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IWMI-TATA
Water Policy Program

Water Policy Research
HIGHLIGHT

Can solar pumps energize Bihar's agriculture?

With improved affordability and plenty of support from the central and state governments, solar irrigation pumps are slowly capturing the interest of farmers in Bihar. Launched in 2012, Bihar Saur Kranti Sinchai Yojna (BSKSY) offers up to 90 per cent capital subsidy on solar pumps to smallholder farmers. Based on recent field studies in Bihar, this highlight presents an early appraisal of BSKSY and its impact on increasing irrigated area and expanding access to affordable irrigation among small and marginal farmers. We argue that rather than the current policy of offering high capital subsidies on solar irrigation pumps, competitive solar irrigation service markets can better serve the objective of providing affordable irrigation to small and marginal farmers.

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Can solar pumps energize Bihar's agriculture?*

Research highlight based on Pathak (2014) and Gupta and Kiran (2015).

1. Economic Scarcity Despite Natural Abundance

Despite sitting on one of the world's best groundwater aquifers, farmers in Bihar face economic water scarcity due to the lack of rural electrification and the high price of diesel. Over the last decade, irrigated area in Bihar has grown by a mere 5 per cent per annum (GoB 2014). The extent to which economic water scarcity limits agrarian growth is illustrated by the fact that only 37 per cent of the cultivated area is cropped more than once; the corresponding figures for Punjab, Haryana and even neighbouring West Bengal lie between 85 and 90 per cent (FAI 2011). Some scholars have argued that multiple cropping in Bihar is constrained by cultural and climatic factors while others have argued that recurrent floods and water logging restrict winter cultivation while the severe heat discourages summer cultivation. However, these arguments seem weak when we compare Bihar's cropping intensity with that of neighbouring West Bengal which faces similar severity of heat but where *boro* (summer) paddy is highly productive.

In 2008, the government of Bihar started a conditional cash transfer scheme to provide subsidy on diesel to mitigate the effects of drought on paddy production. This scheme intends to provide support to drought-affected farmers so that they are not compelled to leave their land fallow. By 2013, the government had spent close to ₹1,923 Cr. but the scheme has proven to be ineffective in promoting protective irrigation. Instead, it ended up being a drought relief scheme giving ex-gratia payment to farmers who produced a diesel receipt. Kishore (2015) found the scheme riddled with poor targeting and high transaction costs.

A new scheme aimed at increasing irrigated area is that of promoting solar irrigation pumps. In 2010, Rajasthan became the first state to offer 86 per cent capital subsidy on small solar irrigation pumps. Over the next 5 years, Rajasthan installed close to 20,000 solar pumps (SSEF 2015). In 2013-14, several state governments followed suit and launched solar pump promotion schemes offering 70-90 per cent capital subsidy. Under the *Bihar Saur Kranti Sinchai Yojna* (BSKSY), 1,560 solar irrigation pumps have been deployed in the last three years.

2. Study Location and Sampling

BSKSY is aimed at increasing irrigated area by providing highly subsidized solar pumps (90 per cent capital subsidy) of small size (2 kWp) to farmers having one to five acres of land, a functional borewell and willingness to contribute 10 per cent of the capital cost (₹28,000 for AC pumps and ₹29,700 for DC pumps). In 2015, the IWMI-Tata Program recruited two IRMA students for a quick field study to understand if the scheme is taking off among farmers and if it has the potential to trigger an agrarian transformation in Bihar (Gupta and Kiran 2015). Interviews were conducted with officials of Bihar Renewable Energy Development Agency (BREDA), the implementing agency for the scheme, several solar pump manufacturers and NABARD officials. Thirty one beneficiary and thirty non-beneficiary farmers spread across three districts – Purnia, Kishanganj and Arariya – were surveyed to capture their perspective and assess any early impacts of the scheme (Table 1; Figure 1).

3. Discussion

Our survey suggests that despite having a vibrant market for domestic solar applications, there is little enthusiasm for the 2 kWp solar irrigation pumps being offered under BSKSY. We tried to understand why.

