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Anand, the small Gujarat town that gave India its dairy cooperative movement, has now spawned a new cooperative that may well grow into a genre of its own. The Dhundi Solar Pump Irrigators' Cooperative Enterprise (SPICE) provides the proof of concept for promoting Solar Power as a Remunerative Crop (SPaRC). We argue that SPaRC presents the best chance of taming western India's groundwater anarchy, of improving the finances of power distribution companies, of curtailing the carbon footprint of our agriculture and of creating a new, risk-free source of serious cash income for India's farmers.

IWMI-TATA
Water Policy Program

Water Policy Research
HIGHLIGHT

Solar Power as Remunerative Crop

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Solar Power as Remunerative Crop*†

Research highlight based on Shah *et al.* (2016).

1. Promise of Dhundi Solar Pump Irrigators' Cooperative

In May 2016, the world's first Solar Pump Irrigators' Cooperative Enterprise (SPICE) commenced operations in the village of Dhundi in central Gujarat (see Picture 1). Solar pumps are not new in India. Their number has already grown from less than 7,500 in 2010 to over 66,250 in 2014-15 (MoSPI 2016). But Dhundi solar cooperative is the first of its kind. Its members will use solar energy to run irrigation pumps. But they will also pool their surplus solar energy and sell it to *Madhya Gujarat Vij Company Ltd.* (MGVCL), the local power distribution company (or DISCOM in short), under a 25-year power purchase agreement it has signed with the cooperative. Farmers are happy with the power purchase guarantee but grudge the Feed-in Tariff (FiT) offered to them, which at ₹4.63/kWh is the lowest any solar generator gets in India. IWMI (International Water Management Institute) and CCAFS (CGIAR research program on Climate Change, Agriculture and Food Security), which piloted the Dhundi cooperative, have offered to top up the MGVCL FiT with a Green Energy Bonus of ₹1.25/kWh and a Water Conservation Bonus of another ₹1.25/kWh. These take the total FiT to ₹7.13/kWh, which is close to what IWMI researchers think solar farmers ought to get, as we argue later.

Six solar pumps, with a total capacity of 56.4 kWp[1], installed in Dhundi are expected to generate some 85,000 kWh/year[2] of solar energy. Their owners will use around 40,000 kWh/year[3] for irrigation, and inject the remaining 45,000 kWh/year to the grid and earn ₹300,000/year in net cash income from solar power sales. Despite some teething troubles with two pumps and even after using solar energy for irrigating summer *bajra* and pre-monsoon land preparation, by 24th December 2016, the Dhundi SPICE had already evacuated more than 22,000 kWh of solar energy to the grid (see Figure 2) worth ₹1,61,000. It has already received seven monthly payments from MGVCL and IWMI. Their additional gain is the saving of some ₹1,25,000 that these six farmers would have spent on diesel for running their irrigation pumps so far.

Picture 1: Member farmers of the *Dhundi Saur Urja Utpadak Sahkari Mandali*

2. Benefits to Farmers

Dhundi farmers not only find solar pumps decidedly preferable to expensive-to-run diesel pumps they used for irrigation so far, but also better than subsidized grid-power they have hankered after. Grid power in Gujarat is better than in other states but it still comes for only 7-8 hours each day with frequent interruptions and voltage fluctuations, and is supplied during nights for half the days in a month (Shah and Verma 2008). Irrigating at night is irksome, hazardous, costly and wasteful; so farmers abhor night power supply. Solar power, in contrast, is uninterrupted, predictable, available during daytime and free of cost. Initially, farmers were worried about the land-footprint of solar panels; but they are already experimenting with a range of high value crops such as spinach, carrots, garlic, turmeric, beet and some medicinal plants that grow well under panels. Some also grew paddy underneath panels.

No wonder that IWMI and CCAFS are flooded with requests from farmers from near and afar to form similar cooperatives. Farmers are excited by the idea of 'growing' and selling solar energy as a cash crop that needs no seeds, fertiliser, pesticides, irrigation and backbreaking labour, and has a

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[1] Potential kilo watt. A solar panel of 1 kWp will generate 1 kWh only under ideal conditions of insolation and temperature, and less in other conditions.

