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Several benefits can be derived from the use of solar energy – electricity services where transmission and distribution lines have not yet been extended and/or compensating for inadequate grid-supply, and reducing the need for conventional energy resources and thereby reducing their environmental impacts. While solar-powered water-heating and energy generation for various uses have been in use for years, the continued fall in the prices of solar photovoltaic (PV) panels has made them affordable even for families and farms.

At present, the weather in much of the Indian sub-continent is ideal for solar energy generation and use. Sunny days and clear skies permit unhindered solar insolation, while low night temperatures necessitate heating of water for morning use, and the absence of precipitation in most regions makes power for irrigation essential for the current crop. In this newsletter, we therefore look at aspects that help or hinder larger-scale replication of solar water heating and solar-powered irrigation. We also look at the installation of solar PV panels above/adjacent to canals, through which not only can energy be generated for irrigation and other uses, but water conserved through reduced evaporation.

Solar power for water heating:

Solar water heaters **(Swh)** are useful in India, as the solar insolation is adequate for heating bath water during most of the year. The use of conventional energy resources can definitely be reduced, even if supplementary/alternative heating is required in cloudy weather and during rains. Numerous suppliers are in operation, so that buyers have a choice, depending on their location and requirements.

Swh are relatively more beneficial for commercial and industrial establishments than for homes, because the greater the heated water requirement (and consequent energy use) and the higher the tariffs payable for this energy, the larger the monetary saving and quicker the payback of investment. Hotels use swh for obtaining bath-water and other heated-water requirements (in the kitchens/laundries) and industrial units for supplementing process heating. For power utilities, replacement of electric water heaters by swh is beneficial as the morning peak power demand is reduced.

Government-instituted measures to further the use of Swh include:
* Some states (e.g. Karnataka, in 2007) and several municipal corporations have issued orders making solar water heater installation compulsory for new houses constructed on plots of more than a specified area (e.g. houses of 600 ft^2 or 56 m^2 and above, on plots of at least 1,200 ft^2).

*A few municipal corporations (e.g. Thane, Amravati, Nagpur, in Maharashtra, and Durgapur in West Bengal) provide 6–10% rebates in the property tax for users of solar water heaters.

* Some electricity distribution companies offer rebate in monthly electricity bills (e.g. Karnataka's electricity distribution companies provide a rebate of Rs 0.50/kWh, subject to a maximum of Rs 50/month for domestic swh installations; Rajasthan's provide Rs 0.25/kWh, capped at a maximum of Rs 300/month).

* Several states offer an installation subsidy for residential swh systems and at the national level, the Indian Renewable Energy Development Authority (IREDA) has an interest subsidy scheme that enables banks to offer concessional finance.

While most households perceive the benefits of swh, there are valid objections from some regions; for example, along the coasts, heated water is not needed during the summer (nearly four months) and solar insolation is not adequate during the rainy season (another four months), so that the value of energy saving does not justify the purchase of the swh system.

Further, while swh have been proved effective for in single-family dwellings, there are likely to be problems in multi-family units (e.g. multi-storeyed apartment-buildings). The problems experienced/envisaged include:

* The terrace or roof-top space is not sufficient for location of swh systems (collectors and tanks) to adequately meet the hot-water needs of all the residents.
* Equitable distribution of heated water between multiple independent families is difficult to implement. (Thus far, metering of even the ordinary water supply is not being carried out).
* While insulation of the storage tank (with polyurethane foam/rockwool/aluminium stucco) is required in all cases, in the case of multiple users, extensive cladded piping would also be needed - to convey heated water to multiple usage points (i.e. at least one for every apartment, at every level of each building). The increased costs would adversely affect financial feasibility. Further, those on the lower floors (and therefore further away from the roof) would be deprived.

Multi-storeyed apartment buildings have been necessitated by the burgeoning urban population, and the trend is expected to continue. Hence, if the use of swh are to be used, solutions to these problems are urgent.

