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# Solar Pumps are Key to Bihar's Rural Electrification Strategy

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*Bihar's strategy of accelerating pump electrification may expand irrigation but unauthorised pumps and unpaid tariffs will create anarchy in the rural grid and hinder rural development. However, solar pumps can help Bihar electrify villages sustainably and catalyse hypercompetitive water markets.*

## Bihar's Irrigation Challenge

Providing *Har Khet Ko Pani* (Irrigation to Every Field) in five years is one of Bihar Chief Minister Nitish Kumar government's *Saat Nishchaya* (Seven Resolves). However, in several ways, the state's irrigation economy is already among the most advanced in India. According to the National Sample Survey Organisation (NSSO) (2017-18; Report 587), Bihar is among the top three Indian states in proportion of its (a) gross cropped area receiving irrigation; (b) farmers using irrigation; (c) farmers depending on groundwater irrigation; and (d) farmers buying irrigation services. Moreover, according to the sixth Census of Minor Irrigation Schemes (GoI 2023), the use of pipes for irrigation is the highest among Bihar farmers.

Bihar, and much of the eastern Ganga basin, has an abundance of groundwater. Monsoon floods here are, in part, the "rejected recharge" of massive monsoon surface flows by the basin's porous but saturated aquifers. Since the plains offer no suitable site for building surface reservoirs, scientists have long proposed the idea of a "Ganges Water Machine" (Revelle and Laxminarayan 1974). Their argument is that accelerated dry season irrigation with groundwater can draw down groundwater levels to enhance monsoonal groundwater recharge. This can ease surface flooding and improve agrarian livelihoods.

Unfortunately, the water machine has failed to operate at full speed because the high cost of irrigation has stifled demand for it. Bihar uses only 40% of its renewable groundwater (CGWB 2022) because farmers irrigate only to save their crop, not to maximise earnings. The 77th round survey of the National Sample Survey Office (NSSO) shows that despite similar irrigation penetration, 43.5% and 27.2% of Bihar's paddy and wheat farmers reported crop losses due to moisture stress while only 6.2% and 9.2% of Punjab's paddy and wheat farmers did so (Shah 2024).

> The dominance of diesel pumps and a dependence on irrigation service markets give the Ganga basin its high-cost irrigation economy. Among Bihar's farmers, 71.9% purchase irrigation services from private service providers.

With ample sunshine and no floods and pests, summer can be ideal for irrigating high-value market crops in Bihar. However, because of costly irrigation, most of the state's farmers either leave their land fallow or grow rain-fed mung or fodder—Bihar sows only 3% of its kharif area during summer (Durga and Rai 2019). The key to a green revolution in Bihar is affordable irrigation.

The dominance of diesel pumps and a dependence on irrigation service markets (ISMs) give the Ganga basin its high-cost irrigation economy. Among Bihar's farmers, 71.9% purchase irrigation services from private service providers (66.5% in Uttar Pradesh and 49.9% in West Bengal) (NSSO 2021: Report 587). With holdings fragmented into dozens of plots, farmers have a borewell or two in their best plots but buy irrigation services for the rest. Deploying diesel pumps and flexible overland delivery pipes, Bihar's water sellers price their service at 1.5 to 2.5 times the price of diesel consumed.

Post-1990, as the price of diesel soared, so did the price of irrigation (Shah et al. 2009), forcing farmers to cut down on irrigation expenses during droughts. The Bihar government tried providing a subsidy for diesel irrigation but this suffered high leakages (Kishore et al. 2022) and did not reduce the price of purchased irrigation. Crowding out diesel pumps by promoting electric pumps is now widely considered necessary to ensure Har Khet Ko Pani.

## Tubewell Electrification

Diesel delivers power to pumps at Rs 22-23 a unit. Grid electricity costs only around a quarter of this even when metered and priced at commercial rates. Kishore (2020) has therefore forcefully argued that subsidising electric tubewells and ramping up their numbers—rather than subsidising electricity—will make irrigation service markets competitive and ensure affordable irrigation.