[2] @ 5 units per kW/day * 56.4 kW installed * 300 sunny days = 84,600 kWh/year.

[3] The 6 farmers have 7 acres of land; it is assumed that 40,000 units of electricity, equivalent to 3,600 litres of diesel, will suffice their energy needs for three season irrigation.

ready buyer at their door-step at an assured price. Income from the solar crop is free of risk from droughts, floods, pests and diseases. Moreover, with MGVCL's 25-year contract, they face neither price risk nor market risk. All that SPaRC needs is land for erecting panels; and that too can be put to alternative economic uses.

High capital investment in solar panels is the major deterrent. However, convinced of these many benefits of SPaRC, farmers are now willing to invest more in solar pumps. The first six members of Dhundi SPICE contributed only ₹5,000/kWp towards the capital cost of solar pumps, the balance subsidized by IWMI/CCAFS research grant. This is not surprising; they were neither sure whether solar pumps will deliver enough water nor whether MGVCL will actually pay for the surplus power farmers evacuate to the grid. Now that both these doubts are put to rest, four new farmers joining the cooperative have contributed ₹25,000/kWp, nearly 40 per cent of the total investment. A solar pump is viewed in Dhundi not only as an irrigation asset but also an income-generating asset that has potential to deliver 'climate-proof', risk-free income stream. 'Solar crop' offers them better income insurance than any other crop.

3. Gains to Discoms

Under the power purchase agreement (PPA) with MGVCL, Dhundi solar farmers surrendered their right to apply for grid power connections for 25 years. This suggests the potential to get India's 15 million electric tubewell owners to surrender their grid power connections in lieu of solar pumps with an attractive power purchase guarantee. India's electric tubewells receive annually ₹70,000 crore in electricity subsidies at an average of ₹46,600/ connection. Solarising these can save this deadweight of subsidies that keeps DISCOMs in financial morass. Dhundi farmers hope that once the Dhundi experiment takes off, it will be clear why such solar cooperatives deserve a better FiT than ₹4.63/kWh offered now. Arguably, they decidedly deserve better FiT than what MW-scale solar plants or roof-top solar installations because of the savings they offer to DISCOMs. MW scale plants require large public investments in transmission infrastructure but Dhundi cooperative required no new investment from government. Even the micro-grid in Dhundi was erected by farmers who also bought their own transformer from MGVCL. Rooftop solar plants will deprive DISCOMs of business with their highest-paying consumer segments. In contrast, Dhundi SPICE will liberate MGVCL and government from debilitating farm power subsidy, and that too, without hurting farmers.

Had the Dhundi farmers got 56.4 kW of grid power connections instead of solar pumps, MGVCL would have been obligated, under the current subsidy regime, to provide them every year some 162,000 units[4] of grid electricity at ₹0.7/unit against its cost of ₹4.5/unit to deliver[5]. Even if only 2/3rd of the subsidized grid power supplied were used in irrigation, MGVCL would bear a subsidy of over ₹4 lakh per year[6]. In addition, MGVCL would have also invested ₹12 lakh[7] on poles and cables to connect these tubewells to the grid, at an amortized annual cost of ₹1.2 lakh[8]. Dhundi cooperative saved it all these costs.

Finally, with regulatory changes proposed and stricter enforcement on DISCOMs of enhanced Renewable Purchase Obligation (RPO), the market for Renewable Energy Certificates (REC) is already reviving (see Nayar 2016). In principle, the REC should accrue to the Dhundi SPICE but under the power purchase agreement, MGVCL insists that all RECs generated by parties under its PPA will accrue to MGVCL. If MGVCL is to claim REC only for 45000 kWh actually bought by it, then Dhundi SPICE can claim REC for the remaining 40,000 kWh and sell them on the exchange. But MGVCL's PPA does not allow that; by implication, MGVCL will claim RECs for all 85,000 kWh generated by Dhundi cooperative as specified in the PPA. For these, MGVCL will earn, as a 'Renewable Purchase Obligated entity', at least ₹2.97 lakh per year[9].