Solar-power for water-pumping: Irrigation is required for cropping beyond the rainy season, for reducing vulnerability to changing rainfall patterns, and for increased yield. But for most farmers in the Indian sub-continent, irrigation depends on their ability to extract groundwater. This necessitates energy for pumping; with power shortages and system problems, solar-powered pumps and electricity from solar power are worthwhile options. In dry regions where pumping from deep-wells for irrigation is high, shifts to solar power would ease the burden of subsidised supply on electricity utilities; in the riverine plains where diesel-powered pumps are used at less deep aquifers, solar power would lower the farmers' fuel cost burden.

Solar-powered pumps – Here, the electric motor driving the pump is powered directly by arrays of PV cells located at the pump site.

At the 2018-19 budget, the central government had proposed KUSUM (*Kisan Urja Suraksha evam Utthaan Mahaabhiyan*), for assisting farmers with solar power. It was intended[1] that 30% of the cost would be provided by the central government, a matching 30% by the state government, 10% by the farmer(s), and the remaining 30% as loans from banks.

However, while energy is "free" and accessible conveniently during the daylight hours when farmers work in their fields, such a "green" alternative could also encourage excessive use, thereby having a negative impact on groundwater through over-exploitation[2].

But, if farmers could sell excess energy, this potential earning would incentivize them to irrigate their crops efficiently, thereby also conserving groundwater. Importantly, farmers would get payments when the rains failed as the energy generation during the longer hours of sunlight could compensate them for the fall in income from reduced crop output.

The International Water Management Institute (IWMI), which leads the CGIAR[3] Research Program on Water, Land and Ecosystems has been promoting the use of solar-powered pumps for irrigation, while enabling farmers to sell back surplus solar-powered energy to the utility grid, to motivate conservative use of scarce water. They call this "SPaRC" (Solar Power as a Remunerative Crop) -- another source of income that can be "cultivated".

There are state-funded schemes that provide financial assistance for solar-powered irrigation pumps. For example in Madhya Pradesh (in central India), has *Mukhyamantri solar pump yojana* (literally, Chief Minister's plan for solar pumps). This scheme provides subsidies for farmers desiring solar -powered irrigation pump-sets, in villages without electricity or at least 300m from the grid lines. Karnataka state (in southwestern India) has its *Surya Raitha* ("sun farmer") scheme[4], also intended for subsidising installation of solar pump-sets. Subsidies and soft loans are accessible through the state's regional electricity distribution companies (discoms) that will also purchase excess energy[5]. Net metering is intended (as in the case of roof-top systems), with the loan recoverable through the payments for electricity exported to the grid.

However, high state subsidies for purchase of solar pumps could create unintended incentives for the solar industry to maximize its gains by raising solar panel prices. An open market would thereby be limited, with subsidies captured by the elite, and continued groundwater

[1] But the required fund allocation has not yet been obtained.
[2] This problem has already been experienced because payment for the unit cost of grid-supplied electricity is not compulsory. Solar-powered irrigation pumps could therefore threaten aquifers just as electric pumps powered by free or subsidized grid electricity have done.
[3] CGIAR is a global partnership of organizations engaged in research for a food-secured future.
[4] The scheme was originally launched in the year 2014.
[5] The purchase rates in August 2018 were Rs 9.56/kWh from those who did not take a subsidy, and Rs 7.20/kWh from those with subsidised systems.

over-extraction. IWMI's 'smart solar pump' policy recommends countering this through lower purchase subsidies, but readily available bank financing and other solutions tailored to the local conditions. While the feed-in tariff (for excess energy sold to the utility) should be higher, to help the farmers, there should be tamper-proof meters and farmers' associations or cooperatives rather than many dispersed individual sellers, to curtail the utilities' transactions and vigilance costs.

In 2016, a Solar Pump Irrigators' Cooperative Enterprise[6], consisting initially of only six farmers, was established in the village of *Dhundi*, in Kheda district, Gujarat state (western India), through a pilot project of the IWMI-Tata Trusts program[7]. The regional utility MGVCL[8] has a 25-year contract with the co-operative. It meters, monitors and pays the cooperative, based on its own meter reading at a single evacuation point; the cooperative then distributes the proceeds among its members, based on units recorded on individual meters. The farmers get daytime energy that is free and more reliable then the grid-supply; if diesel was used earlier, that cost is now avoided. The farmers' contribution towards the capital cost (mainly provided by IWMI-Tata), is compensated for by the higher-value vegetables being cultivated; their only complaint is that the feed-in tariff should be higher. Many more farmers now want to be involved, even with higher contributions towards the initial cost.