Table 1: Farmers surveyed across study districts

District	Sample Size	
	BSKSY beneficiaries	BSKSY non-beneficiaries
Purnia	12	13
Kishanganj	9	9
Arariya	10	8
TOTAL	31	30

Figure 1: Location of study districts in Bihar

*This Highlight is based on research carried out under the IWMI-Tata Program (ITP) with additional support from the CGIAR Research Program on Water, Land and Ecosystems (WLE) and CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). It is not externally peer-reviewed and the views expressed are of the author/s alone and not of ITP or its funding partners.

3.1 Scheme design and targeting

BREDA officials reported that BSKSY is aimed at increasing irrigated area by providing affordable irrigation to small and marginal farmers. Smaller pumps are offered because the targeted beneficiaries are expected to have small pumping requirements. However, higher subsidy component limits the total number of pumps available which often means that they end up with the influential village elite.

In our survey we found that the average beneficiary owned 5.48 acres of land; only marginally lower than the average landholding of non-beneficiary pump owners (5.68 acres). The 5 non-beneficiary farmers who did not own any other irrigation pump had an average land holding of only 3.00 acres. Of the 31 beneficiaries, 6 had both diesel and electric pumps in addition to the solar pump; and only 4 relied exclusively on solar. Hence, rather than making irrigation more accessible to small and marginal farmers, the high capital subsidy tends to benefit medium and large farmers who already have irrigation access. This often implies that the pumps tend to act as *"back up"* pumps and are routinely under-utilized. Only 4 out of 31 beneficiary farmers reported using their solar pumps for selling irrigation to other farmers; among the non-beneficiaries, the number of sellers was 9 out of 30 (Table 2).

Table 2: Profiles of beneficiary and non-beneficiary farmers

Particulars	Beneficiaries	Non-beneficiaries	
	Pump Owners	Pump Owners	Irrigation Buyers
Number of respondents	31	25	5
Average Landholding (acres)	5.48	5.68	3.00
Number of farmers having only solar pumps	4	-	-
Number of farmers having diesel pumps	27	25	-
Number of farmers having diesel and electric pumps	6	-	-
Number of farmers selling irrigation service	4	9	-
Average annual income from selling irrigation	₹7,000	₹10,667	-

Beneficiary farmers complained that due to small size, it takes them twice as long to irrigate a *bigha* (1 acre = 1.6 *bigha*) compared to diesel or electric pumps; also increasing labour costs. Farmers argued that pump utilization would improve if the limitation on pump size was removed In 2015, NABARD launched a scheme for 1,350 solar pumps where the subsidy amount per pump is fixed and the remainder is to be paid by the beneficiary as instalments towards a bank loan (Table 3).

Given the farmers' preference for larger pumps, one would have expected greater interest in this scheme. However, the process of accessing this subsidy is complex; making it unattractive to small farmers. Since its launch, only 2 farmers have availed solar pumps under the scheme.

Table 3: New solar pump subsidy-cum-loan scheme introduced by NABARD in 2015

Pump size	Subsidy amount	
	DC Pumps	AC Pumps
2 kWp	₹ 57,600 per kWp	₹ 50,400 per kWp
2 – 5 kWp	₹ 54,000 per kWp	₹ 43,200 per kWp
5 – 10 kWp	₹ 194,400 per pump	

3.2 Empanelment of solar companies

MNRE (Ministry of New and Renewable Energy) empanelled companies that have experience of more than 3 years and annual turnover of more than ₹10 crores are eligible to apply for participation under BSKSY. This creates an entry barrier for the new companies. Since the last three years, only five companies have been supplying pumps under BSKSY (Figure 2).

The lowest quoted price becomes the base price for BREDA and all empanelled companies that agree to supply pumps at the base price become eligible. Farmers don't get to decide the brand of the pump but only the type: AC or DC. Depending on the type and demand, BREDA allocates districts to different companies. This means that each eligible company gets supply order irrespective of the performance of their pumps or their after sales service; there is little competition for market share.