Taken together, thanks to Dhundi cooperative, MGVCL will be better off by ₹8.17 lakh/year[10] for 25 years. Even if the DISCOM shared a third of these gains with the Dhundi cooperative members, the latter would get additional FiT of ₹6.05/unit[11] over and above the DISCOM's average power purchase cost (APPC) of ₹3.5/kWh[12]. And even after paying such a remunerative FiT, the DISCOM will be much better off than supplying farmers grid power at ₹0.70/kWh. The only situation in which the above formulation will break down is the one in which farm power subsidies are phased out. However, given the politics of farm power subsidies, it is extremely unlikely that this will happen anytime soon.

4. Climate Smart Solar Pump Subsidy Support

There are two buckets of money that can be used to incentivize solar pump adoption: funds from central and state governments to subsidize solar pumps; and the larger bucket of grid-power subsidy which solar pumps can curtail. State governments have so far promoted solar irrigation pumps only by offering 70-95 per cent subsidy on capital cost to farmers who opt out of the queue for grid power

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[4] 8 hours/day * 360 days * 56.4 kW = 162,432 kWh per year

[5] Given by Gujarat Energy Research and Management Institute (GERMI) and confirmed by MGVCL.

[6] 162,000 kWh * 0.66 * (₹4.5-₹0.7) = ₹406,296 per year

[7] The average cost of providing new tubewell connections to Gujarat DISCOMs is around ₹2 lakh which rises to ₹3.5 lakh for HVDS connections (source: GERMI, Gandhinagar).

[8] Assuming interest and depreciation cost of this investment at a conservative 10% per annum in perpetuity.

[9] REC's currently trade at ₹3,500/MWh (see www.iexindia.com). This price may change in future depending on the demand-supply dynamics.

[10] Subsidy on grid power saved (₹4 lakh) + amortized cost of connecting tubewells (₹1.2 lakh) + value of REC earned ₹2.97 lakh = ₹8.17 lakh

[11] (0.33 * 8.17 lakh) / 45000 units = ₹6.052/unit

[12] Which is currently around ₹3.50/unit (Source: MGVCL).

connections. But a power purchase guarantee at an attractive FiT can encourage farmers to aggressively take to solar pumps at far lower capital subsidy.

The Dhundi experience shows that state governments should scale down capital cost subsidy on solar pumps to around ₹50,000/kWp from the current ₹90,000, and use the saving to offer solar farmers feed-in tariff of ₹7.0-7.5/unit to all farmers who surrender grid power connections in lieu of solar pumps with a power purchase guarantee. In fact, DISCOMs would be better off offering such a deal even to net metered grid connected farmers unwilling to surrender grid-power connection. Once net-metered, every kWh of power (grid or solar) farmers use for pumping has an opportunity cost equal to the FiT and will impel them to behave as if their energy cost in tubewell irrigation is ₹7.0-7.5/kWh, and not ₹0.7/kWh, the official price of grid power to them.

However, DISCOMs loathe the prospect of net-metering individual tubewells, of billing and paying individual farmers with small marketable surplus of solar power. Their transaction and vigilance costs would be too high for them to make the arrangement acceptable, given that tubewell connections are spatially far more dispersed than even urban roof-top installations. Dhundi SPICE is the answer to this problem. In Dhundi, the MGVCL meters, monitors and pays the cooperative based on its own meter reading at a single evacuation point. It is for the cooperative then to distribute the proceeds among its members based on units evacuated by each as recorded on individual meters. This arrangement will continue even as new members join, making MGVCL's task simple and cost-effective (see Picture 2).

