desirable as the marginal cost of electricity for the society is much higher than the private marginal cost. Faced with similar marginal returns, a grid-connected "SPaRC farmer" will stop irrigating after the fourth irrigation because s/he can earn ₹7/kWh simply by evacuating it as surplus power. In both cases, the average returns from irrigation will be the same (close to ₹50/kWh) but pumping behaviour will be very different, leading to efficient outcomes.

[3] The Madhya Gujarat Vij Company Ltd. (MGVCL) is responsible for supplying electricity in seven districts of central Gujarat: Anand, Chota Udaipur, Dahod, Kheda, Mahisagar, Panchmahal and Vadodara. According to the Fifth Minor Irrigation Census, 2013-14 (GoI 2017), these seven districts have 156,789 electric pumps with a total connected load of 10.14 lakh HP. According to PFC (2015), the total energy supplied by MGVCL for agriculture in 2014-15 was 1,052 million units (KWh). The average T&D losses for MGVCL in the year were 10 per cent (PFC 2015) but given that such losses are higher in agriculture, we assume 20 per cent T&D losses and estimate that the energy actually consumed by agricultural pumps in central Gujarat was 841.6 million kWh. This means that an average electric pump in central Gujarat consumes 830 kWh/HP/year.

[4] Between April 2017 and March 2018, the nine member farmers of the Dhundi Saur Urjja Utpadak Sahkari Mandali (DSUUSM) consumed 23,394 kWh of energy against their connected pump load of 52.5 HP. This implies energy consumption of 446 KWh/HP/year.

commercial clients better (with excess grid capacity made available) and at lower prices. Therefore, in the short term as well as in the long run, it is beneficial for DISCOMs to solarize farmers. If, on the other hand, farmers continue to consume free or highly subsidized grid power and commercial clients solarize[5], DISCOMs will continue to bleed and rely on government subsidies even more than they do now.

Grid-connected SIPs are also a part of the Government of India's ambitious KUSUM (*Kisan Urja Suraksha Evam Utthaan Mahaabhiyan*) scheme (see PIB 2018). The financial model proposed in KUSUM is 30-30-30-10 [30 per cent MNRE subsidy; 30 per cent state government subsidy; 30 per cent loan; 10 per cent farmers' upfront contribution]. Under Gujarat's SKY, the 30 per cent state government subsidy has been converted into an EBI. The FiT at which utilities will buy power from the farmers has been set at ₹3.50/kWh – the average power purchase cost (APPC) in Gujarat. It is important to note that both the FiT as well as the EBI will only have to be paid for the energy that farmers evacuate – not on the entire energy produced by the solar panels, as is the case in MW-scale solar power plants. Further, the EBI will be available to farmers only for the first seven years, the period of loan repayment. Even if we ignore the capital saving to the utilities, for each HP of agricultural load shifting from grid power to solar power, Gujarat utilities will save ₹4,000/ year[6].

5. Promoting Solar Pumps is complicated

Sahasranaman *et al*. (2018) have argued that rather than promoting grid-connected solar pumps, a "far more straightforward" proposal for creating an incentive for farmers to be energy (and therefore groundwater) efficient would be to implement universal energy metering and pro rata tariffs. In principle, we agree with the argument but it fails to take into account the historical reasons why several states moved away from metering agriculture and also, importantly, completely ignores the political economy of farm power subsidies. Universal metering has been discussed, debated and attempted by almost all Indian states since the turn of the century – without much success. Gujarat – which most experts agree has been at the forefront of "managing" the invidious energy-irrigation nexus – has been tempting, threatening, browbeating unmetered tubewell owners to accept metering. After 2003, all new applicants could have only metered connections. Metered supply is offered at just ₹0.70/kWh, a 90 per cent discount on cost-to-serve. And yet, in 2017-18, out of 14,80,000 tubewell owners in Gujarat, 1/3rd are still unmetered[7]. Rather than simply wishing for pro-rata tariffs, if Sahasranaman *et al*. (2018) can offer a way for a democratically elected government to implement it without attracting farmers' ire, it would be a great service to the nation. The solution we have proposed is admittedly "second-best" and "less straightforward", but one that is likely to find more acceptance among farmers and therefore greater policy traction.

6. Alternate Policy Trajectories

The number of SIPs in India has increased from less than 18,000 in 2014-15 to more than 14,00,00 by November 2017 (MNRE 2017). Whether we take any action or not, solar pumps are going to reconfigure India's energy-irrigation nexus. How quickly and to what extent this will happen depends on two critical factors: [a] how solar pumps are promoted; and [b] how rapidly the technology evolves and unit costs decline. Table 2 explores three broad alternate policy trajectories: [A] The 'IRAP proposal' to stop subsidizing SIPs as argued in Sahasranaman *et al*. (2018); [B] the current model of SIP promotion being implemented by government agencies; and [C] IWMI's 'SPaRC' model of promoting grid-connected SIPs with low capital subsidy and buy-back arrangements through FiT and EBI.

The Sahasranaman *et al*. (2018) proposal is akin to "*doing nothing*" in the solar irrigation space. The remedy they propose – universal metering of farm pumps and pro-rata tariffs – will work, in theory, but is likely to face tremendous farmers opposition. If metered power is sold at 90 per cent discount, it is as good as 'free power'. Popular Chief Ministers in Andhra Pradesh (Chandrababu Naidu) and Madhya Pradesh (Digvijay Singh) have seen their governments fall at the hint of imposing metering on farmers. In Punjab, under pressure from the electricity regulator, the state government proposed to meter just 5 per cent of the farm pumps to better understand power use in agriculture. Despite assurances that the meters will not be used to charge farmers, the farmers refused to allow their installation. Eventually, the state government had to resort to metering agricultural feeders (after implementing feeder separation).