The unit price for solar pumps under BSKSY seems inflated, suggesting some sort of cartelization. BREDA pays between ₹140,000 and ₹150,000 per kWp (₹280,000 for 2 kWp AC pumps and ₹297,000 for 2 kWp DC pumps). Corresponding prices in other states like Gujarat are close to ₹70,000 to ₹80,000 per kWp. Recently, the government of Maharashtra put on hold their procurement of solar pumps when they found that Gujarat is procuring 5 kWp pumps at ₹350,000 (₹70,000 per kWp) while the lowest bid they received was ₹540,000 (₹108,000 per kWp) (ET 2016).

The lack of competition is evident from the poor after-sales service provided by the empanelled companies. Twenty nine out of thirty one BSKSY farmers faced performance and service issues once or twice in the last year. Companies claim to resolve the problem within 48 hours but our survey suggests that take around 3 weeks to repair; in some cases, this time is close to three to five months. Since there is no incentive for companies to establish a strong brand image, they neglect after-sales service even though they get paid for it. BREDA claims that the process of allocating districts to companies makes it easier for them to provide service. However, this does not seem to be happening on the ground; we found several pumps in a state of disrepair with farmers waiting for companies to act (Figure 3; Figure 4).

The idea of giving highly subsidized solar irrigation pumps does not seem to produce much impact on the irrigated area

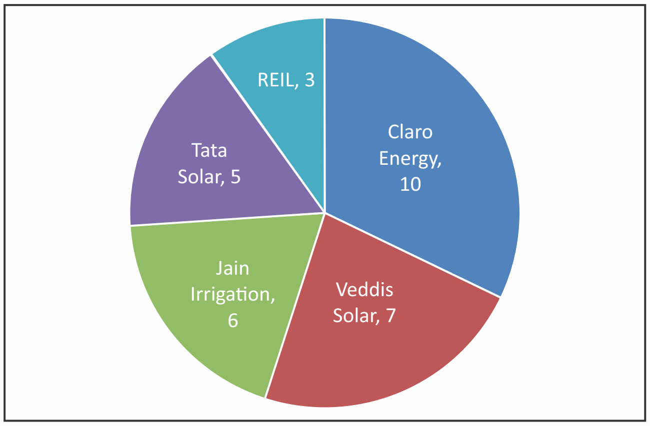


Figure 2: Brand-wise distribution of solar irrigation pumps among surveyed beneficiary farmers (N=31)

since it fails to replace diesel as the main source of energy for irrigation. Further, in a state where most farmers are water buyers (Kishore 2013), providing capital subsidy to well owners might be inadequate to achieve the objective of enhancing irrigation access to small and marginal farmers.

4. Alternative Policy Regime

The role of groundwater irrigation markets in extending irrigation access to resource poor farmers has been well documented (see Kolavalli and Chicoine 1989; Shah 1993; Shah and Ballabh 1997; Kahnert and Levine 1993). Simply put, irrigation service markets (ISMs) are an informal arrangement under which pump owners sell irrigation as a service to other farmers for a consideration. These markets emerge because of two reasons: [1] there are farmers who own or can lease in some land but do not have access to a well and pump; and [2] land holdings are so fragmented that even large farmers cannot afford to have a well and pump-set in each parcel of land (Shah 1993). Such markets emerged all across India after most states adopted the flat tariff regime for farm power supply (Shah 2009). Zero marginal cost of pumping and surplus pump capacity available with pump owners pushed them to sell irrigation to other farmers to recover the high annual flat rate. They invested in infrastructure like underground pipelines which enabled them to increase their area of operation. In Gujarat, farmers started investing in tubewells primarily to become providers (ISPs). In Navali village that Shah (1993) surveyed in 1989, 22 ISPs had invested in 65 km of buried pipes and served irrigation to 1,200 acres of land belonging to 550 farmers. In Bihar, however, the lack of grid penetration and prevalence of costly diesel irrigation has restricted the emergence of vibrant and competitive ISMs. Instead, pump owners or ISPs enjoy strong monopoly power, and pumps are used more for power than for profit (Shah and Ballabh 1997, Dubash 1995).