India's 15 million grid-connected irrigation tubewells claim a quarter of our total power generation and impose some ₹70,000 crore of farm power subsidies that are responsible for the financial mess in our DISCOMs. Cutting these subsidies will be hard for many years to come for the fear of farmer backlash. Dhundi pattern solar cooperatives can painlessly eliminate farm power subsidies once and for all while putting more cash in the hands of the farmer. As a bonus, solarizing tubewells can deliver our entire targeted 100 GW solar capacity. Given India's massive agricultural load, Dhundi pattern SPICE which get integrated at the tail-end of the grid, can contribute enormously in improving the voltage profile. All this while incentivizing farmers to use groundwater judiciously and significantly reducing the carbon footprint of India's groundwater irrigation.

Picture 2: Dhundi cooperative's meter house with individual members' meters and MGVCL meter

5. Taming the Groundwater Anarchy

SPaRC presents a powerful counterpoise to India's challenge of unsustainable groundwater over-exploitation. Elsewhere in the world, 'persistent groundwater depletion is always self-terminating' (Vaux 2011) because rapidly rising energy cost of pumping makes groundwater irrigation progressively unprofitable forcing farmers to turn to rainfed farming. In India, however, for over 40 years, perverse subsidies on farm power supply have not only maintained deep tubewell irrigation profitable for farmers but has, in fact, incentivized waste of energy and relentless depletion of aquifers. Data from the 4th Minor Irrigation Census shows that over 90 per cent of India's electric tubewells and 80 per cent of total groundwater use in irrigation are both concentrated in 10 western states which offer free or subsidized farm power supply. 4/5th of India's groundwater over-exploited blocks too are concentrated in the western corridor (Figure 1).

Governments and NGOs have been offering a wide range of solutions to unlock this perverse nexus between energy subsidies and groundwater depletion — such as community-based groundwater management, participatory groundwater management, and such like. Yet, as long as this perverse nexus continues, these are unlikely to work. The trouble is that no political leader has the gumption to abolish perverse power subsidies because of its perilous vote-bank fallout. In many parts of western India, thanks to water levels dropping

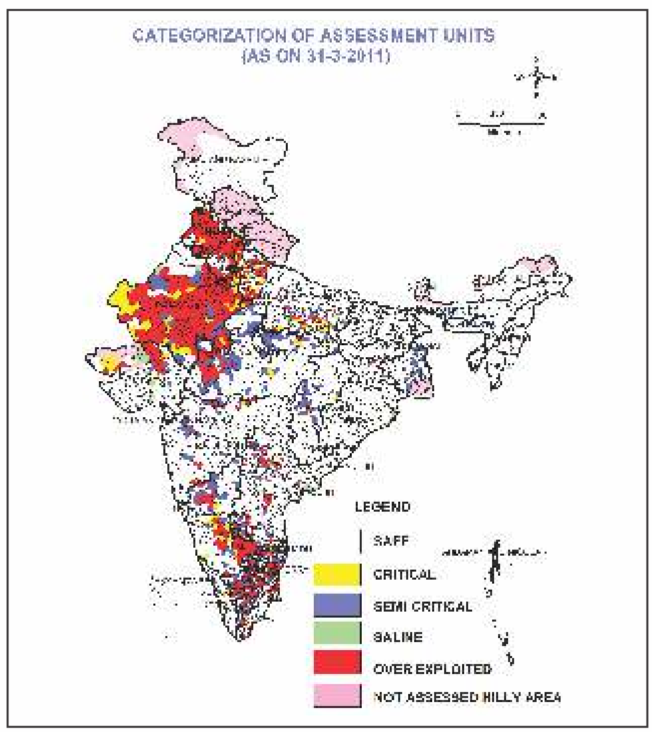

Figure 1: District-wise level of groundwater development in India

for many years, energy needed to pump a cubic meter of groundwater has become so large that abolition of power subsidies may invoke farmers' wrath on a massive scale. Under business-as-usual thus, India will have to live, for many years to come, with these perverse power subsidies.

