Ashden India Renewable Energy Collective

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Briefing paper series on decentralised renewable energy for sustainable energy access

Priming the Solar Pump

Context and concerns

Water pumps are of major importance to the economy and energy use of India. Pumping water is critical for Indian agriculture, which otherwise relies on seasonal rain.Indian farmers are currently drawing more water than is sustainable, removing about 212 million megalitres from the ground each year to irrigate about 35 million hectares.[1] Estimates suggest that 60% of India's groundwater sources will be in a critical state of degradation in the next two decades.[2]

Forty percent of Indian farmland is under irrigation, requiring some 27 million groundwater pumps nationwide. Seven to eight million of these pumps run on liquid fuel. This fuel is typically diesel, but as many as a million pumps run on subsidized kerosene—originally meant for lighting usage. The remaining 19–20 million pumps run on electricity and the power used for pumping irrigation water is one of the largest strains on the Indian power grid.

Farmers with small holdings grow crops on very small plots (nearly 80% of farmers work on less than 2 hectares of land), frequently irrigated by treadle pumps. There are approximately one million human-powered treadle pumps in India, largely in the east and central regions. In most instances, the pumps are used because the small-holders do not have access to electricity or cannot afford a diesel unit.

For those farmers who can afford a motorized pump (and lessee farmers who are typically not authorized to get an electrical connection for a pump), the only alternative is to buy or rent a liquid fuel pump. Renting of diesel pumps is widespread, especially in the eastern part of the country. A supply chain of diesel pump renters exists, especially on the Indo-Gangetic plain. Farmers with electricity connections also sell or barter water with neighboring farmers who do not have a pumping system.

Municipal water supply in India is not pressurized, which requires every house and apartment complex to fill an underground reservoir and pump water to an overhead tank to achieve the necessary pressure for gravity flow. Furthermore, there are over 7900 towns and 600,000 villages in the country, with 80% of the villages dependent on groundwater as the main source of water supply. As with cities, in rural India a majority of buildings and homes are not connected to piped water.

This schematic overview reveals that the status of pumps in India raises a number of issues that must be addressed in the short and medium terms. Primary concerns include broadening access to pumps within the agricultural sector, reducing dependency on fossil fuels, and avoiding further depletion of irrigation groundwater. Central and state governments, along with the private sector, are actively exploring solutions that focus on harnessing renewable energy in the form of solar-powered pumps for use in various applications.

Liquid fuel pumps are the first problem. They are used because half a billion Indians do not have sufficient access to electricity. Most diesel pumps are highly inefficient

[1] <http://spectrum.ieee.org/energy/environment/pumping-punjab-dry>

[2] <http://www.globalwaterforum.org/2012/07/30/indias-groundwater-crisis/comment-page-1/>

>> Highlights

- Water pumps are the backbone of agriculture productivity in India.
- Subsidized electricity and fuel to drive water pumps significantly affect economics and politics of energy supply.
- Solar pumps can help significantly to transition into a sustainable energy future.
- Solar pump applications include farmland irrigation, municipal and rural water supplies, and hydro electricity generation.
- Small farming can become financially viable using solar pumps replacing polluting and expensive diesel or kerosene pumps.
- Solar pumps will reduce use of subsidized energy improving economic health of electric utilities and energy companies.
- Motorized pumps, including solar pumps, pose danger to the already unsustainable groundwater depletion in India.
- Combination of solar pumps with efficient irrigation practices is a perfect pair to optimize the energy and water consumption.

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and perform in the 15%–20% efficiency range (65% is a reasonable goal). They emit greenhouse gases in their exhaust and they are noisy. Each of these pumps on average uses 1000 litres of diesel annually and despite a subsidy of about Rs 8.50 per litre, diesel fuel is expensive. Over the past 10 years, the price has increased 8% annually on average, and nearly 40%–50% in the last three or four years.