After all, despite groundwater scarcity, electric tubewell owners in Gujarat, Madhya Pradesh, and Rajasthan have for long offered affordable irrigation services denied to water buyers in the water-abundant eastern Gangetic plain (Shah 1993). Replacing diesel pumps through tubewell electrification, it is argued, will make Bihar's irrigation service markets more competitive and pro-buyer.

But ramping up electric tubewell numbers did not make irrigation service markets any more competitive and pro-buyer in West Bengal. Until 2007, stringent permit and high grid-connection fees kept West Bengal's irrigation service markets dependent on diesel. Between 2007 and 2011, West Bengal liberalised tubewell permits and even subsidised the connection cost. It also abandoned the system of charging a high flat tariff linked to pump horsepower (HP).

> Buisson et al.'s survey found that new owners of electric pumps gained from intensive irrigation, larger boro rice area, and higher crop yields but that it did not benefit their buyers.

Instead, tubewells were metered and made subject to commercial time-of-the-day tariff. As a result, electric tubewell numbers soared from 87,776 in 2007 to 303,018 in 2018. Mukherji et al. (2012) predicted that the new policy would launch a "second green revolution in West Bengal" and increase the net irrigated area from 2.98 mega hectares (mha) to 4.83 mha in three to five years. This was to result in a 4.62 million metric tonnes (MMT) increase in boro rice production and yield an additional farm income of Rs. 460 crore. But studies found no such impact.

Using data from 326 blocks for the period from 2008 to 2020, Mukherjee et al. (2020) found no significant impact on cropping pattern and intensity, cropped area, production or yield. Buisson et al.'s survey (2021) found that new owners of electric pumps gained from intensive irrigation, larger boro rice area, and higher crop yields but that it did not benefit their buyers.

Shah and Chawdhury (2018) found buyers from electric tubewell owners worse off than they were before 2007 when tubewell owners paid a high flat tariff or had 105-day temporary boro season connections for a lump sum tariff. Under the new metered tariff, they found that tubewell owners forced buyers into inter-locked contracts to lease out land cheap for boro cultivation against a promise of kharifirrigation. West Bengal's tubewell reform led to a transfer of wealth from water buyers to tubewell owners. So, if increasing metered electric pumps in West Bengal had no impact on irrigation service markets, why would doing so deliver a better outcome in Bihar? But, in south Bihar, it actually did.

## Competition in South Bihar

Bihar followed West Bengal's tubewell electrification campaign with a decade's lag. Until 2017, electric tubewells stagnated at 160,000, that too in a few districts of south Bihar. Bihar's average electricity use per hectare was just more than 200 units against 5,500 units in Telangana, 3,200 units in Punjab, and 1,150 units in Uttar Pradesh (CEA 2024). However, in 2023, Bihar had 395,000 electric tubewells, more than two thirds of them in south Bihar where villages had 20 to 22 hours of power supply.

Unlike West Bengal, the proliferation of electric tubewells has resulted in hypercompetitive irrigation service markets that have had many beneficial irrigation impacts. Water prices have plummeted. Irrigating an acre of wheat in a diesel-dependent north Bihar village may cost up to Rs 2,500, but in a Nalanda village saturated with electric tubewells it may cost as little as Rs 300 to Rs 900. The cropping intensity in such villages has increased to 250% or more with intensive cultivation of irrigated market crops, mostly vegetables, especially in summer.

> Accidental deaths by electrocution are not uncommon. On peak irrigation days, private cables are seen strewn across fields in villages, with many service providers using a kilometre or more of cables to provide irrigation with stolen power.

Power distribution companies or discoms are unable to cope with the strong demand for new electric tubewells because of the time needed for extending the grid. Nevertheless, illegal mobile electric pumps of 2-3 HP are hooked on to 11 kilo-volt (kV) lines. These pumps on shallow borewells or surface water irrigate land at a throwaway price. With an electric pump, bundles of cables and delivery pipes loaded on bicycles or motorcycles, such itinerant service providers take irrigation to buyers' fields on demand. In some villages we visited, every household had a member engaged in such activity.