However, SPaRC offers a painless way to bring these to end. Dhundi pattern solar cooperatives can inject powerful antidote to perverse incentives driving our water crisis by weaning farmers off grid power and helping them make money by conserving energy and water. Presented properly, farmers would readily take to SPaRC. If there is a proper subsidy-cum-financing model for helping them invest in solar pumps, why would farmers not embrace a proposal in which: [a] they continue to have the option to use subsidized grid power; [b] they also have more and better quality solar power; [c] they can also sell their surplus solar power to the grid at an attractive price; and [d] they can make even more money by conserving water and energy by adopting water-saving crops and efficient irrigation technologies. It is early days in the Dhundi cooperative to come to a conclusion; but Figure 2 shows the picture since December 2015 when the solar pumps began generating power. Until May, they had no alternative use for their 'free' power; so all of it was used to pump water. In May 2016, as soon as evacuation of surplus energy to the grid began, energy use in pumping began declining.

Dhundi's groundwater market is dominated by 45 diesel pump owners who sell expensive irrigation service to other farmers at ₹400/bigha/watering. Solar irrigators were able to undercut diesel-pump irrigators and began offering ₹250/bigha/watering. While benefiting their clients, solar irrigators are still able to earn ₹11-12/kWh of their solar energy in selling irrigation service than by evacuating it to the grid. A newspaper report (Nair 2016) suggested this went against the SPaRC proposition. But actually it did not; what is surprising is that Dhundi members evacuate power to the grid despite the high returns from water selling.

The diesel pump domination of the Dhundi kind is exception than a rule in Gujarat's villages where electric tubewells dominate local water markets and sell irrigation service at around ₹5-6/kWh. A power purchase guarantee of the kind Dhundi cooperative has would make it hugely more attractive for solar pump owners to sell power to the grid than to sell water. Some argue that net-metering solar pumps and grid-power pumps will lead farmers to pump with solar power during the day and grid power during the night. This is a distinct prospect at zero or very low FiT; however, at a remunerative FiT of ₹5-7/kWh, the opportunity cost of using grid power in the night for irrigation too will be ₹5-7/kWh.

According to some simulations we have run under certain assumptions[13], different levels of feed-in-tariff would have different impacts on various players as summarized in Table 1 which compares five alternatives described in rows. Row 1 is the current Gujarat policy of providing farmers some 2,800 kWh/kW of farm power supply at ₹0.70/kWh (8 hours/day for 360 days); the farmer uses 930 kWh/kW/year in irrigation; and the DISCOM loses ₹3,999/kW/year towards unrecovered cost-to-serve at ₹4.30/kWh. In options 2, 3, 4, 5 and 6, the farmer has a solar pump in addition to subsidized grid power and is offered a buy-back of surplus solar power at ₹2, 5, 6, 7 and 8 per kWh respectively.

Our simulations show that: [a] farmers will drastically curtail their use of grid power in irrigation once they are offered a FiT for evacuating net-metered solar power; and [b] as FiT increases, there will be reduction in groundwater abstraction but there is little chance that farmer will switch to rainfed farming or quit farming all-together, as some fear. Our model also shows that the DISCOM as well as the farmer will be net gainers in 2, 3 and 4. The farmer will not off-take subsidized grid power and will increase his sale of power to the grid as the FiT increases.

At a FiT of ₹5, the DISCOM will gain ₹1,209/kWp/year (instead of a loss of ₹3,999/kW/year); but the farmer will also earn ₹9,125/kWp/year instead of ₹4,325/kWp/year under the present regime. At a FiT of ₹7, the DICOM will lose in net terms but the gains of the farmer will increase. Even at a FiT of ₹6, the DISCOM will be better off compared to now; but the farmer will be much better off, earning ₹10,105/kWp/year. The group that will lose by SPaRC will be water buyers who will face a rising price of irrigation service in response to increasing FiT. Tightening the water market will help improve overall water and energy productivity in farming; however, to ensure acceptable equity outcomes, strong policy emphasis will be needed to ensure that SPaRC is not captured by the rich and powerful. This is best done by: [a] capping solar capacity to match the sanctioned pump size; [b] include checks that ensure farmers do not get multiple solar pumps for their different land parcels; [c] prioritize small and marginal farmers for inclusion in SPaRC; and [d] offer a moderately attractive FiT of ₹5-7/kWh.

