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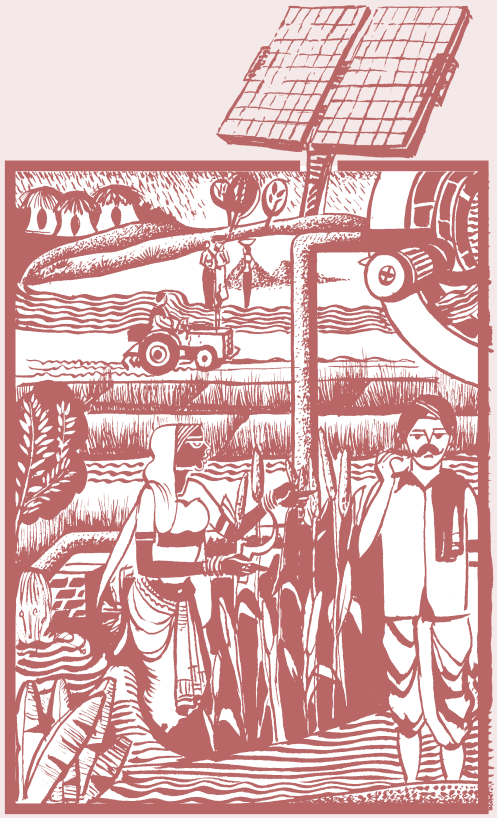

Agricultural growth in many Indian states has, during recent years, been fuelled by explosive, and often unsustainable expansion in groundwater irrigation. Bihar however is not one of these. The state has abundant groundwater; however, much of this remains untapped because of lack of electricity and high price of diesel. Providing farmers reliable and affordable energy for groundwater irrigation is central to kickstarting Bihar's green revolution. Government of Bihar has recently experimented with solar energy to power a cluster of 34 community tube wells. This Highlight makes a preliminary assessment of the promise offered by solar pumps. It concludes that solar power may indeed have the potential to open Bihar's doors to rapid agricultural growth, that too, at minimal environmental cost.

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HIGHLIGHT

An Experiment in Solar Power Based Community Tube-wells for Irrigation in Nalanda District Bihar

An Assessment

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An Experiment in Solar Power Based Community Tube-wells for Irrigation in Nalanda District Bihar
An Assessment[1]

Research highlight based on a paper with the same title[2]

Bihar's initiative on solar power based irrigation:

Bihar's agriculture growth has been severely constrained by irrigation- energy deficits. Despite vast availability of undeveloped groundwater water resources, irrigation development in Bihar has been very slow. Energy sector in the state is facing multiple challenges such as low generation and availability, inadequate infrastructure and deficient quality of supplies. Consumption of electricity in agricultural activities is extremely low. There is huge dependence on costly diesel based groundwater irrigation. In this scenario, solar power based tube wells can help in plugging the energy deficit and improving farmers' access to economical and reliable irrigation. Encouraged by availability of efficient technologies, Bihar government has taken steps to integrate solar energy with agriculture development plan in the state.

Department of Minor Water Resources, Bihar in partnership with M/s Claro Ventures has launched a key experiment in Nalanda district on solar power based irrigation. Thirty four existing government tube wells were powered with solar energy in March- April, 2012. The initiative is significant. This is first large scale experiment in Eastern India on use of non-conventional sources of energy for groundwater utilization. For the first time in the region, solar energy has been integrated with community managed public tube well irrigation systems. The project thus has shouldered twin challenges: to demonstrate effectiveness of the technology and to showcase an institutional model of solar power based irrigation in the state. The experiment has drawn attention of policy makers and development agencies.

The Highlight discusses key physical and financial aspects of the project and irrigation benefits being realized. Nine solar tube well systems in seven villages of the project area were studied. The assessment aimed at gathering experience and feedback from farmers and analyzing opportunities offered by solar energy based pumps.

Salient features of solar power based energisation project

Thirty four existing tube wells, set up under National Bank for Agriculture and Rural Development (NABARD) Phase VIII program (2004-2005), were selected for energization. The tube wells are located in 20 villages of five blocks of Nalanda district. The tube wells have 7.5 HP submersible pumps with discharge capacity of 70 m^3/hour. Solar equipments were installed by Claro Ventures under this solarization project. Three components/features have been added to the existing tube wells: solar panels, variable frequency drive (VFD) and a communication system.