Farmers are paying Rs. 50,000 to Rs. 80,000 to run diesel or kerosene pumps, and such liquid fuel costs can represent 30%–50% of the total value of the grains produced. Farmers needing cash for diesel will often promise their harvest upfront to pay for the fuel, agreeing to low prices for their crops. As water demand rises during the growing season, diesel prices spike on the black market.

Expensive fuel also means that most farmers can only afford to sow two crops per year: one rain-fed crop that does not need irrigation during the wet season, and another crop requiring irrigation during the dry season. This, and the fact that farmers travel long distances to procure diesel for their pump, limits overall agricultural output.

Electric pumps present a different set of issues. Twenty percent of India's electricity is used for agriculture pumping, but since independence in 1947, the Indian government has heavily subsidized electricity destined for irrigation. It is either provided at no cost, or the equivalent of one or two cents per kilowatt hour. Farmers have consequently become financially dependent on a free or low-cost source of pumping power, but because the utilities lose money in this sector, farmers usually get electricity during off-peak periods and in a sporadic fashion. Farmers do not know when or for how long electricity will be supplied—they often get it in the middle of the night—which in turn lowers their productivity and limits the crops that they can grow to those that tolerate variable water supplies.

Free or low-cost electricity also provides no incentive for farmers to improve the efficiency of their pumps, or for utilities to approve applications for electric irrigation pumping even where there is pent-up demand. In some Indian states, the number of outstanding applications for irrigation pumps can reach twenty times the number of annual approvals.

Solar pump solutions

Irrigation

Irrigation can increase crop yields to up to four times that of rain-fed agriculture, providing 40% of the world's food from 20% of its arable land. Irrigated agriculture is critical to food security globally, and as India is the world's largest irrigation practitioner, solar power is a necessary focus.

Irrigation is an area that offers enormous potential for water and energy efficiency, and solar pumps are well suited to the irrigation task. To many observers, solar irrigation is a near–perfect application of solar energy; on sunny days water is pumped when the crops need it and when the farmer must work the field, while on cloudy or rainy days the solar output is lower, but the need for water is minimized. A small micro solar pump with less than 200 W_p of power could do a similar function as a treadle pump, additionally providing battery charging when the pump is not in use.

'The potential is huge,' Tarun Kapoor, joint secretary at India's Ministry of New and Renewable Energy (MNRE), said in an interview. 'Irrigation pumps may be the single largest application for solar in the country.'

The economics of solar pumps compared to diesel already works favourably. Analysts claim that 8 million diesel pumps (Figure 1) already in use could be replaced economically, and MNRE estimates another 700,000 diesel pumps bought every year in India could be displaced with solar. Falling prices of solar panels (the most expensive component of a solar pump system) suggest that the payback for a solar water pump system ranges from one to four years.

Switching irrigation pumps to run on solar would save an estimated $6 billion USD a year in electrical and diesel subsidies. In addition, if all of the pumps in India were converted to solar it would equal 125 GW (125,000 MW) of electrical power. Solar pumps will also allow farmers to boost agricultural output, reduce national levels of liquid fuel consumption, and address climate change by limiting diesel exhaust.

There is a current trend in rural electricity grids to separate irrigation pumping from rural residential homes—Gujarat and Punjab are examples. A dedicated transformer is connected to a cluster of irrigation pumps, supplying power for a fixed number of hours. This has created an opportunity to introduce super high–efficiency electric pumps coupled to transformer-based solar photovoltage (PV) plants. Each transformer could have a PV plant ranging from 25 (kW_p) to 250 kW_p. The plants can deliver power to a cluster of pumps and return surplus power to the grid.

Such pumps could act as reliable anchor loads in off-grid mini grids, with the original investment costs shared by private developer(s) and local farmers. The relevant farmers association would supervise the operation and maintenance of the units, and the developer(s) and farmers would share any revenue from the sale of electricity. The local utility could use power generated by the local solar pump mini grid towards the renewable purchase obligation (RPO) for the utility.