Accidental deaths by electrocution are not uncommon. On peak irrigation days, private cables are seen strewn across fields in villages, with many service providers using a kilometre or more of cables to provide irrigation with stolen power. These go out of business as water tables fall during summer. In such times, water sellers with 300-400 feet deep boreholes and 3 HP submersible pumps move in and charge Rs 1,000 to 1,200 for watering an acre of wheat.

As of 2023, the cost of purchased pump irrigation across Bihar varied by a factor of 7-8. In diesel-dependent villages, water buyers are very careful about spending money on irrigation. Buyers from electric tubewells irrigating with power from solar mini-grids costing Rs 16 to 18 per unit are similarly frugal. On the other extreme, customers of itinerant irrigation service providers using stolen power get services at throwaway prices.

Contrasting West Bengal with south Bihar shows that electric tubewells by themselves do not deliver competitive buyers' water markets. It is unmetered or free power supply that makes the difference. Changing from unmetered to metered power supply transformed West Bengal's competitive buyers' irrigation service markets into monopolistic sellers' markets after 2011.

Electric tubewells in south Bihar have created competitive water markets because their owners are not subject to metered power tariffs that are rigorously collected. Many are unmetered; many are metered but have not received metered bills for months; many are authorised, unmetered but receive lump sum bills at random intervals. Then there are the unauthorised mobile irrigation service providers who pilfer power. Those who are metered and regularly pay their bills at the subsidised rate of Rs 0.70 per unit are few and far between.

Bihar's rural non-farm consumers, including domestic ones, are being provided smart meters. Their meters are regularly read, bills issued, and collected. They found their power bills have gone up but adapted to the new regime. While the non-farm rural power consumer segment is well-governed, agricultural power supply is in a state of deep anarchy, which may not be good for rural Bihar's future growth and welfare.

## Options for Late Electrifiers

In a recent paper, Ray and Pullabhotla (2023) highlight a marked shift in the priority of rural electrification in early and late electrifiers among Indian states. Before 2000, electrification of every 100 rural homes was associated with 16 irrigation pumps; after 2000, it was associated with only two. The authors attribute this to policy shift in favour of electrifying homes and other non-farm users. However, the real reason may be that electric tubewells spawned uncontrollable anarchy on rural feeders.

> South Bihar's experience shows that electric tubewells spawn competitive markets only because they get unmetered or free power. If they are rigorously metered, as in West Bengal, electric tubewell owners will behave much like diesel pump owners.

Early electrifiers experienced growing anarchy on rural feeders as electric tubewells numbers grew, with mounting power theft, falling groundwater, and rising agricultural power consumption. The end results were disrupted government finances and poor power quality, ruining people's quality of life. States such as Gujarat contained the anarchy by separating agricultural feeders from general ones. However, Bihar's feeder separation may not work as well since the state's 2-3 HP pumps are easily run with single phase power pilfered from domestic lines.

South Bihar's experience shows that electric tubewells spawn competitive markets only because they get unmetered or free power. If they are rigorously metered, as in West Bengal, electric tubewell owners will behave much like diesel pump owners, no matter their

lower energy cost. An anarchic rural grid may be too high a price to pay for competitive irrigation service markets.

Bihar should institute the prudent grid governance applied to non-farm rural power consumers to electric tubewells as well before their owners grow into a powerful vote bank (Oda and Tsujita 2011). It should prioritise regularisation and metering of all electric tubewells and rigorously collect power tariffs, even if at the current subsidised rate. Prepaid smart meters—as on rural homes and on tubewells in Bangladesh's Barind project (Shah 2023)—would be a step forward. This would no doubt harden the irrigation service market but that is a price worth paying for wholesome rural grid governance.

## Solar Pumps

However, Bihar does not have to accept feeder anarchy to give farmers competitive irrigation service markets. Solar irrigation pumps, now nearing commercial viability, are a godsend for Bihar. Promoted right, they can catalyse competitive irrigation service markets and also ring-fence the rural power grid from anarchy. They appear costly compared to electric tubewells. However, solar irrigation pumps are arguably half as cheap as electric tubewells in levelised lifetime cost if we add the cost of extending the grid to connect widely dispersed tubewells to it (Durga and Gaurav 2024).