Meanwhile the utility profits from reduced subsidy on energy-supply to those farmers, while the solar-power generated energy helps them meet their Renewables Purchase Obligation (RPO).

Solar-powered electricity generation dedicated to irrigation – Here, electricity is generated, on a scale appropriate for servicing several pumps. This is preferable to individual solar pumps, for scalability and operational convenience, effectively servicing large numbers of farms. The availability of state electricity grids, now extended to most villages, combined with the national feeder separation (agriculture from others) programme, makes solar-powered electricity supply to agriculture technically feasible. At current costs, it is financially feasible for the utilities (without the need for subsidies).

Harobele village in Karnataka state is the first village to which a dedicated irrigation feeder has been supplying energy generated from solar power (since January 2018), and more than 300 farmers receive electricity for their pump-sets. A farmers' society was formed, primarily to interface between the discom and the members.

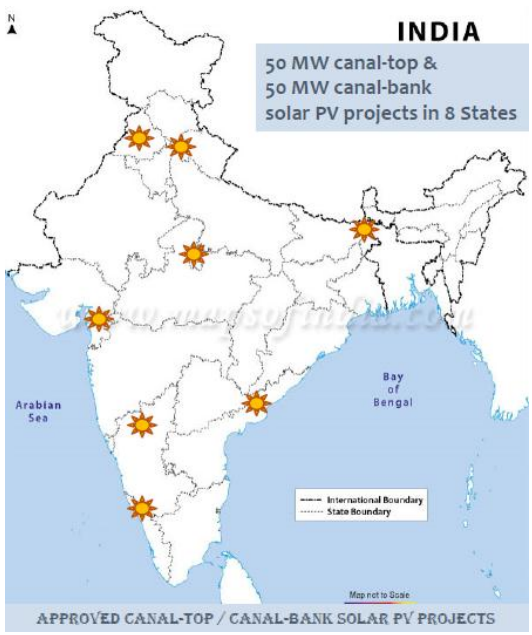
[6] *Dhundi Saur Urja Utpadak Sahkari Mandali*

[7] Financial support has been from the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

[8] Madhya Gujarat Vij Company Ltd.

In Maharashtra (western India), a government scheme[9] for harnessing solar power on a large scale for agricultural pumping is being implemented by the state government and the state's generation and distribution companies. The program consists of developing distributed solar PV plants of 2 – 10 MW each dedicated to feeders servicing agricultural pumps. Supply is expected to be provided for about 12 hours/day.

Solar PV panels atop canals and other water bodies - A key challenge for replication of solar-powered systems is to get access to adequate land on which panels can be installed, without adversely affecting the current users. Mounting solar panels above irrigation canals provides multiple benefits: it not only uses available space for the solar panel structures, as the canals are already under the control of the relevant canal authorities, but reduces evaporation of the water in the canals – a huge benefit in the long term. As the energy is used at nearby farmlands, the transmission and distribution losses are reduced. As the cell modules remain cooler than at ground-mounted sites, the energy generated at canal-mounted sites is also higher. It is also expected that degradation over time will be lower. The country's first canal-mounted solar plant was at Chandrasan, Gujarat.



Thereafter, many other canal-top and canal-bank sites have been approved, and some are under construction, particularly in Gujarat, and seven other states -- Karnataka, Punjab, Uttar Pradesh, Uttarkhand, Andhra Pradesh, Kerala, and West Bengal. The central government provides subsidies of about 30% (to state entities) towards the initial costs. The Maharashtra government is currently considering a 1,000-MW floating solar power plant at Ujani dam in Solapur district, around 300 kms from Mumbai; environmental aspects are being evaluated.

While solar-power has long enabled electricity services like lighting, and helped to reduce the need for fossil-fuels and their environmental impacts, it is now providing reliable and affordable irrigation, and thereby a range of benefits – from increased food production to improved farm livelihood.

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[9] *Mukhyamantri Saur Krushi Vahini Yojana* (Chief Minister's plan for conveyance of energy to agriculture through solar power)