The MNRE offers a flat ₹30/watt-peak subsidy and state governments add their own capital subsidy to this, usually between ₹30 – 40/watt-peak. Rajasthan has about 25,000 SIPs already which have been implemented with 70-87 per cent capital subsidy. Chhattisgarh has around 15,000 SIPs given to farmers at 70-90 per cent capital subsidy; Gujarat has 8,000-10,000 offered to farmers at 95 per cent capital subsidy; Bihar has another 5,000 offered at 90 per cent capital subsidy. Maharashtra, Karnataka, Telangana, Punjab, Haryana and several other states also have plans to give away thousands of off-grid SIPs to farmers with high capital subsidies.

The current government programs for SIP promotion rely too heavily on capital subsidies. Since 95 per cent of the total market for SIPs is driven by government subsidies, there is little incentive for solar manufacturers to constantly innovate on design and reduce unit costs. This will mean that the unit costs will decline but at a much slower pace than they would if farmers were driving the demand. Further, off-grid solar pumps will offer farmers high-quality, day-time power at zero marginal cost and without the option of rationing. As Gupta

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[5] Rooftop solar is rapidly gaining ground among commercial and industrial users, largely driven by high electricity tariffs (BNEF 2017).

[6] Average pump size in Gujarat: ~11 HP; Average annual subsidy per agricultural connection: ₹45,000; therefore subsidy per HP of agri-load = 45000/11 = ₹4,091/HP/year.

[7] Data provided by GUVNL, Vadodara.

Table 2: Likely consequences of three alternate policy trajectories for solar irrigation in India

		No Capital Subsidy for Solar Irrigation Pumps [IRAP PROPOSAL]	High Capital Subsidy for Off-Grid SIPs [CURRENT POLICY]	Low Capital Subsidy with Attractive FiT, EBI for Grid-Connected SIPs [IWMI PROPOSAL]
New SIPs added by	2022	< 50k	100 – 200k	1.0 – 2.0 million
	2030	< 200k	200 – 500k	4.0 – 8.0 million
	2050	< 1.0 million	2.0 – 5.0 million	12.0 – 15.0 million
Will this ensure access to affordable and sustainable irrigation?		NO	Unlikely	Likely
Will this incentivize farmers to utilize farm power and groundwater efficiently?		NO	NO	YES
Impact on India's annual farm power subsidy burden		Continue to rise	Continue to rise	Significant decline in farm power subsidy
Impact on financial viability of electricity utilities (DISCOMs)		NIL at best; ADVERSE as commercial users solarize	NIL at best; ADVERSE as commercial users solarize	POSITIVE as farmers stop using subsidized grid power
Impact on carbon footprint of India's irrigation economy		None to Negligible	Minimal	Significant
Will this offer additional "climate-proof" income to farmers?		NO	NO	YES
How much will this contribute to India's ambitious Renewable Energy targets?		NONE	2.3 GWp by 2030 22.8 GWp by 2050	39 GWp by 2030 87.8 GWp by 2050

(2017) has shown based on data collected in Rajasthan, this will lead to increased pumping of groundwater and worsen the groundwater situation, especially in western and peninsular India.

With the option of selling their "surplus" solar power to the grid, farmers will have an incentive not to waste energy and groundwater. While they will continue to use energy for efficient irrigation, they will, for the first time, have an incentive to invest in energy and water efficient practices and technologies. A smart solar promotion strategy will act as a stepping stone to several other groundwater demand management initiatives that the government is undertaking, including through the recently announced *Atal Bhujal Yojana*..

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About the IWMI-Tata Program and Water Policy Highlights

The IWMI-Tata Water Policy Program (ITP) was launched in 2000 as a co-equal partnership between the International Water Management Institute (IWMI), Colombo and Sir Ratan Tata Trust (SRTT), Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations. Through this program, IWMI collaborates with a range of partners across India to identify, analyze and document relevant water management approaches and current practices. These practices are assessed and synthesized for maximum policy impact in the series on Water Policy Highlights and IWMI-Tata Comments.

Water Policy Highlights are pre-publication discussion papers developed primarily as the basis for discussion during ITP's Annual Partners' Meet. The research underlying these Highlights was funded with support from International Water Management Institute (IWMI), Tata Trusts, Indian Council of Agricultural Research (ICAR), Swiss Agency for Development and Cooperation (SDC), CGIAR Research Program on Water, Land and Ecosystems (WLE) and CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). However, the Highlights are not externally peer-reviewed and the views expressed are of the author/s alone and not of ITP or any of its funding partners.

IWMI Headquarters
127 Sunil Mawatha
Pelawatte, Battaramulla
Mailing Address
P. O. Box 2075, Colombo, Sri Lanka
Tel: +94 11 2880000, 2784080 **Fax:** +94 11 2786854
Email: iwmi@cgiar.org **Website:** www.iwmi.org

IWMI-Tata Water Policy Program
"Jal Tarang"
Near Smruti Apartments, Behind IRMA Gate
Mangalpura, Anand 388001, Gujarat, India
Tel: +91 2692 263816, 263817
Email: iwmi-tata@cgiar.org

IWMI International Water Management Institute

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