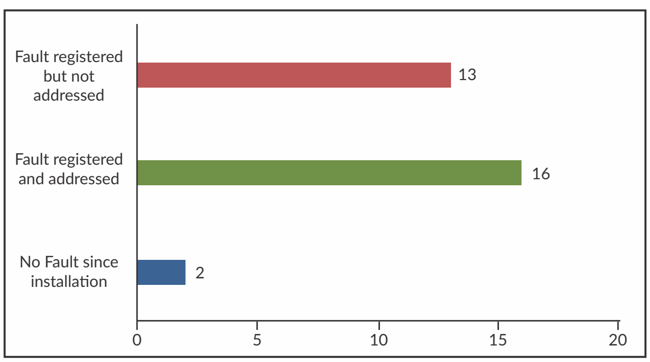


Figure 3: Performance of empanelled companies on after-sales services (N=31)

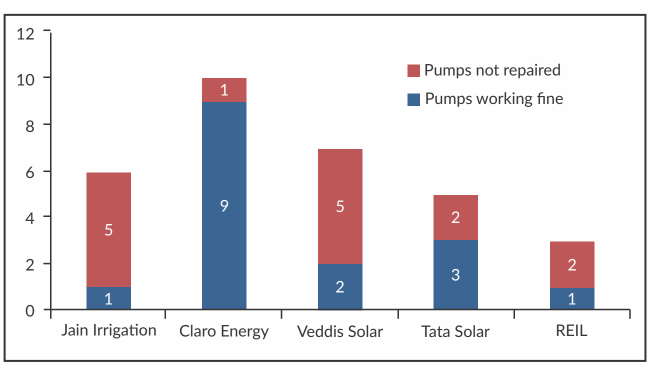


Figure 4: Performance of empanelled solar companies on repair of solar pumps (N=31)

A reasonable farm power supply environment coupled with high flat tariffs can provide a conducive environment for self-perpetuating, vibrant and competitive irrigation institutions that benefit small and marginal farmers. However, rural electrification is unlikely to happen soon in Bihar despite the best intentions of the newly elected Bihar government. It is also likely that the rising farm power subsidy bills in western and peninsular India might convince state governments in eastern India to insist on universal metering of tubewells rather than flat tariffs, as seen in West Bengal. The emergence of solar irrigation pumps offers an alternative model for catalysing equitable ISMs and energizing agriculture. By offering clean and zero marginal cost power albeit at high initial investment, solar pumps beautifully simulate the high flat tariff regime that catalysed irrigation markets in the past.

4.1 The Nalanda Experiment

Solar pumps came into the limelight in Bihar with a pilot project of the Department of Minor Water Resources in 2012. Thirty four public tubewells of 7.5 HP each located in 20 villages of Nalanda district were solarized by Claro Energy. The new source of energy (solar panels) and additional infrastructure was integrated with the existing water distribution network. An operator was appointed by the government to provide irrigation to the nearby farmers at ₹5 per *katha* (1 acre = 32 *katha*). The operator was also responsible for the maintenance of the pump. Field studies by ITP in 2012 and 2014 (Tiwary 2012; Shah *et al.* 2014; Pathak 2014) indicated that this arrangement provided assured and inexpensive day-time irrigation to small and marginal farmers. An 8 kWp solar pump could irrigate 0.6 – 1.0 acre in a day, which meant providing irrigation to 15-25 small farmers with fragmented land holdings.