Solarizing tubewells through grid-connected cooperatives can, by itself, restore western India's groundwater balance in 5-7 years. When energy for pumping has an opportunity cost of ₹7-8/kWh, the average use of energy per electric

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[13] The assumptions are as follows:

[a] irrigation demand function for energy is assumed to be: $P = \alpha_0 - \alpha_1 * Q$
the average cost function of tubewell is: $AC = \beta_0 + \beta_1 * Q$
the assumed values of coefficients are: α_0 = ₹11/kWh, β_0 = ₹1/kWh, $\alpha_1 = 0.004$ and $\beta_1 = 0.001$

[b] the cost-to-serve of grid power to farmers is ₹5/kWh;

[c] the average cost recovery on power sold to farmers is ₹0.70/kWh;

[d] the value of solar power evacuated by farmers to the DISCOM is ₹3/kWh;

[e] grid power is supplied @ 8 hours/day on a roster;

[f] groundwater withdrawn is estimated by assuming 5 m^3/kWh as the tubewell yield.

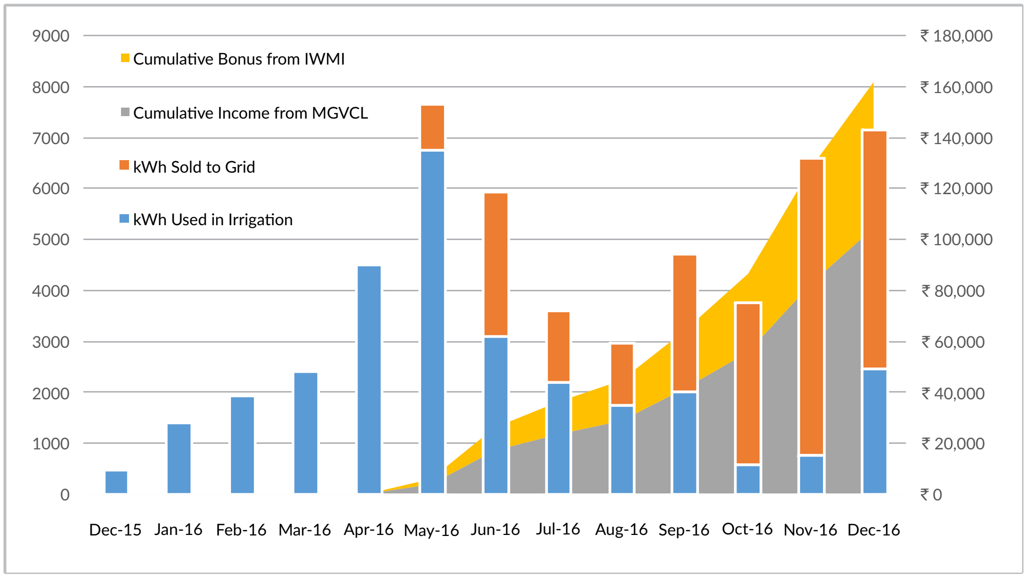

Figure 2: Solar energy used in irrigation and sold to the grid by the Dhundi cooperative

tubewell in western India would drop from around 9,000 kWh/year to around 3,500 kWh, the average for diesel pumps in eastern India that cost much more to run (see Figure 3). Moreover, once solar energy evacuated begins getting metered and paid for, measured withdrawal and application of water will start too, making scientific management of groundwater possible and realistic.