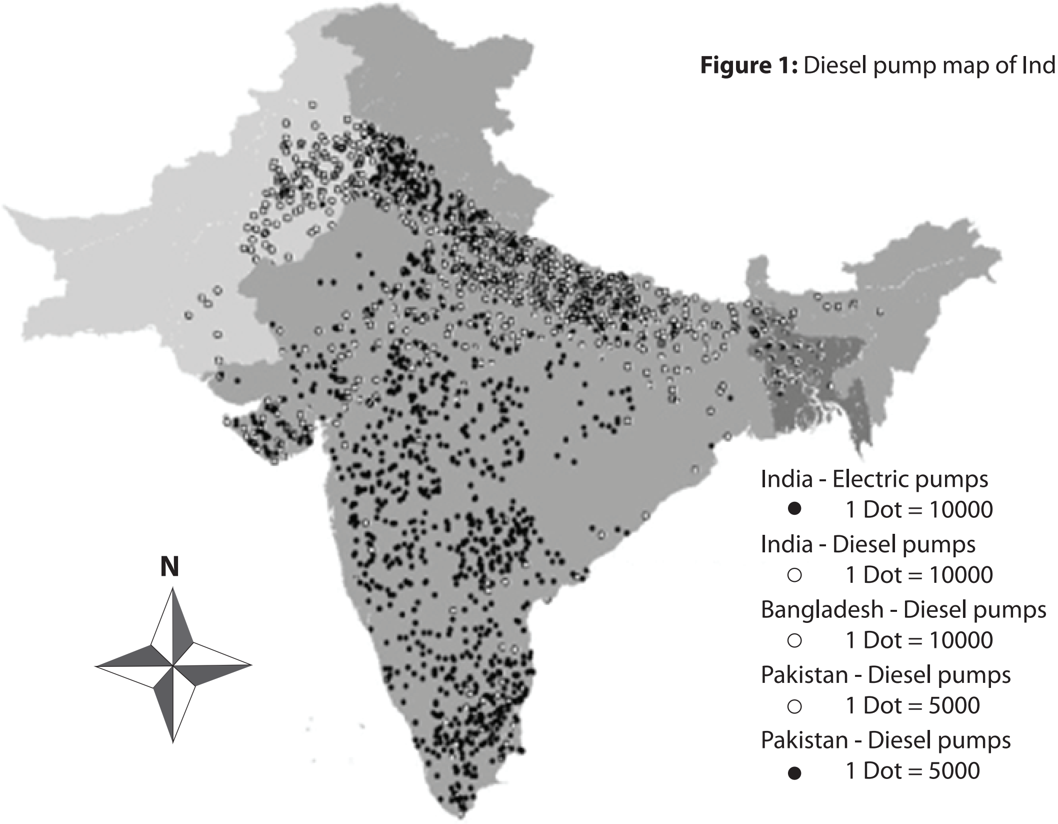

Figure 1: Diesel pump map of India

Source: Tushaar Shah Year Climate change and groundwater: India's opportunities for mitigation and adaptation. Colombo, Sri Lanka: International Water Management Institute.

Drinking water and other municipal services

As per Census of India 2011, there are 7933 towns and 600,000 villages in India. Solar pumps offer an opportunity to relieve rural communities and urban municipalities of recurrent energy bills and to mitigate power interruptions. Variable frequency drive (VFD) technology has made it possible for larger pumps (up to 25 HP) to run directly from solar PV panels. This has allowed urban municipalities and rural communities to install PV panels on roof-tops to drive solar pumps for drinking water and other municipal or community services.

A solar pump programme can be implemented in partnership with local communities that can participate through cost-sharing for installation and maintenance of a solar pumping system. Drinking water being a critical need binds people to form water associations to ensure efficient maintenance of the system.

Such examples exist in Kachch District of Gujarat where Water and Sanitation Management Organisation (WASMO) installed 260 solar pumps in villages with people–public participation. Similar examples also exist in tribal areas of Odisha.

Other applications

Solar pumping systems can also be deployed with water filtration systems such as reverse osmosis or ultra-violet water purification. In most cases micro solar pumps using less than 300 W of solar-power could accommodate such pumping needs.