The arrangement worked well technically but institutional hiccups prevented the pilots from reaching its potential. The operators were appointed on a fixed monthly salary of

₹2,500 and did not have any incentive to maximize irrigated area. As a result, in most cases, they did not maintain the distribution network or solar pump well. No one from the government or Claro Energy went back to the pilots to collect the revenue and to pay salaries to operators after the initial installation. In some villages, the operators started working as entrepreneurs and treated irrigation revenue as their income; this incentivized them to maximize sales. In such cases, they invested private capital to maintain and expand the distribution network. Where possible, some operators also raised irrigation tariffs; in 7 randomly selected locations, Pathak (2014) found that the price charged for irrigation was increased by the operators to ₹10-12 per *katha*. Some water buyers even claimed to pay ₹15 per *katha*. The price of diesel irrigation worked out to be around ₹20 per *katha*. Irrigation from solar pump no longer remained inexpensive. Operators preferred to maximize their short-term income by charging higher tariffs rather than by expanding irrigated area which would have required better management of the pump and distribution system. They could monopolise irrigation service because there were few or no electric pumps in the village and diesel irrigation continued to be more costly.

Although the Nalanda experiment provided an additional income source for the pump operators, it missed the achievable goal of offering reliable and affordable irrigation to small and marginal farmers. Despite missing the bull's eye, the Nalanda experiment suggests a practical model for retuning BSKSY.

4.2 The Economics of Solar ISPs

In Table 4, we compare three scenarios on counts of subsidy burden; solar pump utilization; and total area likely to be irrigated. The first case presents the 'business-as-usual' scenario with the current BSKSY subsidy regime. We compare 4 farmers with 2 kWp pumps acquired under BSKSY 90 per cent subsidy scheme. Given land fragmentation and the small size of pumps, the BSKSY beneficiaries are unable to irrigate a lot of land and their pumps remain idle (or are only used as backup pumps) for most of the year. The subsidy burden is very high (90 per cent) as is the unit cost of solar pumps (₹140,000 per kWp). We find that the cost of adding an additional hectare of gross irrigated area comes to ₹186,667.

The second case presents the 'base' scenario for solar ISPs and is based on the current pumping behaviour of NABARD public tubewells in Nalanda. This would require additional

Table 4: Economics of BSKSY and solar ISP model scenarios

Solar pump size and operations	*Business as usual* [4 * 2 kWp]	*Solar ISP* (BASE) [1 * 8 kWp]	*Solar ISP* (MAX) [1 * 8 kWp]
Size of the solar pump(s)	2 kWp * 4 pumps	8 kWp	8 kWp
Unit cost of solar pump	₹140,000/kWp	₹70,000/kWp	₹70,000/kWp
Total cost of the pump	₹1,120,000	₹560,000	₹560,000
Capital cost of buried pipelines	-	₹200,000	₹200,000
Area irrigated in one day per pump	6 *katha* / 0.2 acre	20 *katha* / 0.6 acre	32 *katha* / 1.0 acre
No. of days pump is run in a year	80 days	200 days	300 days
Price of irrigation per *katha*	₹12	₹12	₹12
Financial model			
Subsidy	90 per cent	₹40,000/kWp	₹40,000/kWp
Total subsidy burden for 8 kWp (including buried pipelines)	₹1,008,000	₹520,000	₹520,000
Down payment by beneficiaries / solar ISP	10 %	₹10,000/kWp	₹10,000/kWp
Down payment by beneficiaries / solar ISP	₹112,000	₹80,000	₹80,000
Loan (₹20,000/kWp)	-	₹160,000	₹160,000
Life of asset	20-25 years	20-25 years	20-25 years
Loan repayment time	-	10 years	10 years
Interest rate on loan#	-	7.0 %	7.0 %
Expected annual returns			
Area irrigated in a year	1,920 *katha* / 24 Ha	4,000 *katha* / 50 Ha	9,600 *katha* / 120 Ha
Gross irrigated area (assuming 4 irrigations per unit of land)	6.00 Ha	12.50 Ha	30.00 Ha
Capital investment per hectare of additional gross irrigated area	₹186,667	₹60,800	₹32,000
Number of farmers served	10-12	30-40	60-70
Revenue from irrigation sales	₹8,000	₹48,000	₹115,200
Payment towards loan repayment	-	₹22,296	₹22,296
Gross annual income for solar ISP	-	₹25,704	₹92,904

Rate for agriculture lending is 7% for loans less than ₹300,000.