6. Reducing Carbon Footprint of Tubewell Irrigation

The biggest bonus of SPaRC is in making India's groundwater irrigation climate-smart. Around 2005, groundwater pumping in India was estimated to emit some 14.38 million metric tons (mmt) of Carbon: 11.09 mmt by electric pumps and 3.29 mmt by diesel pump sets. Electric tubewells are far dirtier than diesel pumps; for lifting every 1000 m^3 of groundwater, an electric tubewell emits 5.5 times more carbon than a diesel tubewell. This is largely because electric pumps are used to pump groundwater from greater pumping depth while diesel pumps become unsuitable for deep groundwater. Deep tubewells, benefiting from farm power subsidies, are the worst carbon culprits. According to IFPRI calculations, India's deep tubewells irrigate only 4.1 million of the 31 million ha under electric pump set irrigation; but account for nearly 2/3rd of carbon emission from electric pump sets (Shah 2009). Solarizing electric tubewells has the

Table 1: Simulated impact of different policy options on farmers' income, DISCOM's pay-outs, groundwater draft and water price in the village irrigation service market

Option Parameters	Energy use in own irrigation and water selling	Farmer's profit from tubewell	GW draft	Decline in use of grid power	Solar power injected to the grid	DISCOM's Net pay-out to farmer*	DISCOM's gains**	Water Price
	(kWh/kW/yr.)	(₹/kW/yr.)	(m^3/kW/yr.)	(kWh)	(kWh)	(₹/kW/yr.)	(₹)	(₹/kWh)
1. Grid power at ₹0.70/kWh	930	4,325	4,650	-930	0	3,999	-3,999	7.28
2. Plus 1500 kWh solar power net-metered with FiT of ₹2/kWh	870	6,784	4,350	930	630	-630	4,629	7.52
3. FiT of ₹5/kWh	570	9,125	2,850	930	930	2,790	1,209	8.80
4. FiT of ₹6/kWh	470	10,105	2,350	930	1,030	3,090	909	9.12
5. FiT of ₹7/kWh	370	11,185	1,850	930	1,130	4,520	-521	9.52
6. FiT of ₹8/kWh	270	12,365	1,350	930	1,230	6,150	-2,151	9.92

* Net of value of solar power at ₹3/kWh
** ₹5/kWh for grid power saved plus savings on solar power purchase

potential to eliminate the carbon footprint of our gigantic groundwater economy, and reducing India's annual carbon emissions by 4-5 per cent.

7. Rethinking the National Solar Mission

India's Prime Minister has set the country an ambitious target of establishing 100 GW of solar generation capacity by 2022. The current plan is to meet this target primarily by incentivizing utility scale solar plants with power purchase guarantees. Some space is also reserved for rooftop solar. However, solar pumps are viewed more as irrigation solutions than energy solutions, and are marginal to the National Solar Mission.

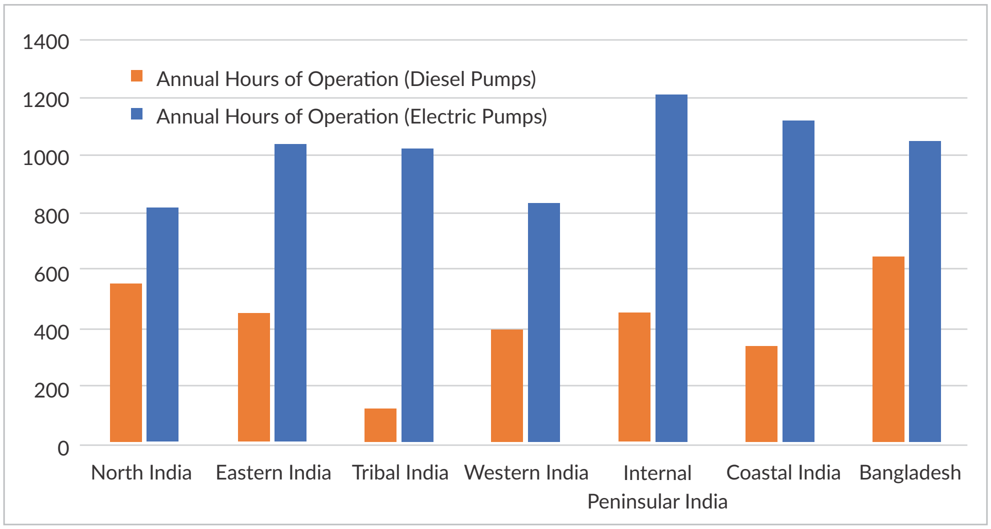

Figure 3: Annual hours of pumping for electric and diesel pumps in India and Bangladesh