Early electrifiers justify a generous capital subsidy on solar irrigation pumps instead of allowing new electric tubewell connections to save on the cost of extending the grid and paying the farm power subsidy bill. For Bihar, and other Ganga basin states, it is also important that the near-zero operating cost of solar irrigation pumps incentivises their owners to behave as highly competitive water sellers. Solar irrigation pumps can spawn competitive irrigation service markets without the subsidy burden and grid anarchy associated with unmetered electric tubewells.

It is therefore intriguing that groundwater-abundant Bihar and other Ganga basin states have remained lukewarm to solar irrigation pumps while India's water-stressed western states have promoted them enthusiastically. Over the last decade, India's solar irrigation pump numbers have soared to more than 500,000, mostly in the western states that were early electrifiers. Besides Chhattisgarh, which has installed 120,000 solar irrigation pumps, Bihar had subsidised only 2,813 solar irrigation pumps by 2023; West Bengal 23,700, and Assam none (MNRE 2024).

> Solar irrigation pumps can spawn competitive irrigation service markets without the subsidy burden and grid anarchy associated with unmetered electric tubewells.

In 2019, Bihar discontinued its own solar pump promotion scheme, the Bihar Saur Kranti Sinchai Yojana (BSKSY) and it did not send any demand for promoting solar irrigation pumps under the union government's ambitious PM-KUSUM scheme. As of now, Bihar has all but given up on solar irrigation pumps.

The Bihar Saur Kranti Sinchai Yojana did little to catalyse competitive irrigation service markets. The scheme subsidised 2-3 kilowatt (kW) solar irrigation pumps designed to meet the own irrigation needs of small farmers, but were too small to supply irrigation services to distant plots of buyers with flexible delivery pipes. These solar irrigation pumps operated at full power for only three to four hours a day, suffered a severely reduced water yield during the summer, and did not have the power to push water through delivery pipes to far-off fields.

Unlike diesel pumps, a farmer cannot move a solar irrigation pump from one parcel of land to another to water his fragmented holding. Studies showed that beneficiaries used the Bihar Saur Kranti Sinchai Yojana's solar irrigation pumps mostly as a standby, using larger diesel or electric pumps as their mainstay of irrigation (Durga et al. 2016). Finally, with a small number of solar irrigation pumps scattered over many districts, the maintenance and repair ecosystem remained poor, leaving many pumps in a state of disrepair (ibid).

The Aga Khan Rural Support Programme and the International Water Management Institute (IWMI) experimented with a different approach to promoting solar irrigation pumps in a 2015 pilot project in the villages of Chakhaji and Chandauli in Samastipur district. They aimed to use the solar irrigation pump's zero-marginal cost structure to catalyse competitive village-scale irrigation service markets.

Since then, the Aga Khan Rural Support Programme has promoted more than 200 such solar irrigation pumps in several village clusters. Instead of targeting 2-3 HP solar irrigation pumps to individual farmer's irrigation needs, the Chakhaji-Chandauli pilot targeted 5-6 HP solar irrigation pumps to entrepreneurial young farmers to set them up as solar irrigation entrepreneurs (SIEs) equipped to serve

50-70 adjacent plots with quality irrigation service.

> As aggressive water sellers, solar irrigation entrepreneurs crowded out diesel pumps, expanded the irrigated area, and promoted intensification and diversification of the farming system, especially by promoting summer irrigation of market crops.

These solar irrigation entrepreneurs were also helped to install 1,500 feet of buried PVC pipelines to quickly move water to distant fields. The pilot promoted six to 15 such solar irrigation entrepreneurs in a village with overlapping command areas to promote competition among them. Finally, solar panels and buried pipelines were partly financed with a low interest loan to be repaid in annual instalments. The loan financing was to create pressure on solar irrigation entrepreneurs to generate revenue to repay the instalments by serving larger areas and more clients.

A slew of studies—Gupta and Kiran (2015); DMI (2017), Shah et al. (2018); Durga and Rai (2019), Kumar and Goel (2018), Banerjee (2019)—affirm that the Chakhaji-Chandauli pilot catalysed pro-buyer irrigation service markets. As aggressive water sellers, solar irrigation entrepreneurs crowded out diesel pumps, expanded the irrigated area, and promoted intensification and diversification of the farming system, especially by promoting summer irrigation of market crops.