For each tube well, six sets of solar panels have been installed on about 1000 square feet area on the land adjacent to the pump houses; together they generate about 600 Volts. The output power from solar panels is fed to the VFD. VFD converts current produced by solar panels to three phase AC and feeds it to the irrigation pump. An advanced communication system is the integral part of the solar energization project. The system supports real time data collection, operation modes, and remote monitoring. The solar tube wells of the project have twenty five years' power warrantee; as the implementing agency, Claro Ventures has the responsibility of operations and management of the solar energy related installations for five years.

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[1]This IWMI-Tata Highlight is based on research carried out under the IWMI-Tata Program (ITP). It is not externally peer-reviewed and the views expressed are of the author/s alone and not of ITP or its funding partners - IWMI, Colombo and Sir Ratan Tata Trust (SRTT), Mumbai.

[2]This paper is available on request from p.reghu@cgiar.org

Table 1 Relative Economics of solar energy, electricity and diesel for tubewell operation

	Solar	Electric	Diesel
Capital cost of pump and energy source	high	modest	low
Social cost of connecting to grid power	Nil	high	nil
Cost of energy to the farmer	nil	low	high
Cost of energy to the society	nil	high	high
Carbon footprint	nil	high	high

Table 1 compares solar, electric and diesel energy for irrigation pump operation for key factors that affect their private and social economic benefits. Diesel pumps are cheap to buy but expensive to maintain and costly to run what with diesel prices soaring by the year. Electric pumps too are inexpensive to buy and maintain; and farmers find subsidized electricity attractive when it is available. But the real cost to serve electricity to a tube well are upwards of Rs.5/kWh. Moreover, in a state like Bihar with low power network development in rural areas, the social cost of connecting a tube well to power grid is high. To top it all, diesel as well as electric pumps leave a large carbon footprint. Solar pumps are free of all these pitfalls. They eliminate the cost of connecting tube wells to power grid and provide energy for pumping at near-zero private and social cost. They also have no carbon footprint. Electric and diesel pumps fare worse on all these counts. The only downside of solar pumps is their high capital cost; Claro solar pumps entail a total capital investment of Rs.10 lakh[3]/unit. But these have an economic life of 25 years. Thus solar pumps are cost efficient in long term in financial terms for farmers. However, if their low carbon footprint is factored in, they can be cost efficient in economic terms even in the short to medium terms. As photo voltaic (PV) cell costs keep falling, solar pumps will keep getting even more attractive as alternative to electric and diesel pumps. Where electricity supply is poor and low, solar pumps provide farmers much-needed independence from grid electricity; and compared to noisy diesel engines, solar pumps present hardly any noise pollution. All these together make solar pumping a clear winner.

Solar energy based Irrigation

Thirty four solar pumps would provide irrigation in all three cropping seasons of a year: *kharif (monsoon)*, *rabi (winter)* and *garma* (summer) period. The solar energy based irrigation has been integrated with infrastructure and institutions of existing tube wells. Infrastructure includes a submersible pump, a pump house and water distribution network (underground pipelines and outlets). Beyond outlets farmers are expected to carry water through plastic pipes. Water Users Committees are expected to manage the irrigation, collect fee and maintain the infrastructure. A Secretary and an Operator attached to each tube well manage the day to day affairs of irrigation.

Experience so far

Solar energy related installations were carried out at all locations in March, 2012. Panel and VFD integrated well with the existing submersible pumps and solar energy based irrigation started in April, 2012. These pumps provide water between 8.30 AM to 4.30 PM in general. Farmers have experience of irrigation in two seasons – *garma* and *kharif*; *rabi* irrigation is still awaited.

(I) *Garma* or Summer Crop- Traditionally, *garma* crop is taken over small proportion of cultivated land due to constrains of assured and economical irrigation. Maize, pulses, fodder and some vegetables are major *garma* crops in this region. There was huge demand for water from solar pumps in the command area during *garma* period. Farmers received irrigation in 5-8 acres area for crops like maize, moong, ladyfinger and others. Beneficiaries shared that in *garma* season, a solar power based tube well (7.5 HP) can support irrigation in up to 10 acres of cropped area. Thus solar pumps provide opportunities for increasing cultivation and crop diversification in *garma* period.