However, India's 15 million electric tube wells with an average connected load of 6.7 kW already constitute more than 100 GW of pumping capacity. Solarizing these tubewells through Dhundi type grid-connected micro-grid cooperatives with long term power purchase guarantee can also meet the target of 100 GW solar capacity. All that utility-scale solar plants will do is deliver green power. But besides delivering the same 150 billion kWh/year of green power, SPaRC can: [a] also put ₹52,500 crore in farmers' hands as additional income (for evacuating half the power generated at ₹7/kWh); [b] save DISCOMs and state governments ₹70,000 crore in farm power subsidies; [c] release a third of the grid capacity for alternative uses, now that farmers generate their power *in situ*; [d] reduce groundwater draft in western India from 160 BCM/year to 100-120 BCM/year; and [e] reduce Carbon emission of groundwater economy by some 15 mmt/year.

Reimagining the National Solar Mission through SPaRC has the potential to reconfigure India's agrarian economy, adding a brand new crop that can outdo even rice and milk. Indian farmers today use 55 million ha of land to grow rice worth ₹85,000 crore/year yielding value added of ₹45,000 crore/year but emitting 61 mmt of CO_2. Dairying, which is bigger than rice and wheat combined, takes up 10 mha land to produce ₹1,80,000 crore worth of milk with a value added of ₹1,20,000 crore but generating 66 mmt/year of CO_2. In contrast, the solar crop generates no emissions, needs only 2,00,000 ha land for laying solar panels but can yield ₹90,000 crore worth energy output, most of it value-added.

In this sense, SPaRC can play a big role in fulfilling the Prime Minister's dream of doubling farm incomes. In stabilizing our small-farmer livelihood system, Dhundi pattern SPICE may be as impactful as Amul type dairy cooperatives have proved in many parts. A 7.5 kWp solar pump – delivering 13,500 kWh/year of on-farm energy supply – with a power buy-back contract at ₹7/unit can not only help a 1 ha farmer meet all her irrigation needs but also generate additional income at her farm gate of over ₹50,000/year. She will need to husband 3 buffaloes to match such net income. Dhundi SPICE cooperative is *albeit* a small experiment to illustrate the power of SPaRC. But it holds out the promise of reconfiguring our power economy, our groundwater economy and our agrarian livelihoods.

References

MoSPI (2016): "Statistical Year Book India 2016. Chapter 16: Energy". Ministry of Statistics and Programme Implementation, Government of India. Available online: http://www.mospi.gov.in/statistical-year-book-india/2016/185 [Last accessed: 04-Nov-2016]

Nair, A. (2016): "Gujarat: Solar Cooperative at Dhundi sells water instead of electricity". *Indian Express*, Ahmedabad edition; August 14, 2016. Available online: http://indianexpress.com/article/india/india-news-india/gujarat-solar-co-operative-at-dhundi-village-sells-water-instead-of-electricity-2974172/ [Last accessed: 04-Nov-2016]

Nayar, R. (2016): "Enforcing Renewable Purchase Obligations". *Economic and Political Weekly*, 51 (40): 21-23.

Shah, T. and Verma, S. (2008): "Co-management of Electricity and Groundwater: An Assessment of Gujarat's Jyotirgram Scheme". *Economic and Political Weekly*, 43 (7): 59-66

Shah, T. (2009): "Climate Change and Groundwater: India's Opportunities for Mitigation and Adaptation". *Environmental Research Letters Journal*, 4 (03): 5005 (13pp).

Shah, T., Durga, N., Rai, G.P., Verma, S. and Rathod, R. (2016): "Solar Power as a Remunerative Crop". Submitted to *Economic & Political Weekly*

Vaux, H. (2011): "Groundwater under stress: The importance of management". *Environmental Earth Sciences*, 62 (1): 19–23.

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, 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.

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