Table 5: Comparison between BAU and solar ISP model

Parameters	BAU: BSKSY subsidy regime	Solar ISP Model
Catalysing vibrant, competitive and equitable groundwater ISMs	No	Yes
Promote irrigation entrepreneurs	No	Yes
Subsidy burden per MWp of solar pump capacity	₹12.6 crores	₹4.0 crores
Capital investment per hectare of additional gross irrigated area	₹186,667	₹32,000 - ₹60,800
Subsidy burden per hectare of additional gross irrigated area	₹168,000	₹28,800 - ₹41,600
Additional net income from sale of irrigation service	₹5,000 – ₹10,000 per farmer per annum	₹30,000 – ₹90,000 per solar ISP per annum
Number of farmers serviced per MWp solar capacity	1000 – 1500	4500 – 8000
Additional gross irrigated area per MWp solar capacity	750 Ha	1600 – 3750 Ha
Cost of irrigation for buyers	₹12 per *katha*	₹12 per *katha*
Transaction costs of subsidy delivery for government	High	Low
Transaction costs of after-sales service delivery for companies	High	Low
Transaction costs of accessing subsidy for farmers	High	Low
Capacity utilization of irrigation infrastructure	Very Low	High – Very High
Capacity utilization of grid infrastructure	Low	High

investment in buried pipelines network. With the network, the 8 kWp solar tubewells can irrigate 20 *katha* per day and operate 200 days in a year; their annual revenue would be ₹48,000 and after deducting the payment towards loan repayment (₹22,296), the net annual income would be ₹25,704. In this scenario, the cost of adding an additional hectare of gross irrigated area is ₹60,800.

The third case presents the 'max' scenario for solar ISPs. Since the Nalanda pump operators did not invest in the solar pumps, they neither had much stake nor any incentive to run the pumps as a maximizing enterprise. If they did, competitive ISMs would have emerged. We believe that if the pump operators are organized as solar entrepreneurs, rather than fixed-salary earning employees, they would strive to maximize irrigated area and their incomes. This would require extending the buried pipelines network through some more investment so that the solar ISP would be able to irrigate 32 *katha* per day and operate for 300 days in a year. The annual revenue from irrigation sale would be ₹115,200 and after adjusting for loan repayment, the solar ISP would make an annual gross profit of ₹92,904 (or a monthly income in excess of ₹7,500).

Promoting several solar ISPs in a village or cluster of contiguous villages will also promote competition among the ISPs to capture the largest share of the ISM. This will ensure that the irrigation prices are affordable for buyers (small and marginal farmers) and the quality of service delivery is high. We believe this would be a better way of ensuring access to affordable irrigation.

4.3 BAU vs. Solar ISPs

By mimicking a high flat tariff regime, solar pumps can catalyse vibrant irrigation service markets. In Table 4 we saw how the economics of the proposed solar ISP model is superior to the current subsidy regime. The model also offers greater ease in implementation and has several advantages over the *status quo* (Table 5). One, it will significantly reduce the transaction costs of delivering subsidy for the government since the department will deal with fewer 8 kWp solar ISP compared to large number of 2 kWp farmers. It will also reduce the transaction costs of accessing subsidy since small and marginal farmers will have access to the benefits of affordable irrigation without having to go through complex procedures and protocols. Two, it will create a cadre of solar entrepreneurs who can earn a reasonable livelihood out of this. Three, implementation in clusters will make it easier and more economical for solar companies to provide after-sales service.