During *garma* period, the sky was mostly clear and ample sun shine was available for long hours during day time. Reportedly, tube wells could be switched on as early as 7.30 am/8.00 am in morning and they functioned efficiently till 5 to 5.30 pm. Optimum discharge was available for good 8-9 hours without much daily variation. Log books maintained by operators show that on many days pumps functioned for 9 hours and even clocked 10 hours on some days.

(II) *Kharif* – Rice is major *kharif* crop in the region. In current season, solar pumps are being used for irrigating rice crop in area of about 5-10 acres. Encouraged by the experience in the *garma* season, farmers in the command area were prepared to use solar pumps for paddy cultivation. Beneficiaries at all sites specially mentioned critical support provided by solar pumps in preparation of

[3]One lakh = 0.1 million

nursery for rice crop. Solar pump helped in providing timely and adequate number of irrigation for paddy. Beneficiaries expect this would help in improving the yield. Farmers, based on their experience so far, shared that solar pumps can definitely support paddy in 15-20 acres land.

Patterns of functioning of pumps in *kharif* season: On days with clear sky, solar pumps functioned efficiently between 8.30/ 9.00 am to 4.30 pm. Pumps provided good yield of water during 9 am to 3.30 pm; irrigation was available for 6-8 hours in a day. On cloudy days, water discharge showed intra-day variation during 8.30 am to 3.30 pm during *kharif* season. Brief cloud intervals have no significant effect on yield. Farmers shared that after the onset of monsoon (period between July to October) severe overcast conditions and rains interrupted tube well functioning for about 15 days (total). During rainfall spells in *kharif* season, pumps were switched off. After each rainfall spell there was adequate moisture available in the fields; usually no irrigation was required for following four- eight days.

(III) *Rabi* - First *rabi* irrigation is yet to take place but farmers are upbeat about the utility of solar pumps in *rabi* cultivation particularly for wheat crop. This year farmers expect that one solar tube well would support 10-12 acres of land under wheat crop. However, some farmers even reported that the area benefited can be increased to 15 acres of land with intensive management and with proper distribution infrastructure, the irrigated area can be raised to even 20 acres. In wheat cultivation, there is pressure to meet demands during peak irrigation requirements; farmers believe that solar irrigation would ease the situation.

Irrigation by Solar Power based Tube Wells (7.5 HP Capacity)		
Cropping Seasons	**Irrigated area in current year (by one solar powered tube well)**	**Potential area (by one solar powered tube well)**
Garma	5-8 acres	10 acres
Kharif	5-10 acres	15-20 acres
Rabi	5-12 acres (expected in 2012-13 Rabi)	15-20 acres

Farmers, at all sites, expressed great satisfaction from functioning of solar pumps. They shared that pumps yield water on regular basis for long hours. They consider it a reliable and economical source of irrigation. In plots that benefitted from solar pumps, beneficiaries were saved from costly irrigation based on diesel fuel. Majority of farmers in the region depend on diesel pumps (5 HP pumps, 5 HP and 3 HP). Price of diesel is increasing on regular basis. Diesel based irrigation from water market has gone up to Rs.75- 90 per hour. There are also problems, reportedly, relating to adulteration of fuel and cheating by the pump owners in measurements.

Tube well irrigation based on electric power is available in few villages of the region; facility of three phase electric power is awaited in large part of rural areas. In some villages electric tube wells are working but power is available only for 4-5 hours per day. There is no fixed schedule; farmers keep waiting during interruptions and on many occasions they have to irrigate fields in night.

Functioning of Solar Power based Tube wells				
Cropping Seasons	**Time of start of pump**	**Time of switching off**	**Average hours of functioning**	**Interruptions**
Garma	7.30/ 8.00 am	5.00/ 5.30 pm	8-9 hours	Nil
Kharif	8.30/ 9.00 am	4.00/ 4.30 am	6-8 hours	Severe overcast conditions and rainy days
Rabi	awaited	awaited	awaited	Expectedly during intense fog periods

Water Rates in Villages	
Options of Energy Sources	**Prevalent Rates**
Solar	Rs.3 -5 per *katha* and up to Rs.10 per *katha* (one acre= 32 katha)
Electric	Rs.10 per *katha*
Diesel pumps	Rs.75-90 per hour

Economical Irrigation from solar pumps

Water Users Committees attached to community tube wells with solar pumps are expected to manage the irrigation and collect fee from beneficiaries**.** The rates of irrigation are very nominal. The irrigation rates vary between, Rs.55 to Rs.75 per acre according to the season and the number of irrigations applied.