In large housing complexes, higher capacity solar pumps could replace conventional pumps. Wherever grid power is available, these pumps could be integrated to allow surplus power to be fed back into the grid. In off-grid locations or where only micro pumps are operating, excess power could be used for charging batteries or for water purification.

Pumped-storage hydro electricity plants are another possible application for solar pumping. In a conventional hydropower plant, the water from the reservoir flows through the plant, exits and is carried downstream. A pumped-storage plant has two reservoirs: an upper reservoir created by a dam, with the water flowing through the hydropower plant to create

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electricity; and a lower reservoir that holds the water exiting the hydropower rather than re-entering the river and flowing downstream. Using a reversible turbine, the plant can pump water back to the upper reservoir during off-peak hours, thereby creating a 'battery' of stored water to generate electricity during periods of peak demand.

There is a potential to use large capacity solar PV pumps to refill the upper reservoir. In addition, when the upper reservoir is full, surplus power from the PV array could be fed back to the grid. Particularly in areas where dams are not on perennial rivers, this type of solar pump and hydropower combination could achieve higher plant utilisation as well as help meet peak electricity demand. One such plant of 900 MW is being planned in Purulia district in West Bengal.

Key challenges

Despite an early start in prototype and demonstration programmes, deployment of solar pumps has lagged. The following concerns must be addressed before the use of solar pumps can be scaled up.

- Use of solar pumps has been limited to mainly farmers in prosperous farming belts of Punjab, Haryana, and Rajasthan. Small-holding farmers in high potential zones like the Indo-Gangetic plains are still unaware of solar pumping technology and have limited access to subsidies and bank financing.
- A high rate of capital subsidy offers opportunity for arbitrage with solar panels moving from high subsidy pumping programmes to open markets.
- Potential users lack knowledge of supply channels for operation and maintenance of solar pumping technology.
- Standards, certification, and performance testing of solar pumps have yet to match conventional electric pumps. Unlike the Star rating for efficient electric pumps, there is no identification mark for users to distinguish between available solar pumps. In addition, there is no user guide or reference matrix available to the farmer for decision-making around solar pumps. Each type of soil, crop, and depth of water needs a different capacity of pump.
- Portability of solar panels has been a key need expressed by farmers. Due to security risks and seasonal usage of fields, farmers like to move the solar panels to a safer place near their homes.
- Bank managers are wary of lending to a new technology making it virtually impossible to access bank loans for solar pumps. Public policies and private investments in solar PV are currently aimed at large, grid-connected power plants.

Facilitating large-scale deployment of solar pumping

Apart from focusing on financial incentives for purchase of solar pumps, investments are needed to develop an ecosystem for solar pumps. This ecosystem would include a strategy for communication, training using existing agriculture outreach channels, standards and certification, vendor development, financing through existing points of finance used by farmers, monitoring and evaluation, product development, and research and development of new ideas and innovations.

A solar pumping mission would be able to integrate all the components to provide financial incentives and knowledge investments for accelerated market development of solar pumps. The following is a list of focus areas required to build a robust ecosystem for solar pumps.

- An awareness campaign with a technical literature, along with demonstration pumps and training modules, is needed for agriculture engineering faculty and students at agriculture universities in India.
- An orientation and awareness programme, developed in collaboration with solar pump vendors and suppliers, to target farmers and bankers.
- An exposure campaign for conventional electric pump shop owners would help enlist them as advocates for solar pumps.
- Retraining conventional pump technicians would develop a chain of solar pump mistries (technicians) close to farmer service providers.
- A users' guide for selection of the right pump for local cropping, soil and water needs should be developed.

India has a thriving conventional electric pump manufacturing industry, a spill-over of the Green Revolution in the 1960s. There are about 400 pump manufacturers in three clusters in Gujarat, Tamil Nadu, and Madhya Pradesh. An investment in training and retooling would support the transition of the conventional pump industry to the manufacture, sales, and service of solar PV pumps. In addition, the supply chain of conventional electric and diesel pumps is one of the most robust linkages to the farmers in rural India, with a very strong and efficient manufacturing, sales, and service network. This supply chain could be an engine of growth for the emerging solar pumping industry.