Notably, buyers' irrigation cost per acre fell by 44%. Solar irrigation entrepreneurs charged Rs 100 an hour against diesel pump owners' Rs 120 an hour, and a 5 HP solar irrigation pump watered 3 katha in an hour against a diesel pump's 1.5 katha in an hour (1 hectare is 79.07katha). Moreover, solar irrigation entrepreneurs distributed water through buried pipes and this saved buyers the time and effort of managing delivery pipes.

In a detailed survey, Kumar and Goel (2018: 18) found that Chakhaji-Chandauli experienced an increase in cropping intensity from 1.9 to 2.2; in gross cropped area by 12%; in crop yields by 9% to 34%; and in the value of output of sample buyers by 45%. Chandauli's diesel pump customers, always under pressure to cut irrigation costs, harvested 30% to 50% lower yields of all crops compared to customers of solar irrigation entrepreneurs (Kumar and Goel 2018). Moreover, the water buyers of solar irrigation entrepreneurs harvested similar or higher crop yields than the entrepreneurs themselves.

Instead of rain-fed mung and fodder during summer, Chakhaji-Chandauli farmers now grow myriad market crops such as ladyfingers, turmeric, bitter melons, eggplants, onions, marigolds, yams, maize, cauliflowers, coriander, tomatoes, chillies, sponge gourds, bottle gourds, and cucumbers. Thanks to this rise in productivity, the rental for plots irrigated by solar irrigation entrepreneurs shot up from Rs 64,000 per hectare a year to Rs 120,000 per hectare a year. The solar irrigation entrepreneurs in Chakhaji-Chandauli also make more intensive use of their irrigation assets, operating them for 1,000 to 1,500 hours a year instead of the 250 to 400 hours that the Bihar Saur Kranti Sinchai Yojana solar irrigation pumps function.

## Way Forward

Bihar has so far missed the opportunity to use the PM-KUSUM scheme aimed at increasing the use of electric power from non-fossil fuel sources, but it must recover lost ground. Promoting solar irrigation entrepreneurs can catalyse competitive irrigation service markets, make irrigation affordable, and achieve the vision of *Har Plot Ko Pani*. The capital cost of solar irrigation pumps compare well with grid-connected electric tubewells in levelised lifetime cost.

> …Bihar must prioritise promoting solar irrigation pumps over connecting new electric tubewells. It must also meter existing and new electric tubewells, and rigorously collect the grid electricity tariff.

Solarising pumps can be quicker than electrifying them, given the slow pace of extending grids. Solar irrigation entrepreneurs make irrigation green, ring-fence the rural electricity grid, and can improve the quality of life by improving non-farm rural development. Bihar needs to provide power from the grid to villages and use solar irrigation pumps instead of grid-powered electric tubewells.

To gain the most from this strategy, Bihar must prioritise promoting solar irrigation pumps over connecting new electric tubewells. It must also meter existing and new electric tubewells, and rigorously collect the grid electricity tariff, even if at the current subsidised rate. Solar irrigation entrepreneurs cannot compete with service providers using free or pilfered power from the grid.

Moreover, the emphasis should be on promoting solar irrigation entrepreneurs by supporting right-sized solar pumps and buried pipe distribution networks to target irrigation service markets rather than individual farmers. Solar irrigation entrepreneurs should be required to share the capital cost of panels and buried pipes and encouraged to treat providing irrigation services as an enterprise.

At 20 solar irrigation entrepreneurs per village, Bihar's 40,000 villages need 800,000 solar irrigation pump systems with a total investment of around Rs 48,000 crore at a unit cost of Rs 6 lakh per system (including pump, solar panels and 1,500 feet of buried pipes each). With a low-cost loan on offer, young farmers with entrepreneurial drive might be willing to invest up to half of this outlay, including a 10% upfront contribution. Bihar can achieve Har Plot Ko Pani in five years through the solar route if grid anarchy is eliminated and all grid-connected tubewells are smart-metered.

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