Beneficiaries mainly belong to small and marginal farmer category. Operators have calculated irrigation rates in terms of rupees per *katha*. Our study revealed that rates of irrigation being collected from solar pumps currently vary. Three categories of rates were reported: (i) variable rates of irrigation i.e Rs.3/*katha* in *garma* and Rs.5/*katha* in *kharif*; (ii) fixed rate of Rs.5/*katha* in two seasons and (iii) Rs.10/*katha*. With more clarity, awareness and experience, greater uniformity in rates is expected.

Currently, Operators are maintaining records of irrigation in terms of beneficiaries' name, area of irrigation, duration of irrigation to calculate the dues. Operators are expected to make entries in the log book on daily basis. In most cases, operators have updated the records. In the studied systems, the tube well functionaries informed that large part of the irrigation fee has been collected.

Maintenance of Installations

Claro Ventures has the responsibility of operation and management of solar energy related installations for first five years. In almost all cases, solar pumps have been functioning without any interruptions and problems. Minor problems emerge in wire connections like breakage, need of protective cover. In case of any problem, operators are expected to call local office (in the district headquarter) for help. Presence of a local office with competent technical staff has helped in extending quick response and solutions. In almost cases, timely and satisfactory maintenance service was reported. There have been four instances of theft of portions of panels. The panels were replaced within 5-6 days. Claro Ventures' central office monitors the operations; Operators also get instructions from central office based on data received for monitoring systems.

Operators have received two rounds of training since the solar pumps started functioning. Functionaries have found the operations easy and user friendly. There is no difficulty in handling components of installations and managing daily operations.

Enhancing benefits with institutional strengthening and infrastructural improvement

Solar energy based irrigation pumps have been functioning efficiently since April 2012. Farmers have developed faith in the technology. Based on experience in *garma* and *kharif* period, they reported that solar technology would be very helpful for irrigation. The program is in early stage of implementation, it provides an opportunity to identify bottlenecks and ensure better irrigation to cultivators. Functionaries and farmers shared feedback/suggestions for improvement in irrigation services; measures can be discussed under two sections: institutional strengthening and infrastructural improvement.

(I) Institutional Strengthening:

Various measures will help in improving the institutional practices and management of solar energy based irrigation:

(i) Greater awareness among cultivators in the command area about benefits of solar energy irrigation, ways to access irrigation, and appropriate irrigation scheduling would help in maximizing the benefits.

(ii) Increased awareness and clarity about scheduled irrigation charges/fee among all members of committee, potential beneficiaries, key functionaries of *Panchayat* and others would help in collection of revenue. Simple design of irrigation charges can be communicated easily.

(iii) Irrigation rates can be reviewed to support expenditures on infrastructure (maintenance, improvement and extension). Performance based incentives for functionaries can also be considered.

(iv) Regular training to Operators/Secretaries and simplification of data collection processes would help in better management of records.

(v) Assessment of specific periods of irrigation demand (crop wise) will help in the management of water allocation. With experience, a framework or rules of water allocation can be developed.

(II) Infrastructure improvement:

Infrastructure created during the NABARD program was renovated in thirty four solar power based tube well systems. Functionaries and farmers shared that further improvements in infrastructure facilities would (i) increase access to irrigation service and coverage of land under irrigation, (ii) improve water distribution efficiency; and (iii) ensure the safety of installations. Major suggestions of functionaries and cultivators are listed below.

(a) Need of extension of length of underground pipelines (at least by 200 feet) was voiced at all sites[4] (b) Replacement of faulty valves; at many locations faults have rendered specific pipelines non- functional. (c) Underground pipelines must be renovated by replacement of broken sections of PVC pipes; pipes with greater load bearing capacities should be used for replacement.