The high capital cost of acquiring a solar pump is a major deterrent. The point of finance for farmers such as local regional rural (RRB) or cooperative bank managers are ill-equipped to deal with financing solar pumps. A dedicated product portfolio targeted towards financing solar pumps must be developed. This portfolio could be linked with the priority lending targets for the banks. In lieu of a capital subsidy, the incentive could be put into a fixed deposit from which the monthly installments for paying the loan could be adjusted.

Renting instead of buying a solar pump is another option that could spark solar entrepreneurs. A programme to provide incentives and loan finance to small entrepreneurs to purchase solar pumps would fill this gap. The Ministry of Petroleum and Natural Gas could release diesel subsidies, channeled through public sector oil companies, to replace diesel pumps with solar. Alternatively, each solar pump user could also become eligible for an incentive from the local utility under RPO. With this incentive, the user could borrow money from banks to install solar pumps.

Aggregation of demand could help to reduce transaction costs. Several state governments have goals for large-scale solar pumping programmes and the Solar Energy Corporation of India could facilitate the aggregation of this scattered demand to achieve economies of scale. Incentives could then be bundled under a viability gap funding mechanism, similar to that for large solar-based grid-connected power plants. Bidding would be done both for the cost of the asset and the extent of the viability gap funding (VGF) required by the developer. The bidder with least cost of asset and lowest need for VGF will qualify for the first supply.

Retrofitting of diesel pumps with solar pumps

A programme is proposed to retrofit diesel pumps with solar PV pumps. Under this scheme, the farmer will surrender the old diesel pump and buy a solar pump of choice from the open market. The incentive package would be equivalent to 20 years' diesel subsidy, which the farmer would have used if the diesel pump would have remained operational. Farmers could buy a solar pump by availing a loan from the local bank and then use the incentive to repay the loan. This scheme is similar to the *Bachat Lamp Yojana*, which entails replacement of incandescent bulbs with more efficient compact fluorescent lamps or light emitting diode (LED) lights.

Research and development (R&D) and product development

It is recommended that 5% of the total money spent on solar pump financial incentives be allocated for R&D and product development focused on solar pumps. The key focus of research would be on increasing the efficiency of pumps and reducing the cost of balance of systems.

An important aspect that product development needs to focus on is the portability of pumps. Farmers normally do not want to leave an expensive asset unattended on the farms. They also need power backup at home. Making solar pump components portable would make it more accessible to the farmers and will open avenues for rent-a-pump entrepreneurs. The research portfolio should also include cost reduction in solar panel tracking and mounting structures; lower cost VFD; low-cost electrical inter-connects; and mobile phone-based remote smart metering payment systems. R&D funds could also be used for field prototyping of new developments such as micro solar pumps, transformer-based clustered solar pumps, and ultra high-efficiency pumps. Design schools such as the National Institute of Design, Ahmedabad, and the Industrial Design School at Indian Institute of Technology, Mumbai could be involved in this exercise. Dovetailing with the ultra high-efficient pump programme of the Bureau of Energy Efficiency (BEE) would facilitate the much-needed technology and policy convergence.

A caveat: sustainable water use

Agriculture accounts for 67% of the world's total water withdrawal and 86% of consumption. Globally, 20% of aquifers are reported to be unable to recharge quickly enough to offset withdrawals.[3] Large parts of India, China, and the US fall within the problem areas. According to a 2012 study, production of mainstay crops such as wheat, corn, and rice stagnates in India and the reasons include water scarcity and falling groundwater tables.[4]

By 2025, agricultural consumption of water is expected to increase by 20%. At the same time, domestic and industrial sectors are increasing their consumption of water, compounding the issue. Water demand in India could double by 2030 if practices that are more efficient are not applied.