Further, the solar ISP model can help the government of Bihar achieve its goal of rapid rural electrification. Investment required in extending grid power supply for domestic consumption is nearly a third of what is required for providing farm power supply since domestic electrical loads are lower. A 1 MW additional capacity can service close to 500 domestic power connections or it can accommodate around 200 farm power connections. If farm sector is energized using solar ISPs, grid penetration can be expedited for domestic sector. It is also important to note that the capacity utilization of grid infrastructure is much lower due to the intermittent agricultural demand; domestic demand is near-constant throughout the year and ensures higher grid capacity utilization.

5. Reinventing BSKSY

Our analysis suggests that ISMs can achieve the twin objectives of increasing irrigated area and offering affordable and reliable irrigation to small and marginal farmers. BSKSY can be tweaked to trigger vibrant ISMs which could be a game-changer for Bihar's agriculture. Some features that can be incorporated are:

1. At present, BSKSY is designed to reach out to maximum number of farmers by offering high capital subsidies on small individual pumps. The solar ISP model presents an alternative to reach many more farmers indirectly by subsidizing the creation of irrigation enterprises and catalysing competitive irrigation institutions.
2. For kick starting ISM, the pumps should be large enough to permit a viable solar ISP enterprise. A pump size of 8-10 kWp would be needed to create an irrigation potential large enough to support an irrigation enterprise.
3. In order for the ISP to maximize irrigated area, each ISP should be equipped with a piped water distribution system cutting across neighbouring fields.
4. A compact area of 80-100 ha should be supported by 6-8 such solar ISPs with overlapping command areas such that each buyer has the option of buying from several solar ISPs.
5. A flat subsidy of ₹40,000 per kWp coupled with a financial loan product which allows the solar ISP to pay annual instalments towards the cost of the pump can serve the purpose. The annual instalment will act as a high flat tariff and incentivize the ISP to maximize irrigation sales.
6. With reduced and fixed capital subsidy per kWp, the farmer will have a larger stake in the pump and therefore should be allowed to select the brand of pump s/he wants to install. This will also encourage farmers and solar companies to negotiate a better price and after sales services.
7. The solar ISP should be an independent enterprise and not an employee of the government, as was the case in Nalanda. This way, the ISPs' incentives would be directly linked to sale of irrigation.

There is also scope for third party involvement in this model. An NGO or private developer can lease out solar pumps to ISPs at an annual tariff or lease amount. Such an agency can also provide a range of ancillary services such as training of ISPs, maintenance and servicing of solar pumps etc. If BSKSY is able to catalyse competitive irrigation service markets, it will achieve multiple policy objectives. Not only will this ensure improved irrigation access to small and marginal farmers, it will also energize and rejuvenate the agrarian economy, restore agrarian dynamism, increase agricultural productivity, and positively impact rural labour markets.

References

Dubas, V. (1995): “Pumping for Power or Profit”, Berkeley: University of California (*mimeo*).

ET (2016): “Maharashtra government stays decision to order solar pumps for farmers”, *The Economic Times*, 6th January. Available online: http://articles.economictimes.indiatimes.com/2016-01-06/news/69564396_1_solar-pumps-gujarat-government-jain-irrigation-system [last accessed: 17-Jan-16]

FAI (2011): “State-wise Gross Cropped/Irrigated Area and Area under Foodgrains with Cropping Intensity in India 2010-11”, Fertilizer Association of India 2010-11, data available online through www.indiastat.com [last accessed: 17-Jan-16]

GoB (2014): “Economic Survey 2013-14", Finance Department, Government of Bihar. Available online: http://finance.bih.nic.in/Documents/Reports/Economic-Survey-2015-EN.pdf [last accessed: 17-Jan-16]

Gupta, N. and Kiran, R. (2015): “Can solar pumps rejuvenate agriculture in Bihar?” Unpublished internship report. Anand: IWMI-Tata Water Policy Program.

Kahnert, F. and Levine, G. (eds) (1993): “Groundwater irrigation and the rural poor: Options for development in the Gangetic basin”, Washington, DC: The World Bank.