Another set of suggestions about infrastructural development is related to safety of solar installations. Secretary/Operators of Water Users Committees shared that the protection of solar panels is a major concern. The Department has made provisions for insurance of panels. To protect the structures from theft and damage, functionaries have asked for fencing of the area around panels. Operators expressed concern over security of assets; they can be damaged or stolen. For better visibility and protection during the night, operator-cum-guards have made request for provision of light in the tube well premises.

Summary and Conclusion

Installation of solar energy based irrigation pumps is an important initiative taken by Department of Minor Water Resources, Bihar and Claro Ventures. Two conventional sources of energy for tube well irrigation have posed different set of difficulties for farmers. Electric tube wells are few and they are afflicted with inadequate & irregular power supplies. Cultivators in the region are primarily dependent on costly diesel based irrigation. In this context solar pumps have offered economical and reliable irrigation to cultivators in the command area of thirty four tube wells.

The solar power based technology has integrated quite well with existing community tube well systems; ground water pumping is being efficiently executed. Advanced features (panels, VFD, solar tracking and others) are also working efficiently. Solar pumps are working on an average for 6-7 hours a day.

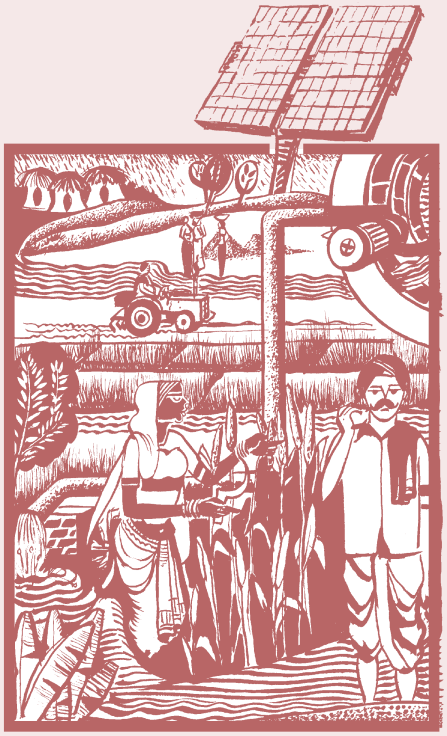
Based on experience with *garma* and *kharif* season, farmers consider the solar power based irrigation as effective and extremely useful technology. Farmers have

[4]Currently, cultivated land beyond outlets can receive irrigation by attaching plastic pipes of different lengths. Farmers manage pipes (self and/or shared). There are instances when water is being carried up to 1000-1500 feet.

found the technology particularly useful for *garma* crops and paddy cultivation. Solar pumps were used for irrigation in 5-8 acres in *garma* period and 5-10 acres in *kharif* period; rise in coverage is expected in coming years. Beneficiaries of solar pumps expressed relief from dependence on costly diesel pump based irrigation. They look forward to using solar pumps for economical and adequate irrigation for wheat crop in *rabi* season. Initial experience show that solar power based irrigation is effective for irrigation in different seasons; it can help in increasing the total cultivated area and crop diversification.

There is a scope to enhance irrigation benefits and coverage area with improvements in institutional practices and infrastructure. Awareness about the irrigation facilities from solar energy and irrigation charges, simplification and compliance of rules, provision of incentives for functionaries and their capacity building and improvement in water distribution infrastructure would help in enhancing service delivery and access of irrigation. Steps should be taken to make tube wells systems more efficient and self sustaining by bringing necessary modifications in the institutional design. The learning from thirty four tube well systems will be very helpful in solarization of irrigation pumps in other parts of Bihar.

The Nalanda experiment demonstrater the effectiveness of the solar technology and it has presented an institutional model for growth of solar pumps. The initiative also showcases immense possibilities that solar power based tube wells offer. Solar pumps can significantly contribute in reducing irrigation- energy deficits and ensuring groundwater based agriculture growth in Bihar. The opportunity must be seized by developing right strategies and policy framework for expansion of solar power based irrigation.



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 IWMI, Colombo and SRTT, Mumbai. However, the Highlights are not externally peer-reviewed and the views expressed are of the author/s alone and not of ITP or either of its funding partners.

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