Motorized pumps, including solar, pose a high risk of over-pumping of the ground-water, threatening sustainability of precious water resources. It is, therefore, imperative that in the immediate future, the solar water solution be combined with intelligent water management and conservation practices.

In agriculture, this means a more effective and targeted utilization of the water pumped, often in the form of

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[3] <http://icid.org/nletter/micro_nl2006_4.pdf>

[4] <http://www.nature.com/ncomms/journal/v3/n12/full/ncomms2296.html>

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efficient irrigation systems such as drip, sprinklers, and lined water channels, where least amount of water is used to avoid evaporation and flow losses. Such practices can reduce water use by up to 70%, and minimize the required pumping capabilities.

Higher efficiencies lead to increased crop yields with less water

To combat these unintended consequences, farmers who accept government subsidies to purchase solar water pumps should be required to switch to an efficient irrigation system. Many states like Punjab, Tamil Nadu, and Gujarat are currently offering generous subsidies for drip irrigation.[5] A practice of water audits and permits to use groundwater could be introduced to increase the mindful use of precious groundwater resource. Information, education, and outreach programme for solar pumps should include best practices for water conservation.

Recent government actions

The Government of India is now actively promoting solar pumping, particularly in the agriculture sector. In 2010/11, it launched the Jawaharlal Nehru National Solar Mission (JNNSM), which is now in the second phase of its programme. One of the focus areas of the Phase II scheme is to 'promote agriculture-based applications like solar pumps.'

In early February 2014, the government estimated that India will draw Rs. 100 billion ($US 1.6 billion) of investment in the next five years as the first 200,000 most easily replaceable pumps are switched to solar.[6]

This was followed in March by a notice that the government had approved Rs. 3 billion ($49 million) in subsidies to help farmers install solar-powered water pumps to boost agricultural yields and reduce diesel fuel use. According to a notice posted on its website, the MNRE will provide grants to install 17,500 irrigation pumping systems through 2016, funded by a carbon tax on coal. The grants will cover as much as 30% of project costs, while state governments that participate in the programme will be required to match with a subsidy covering another 15%. Farmers will cover the remainder. The programme's total cost is estimated at about Rs 10 billion.[7]

And most recently, the Minister of State for Power, Coal and New and Renewable Energy, Mr. Piyush Goyal, said in a written reply to a question in the Lok Sabha that. 'The Government has proposed a programme for installation of one lakh solar pumps for irrigation and drinking water purposes across the country.' He said that Rs 14,788.45 lakh has been sanctioned for solar pumps to 12 states under the Off-Grid and Decentralized Solar Applications scheme of the JNNSM, and that as of 31 March, 2014, a total of 11,626 solar pumps have already been installed in various parts of the country.[8]

Conclusions

Clearly, solar irrigation is urgently needed in India. It replaces costly, fuel-intensive, and wasteful practices, but in the end, it must be integrated into a holistic approach that reduces both the use of fossil fuel and water itself. The advantages offered by drip irrigation make it an ideal solution for sustainable water management. Combining solar pumping and drip irrigation offers a far better solution with reduced carbon footprint, elimination of conventional fuel use, improved yields, and water conservation.

A performance-based incentive package linked with bank finance through easy loan schemes could make solar PV pumps an ideal tool for sustainable water management, energy security, and increased food production. Formation of a cross-ministerial special purpose vehicle could become a mechanism to deliver a large-scale deployment of the programme. A combination of all these efforts could result in installation of more than 1 million solar pumps by 2022.

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[5] <http://timesofindia.indiatimes.com/city/chandigarh/Punjab-announces-80-subsidy-for-sugarcane-drip-irrigation/articleshow/30695751.cms>

[6] <http://www.bloomberg.com/news/2014-02-07/solar-water-pumps-wean-farmers-from-india-s-archaic-grid.html>

[7] <http://www.bloomberg.com/news/2014-03-06/india-approves-3-billion-rupees-in-solar-pump-subsidies.html>

[8] <http://zeenews.india.com/news/eco-news/govt-plans-to-install-1-lakh-solar-pumps_949949.html>