Kishore, A. (2013): “The paradox of agrarian stagnation in Bihar”, The IFFCO Foundation Bulletin 1(1): 1-16, April, India. Available online: http://iffcofoundation.net/Bulletin/The IFFCO Foundation Bulletin.pdf [last accessed: 17-Jan-16]

Kishore, A. (2015): “Droughts, distress and a conditional cash transfer program to mitigate the impact of drought in Bihar”, International Conference of Agriculture Economists, May 2015, Italy. Available online: http://ageconsearch.umn.edu/bitstream/212009/2/Kishore-Droughts,%20Distress%20and%20a%20Conditional%20Cash%20Transfer%20Program-1211.pdf [last accessed: 17-Jan-16]

Kolavalli, S. and Chicoine, D.L. (1989): “Groundwater Markets in Gujarat”, *International Journal of Water Resources Development*, 5(1): 38-44

Pathak, A. (2014): “Assessment of solar irrigation market in Nalanda district of Bihar”, unpublished internship report, Anand: IWMI-Tata Water Policy Program.

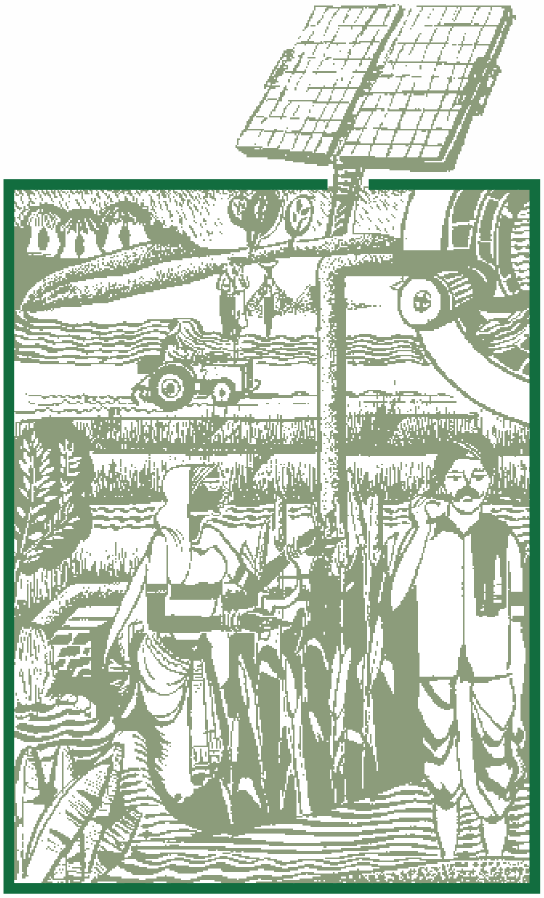
Shah, T. (1993): “Groundwater irrigation in Bangladesh: Access, competition, and performance” in F Kahnert and G Levine (eds). *Groundwater irrigation and the rural poor: Options for development in the Gangetic basin*, Washington, DC: The World Bank.

Shah, T. and Ballabh, V. (1997): “Water markets in north Bihar: Six village studies in Muzaffarpur district”, *Economic & Political Weekly*, 32 (52): A183-190.

Shah, T., Verma, S. and Tiwary, R. (2014): “Solar irrigation in Bihar: A video fieldnote”. Anand: IWMI-Tata Water Policy Program. Available online: http://iwmi-tata.blogspot.in/2014/09/itp-video-solar-irrigation-in-bihar.html [last accessed: 12-Feb-16]

SSEF (2015): “Implementation framework for solar agriculture pump programme”, Shakti Sustainable Energy Foundation, July 2015, 59p. Available online: http://shaktifoundation.in/wp-content/uploads/2014/02/Final-Report-on-Implementation-Framework-for-Solar-Agriculture-Pump_FINAL.pdf [last accessed: 17-Jan-16]

Tiwary, R. (2012): “An experiment in solar power based community tubewells in Nalanda district, Bihar”, Water Policy Research Highlight #27, Anand: IWMI-Tata Water Policy Program.



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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