



## Economic feasibility of solar irrigation pump in India: An insight from Andhra Pradesh

RENJINI V R<sup>1</sup>, GIRISH K JHA<sup>1\*</sup> and J P SINHA<sup>1</sup>

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

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### ABSTRACT

This paper attempts to examine the potential and utilisation of solar power with a special focus on solar powered irrigation system in India. The solar capacity has mostly concentrated in Southern and Western states but most of the states have not attained their solar power potential. Installation of the solar irrigation pump with state and central financial support is impressive in states like Rajasthan, Chhattisgarh and Andhra Pradesh. Further, the life cycle cost of solar photovoltaic (SPV) water pump and diesel pump was calculated based on the field survey data collected during 2019 from three districts of Andhra Pradesh. The capital cost of SPV pump per horsepower is 8 times higher than that of diesel pump but operation and maintenance cost of solar found to be significantly lower than that of diesel pump which is making solar powered irrigation system economically viable.

**Keywords:** Life cycle cost analysis, Photovoltaic, Solar energy, Solar water pump

Irrigation system in India is dominated by electric and diesel pump sets. India has about 30 million (21 million electric and 9 million diesel) pump sets, which account for about 20% and 12% of India's total electricity and diesel consumption respectively (Srinivas 2018). The Government of India is also spending roughly ₹500 billion annually for agricultural subsidies causing significant financial burden to the distribution companies (DISCOM) (Bhati *et al.* 2019). Even though 99.9% villages are electrified in India (CSO 2019), unassured and poor-quality power supply on farm, hindering farmers in timely irrigation of crops. Furthermore, in view of global climate change, environmental safety, volatile crude oil prices and limited supply of fossil fuels, it becomes imperative to use alternative renewable energy sources. Nonconventional energy sources such as solar, wind, and biofuels can play a key role in creating a clean, green and reliable energy sources for farms. Among all renewal energy, solar energy is increasingly being relied upon, as it is abundantly available in Indian condition to bridge the demand-supply gap and enhancing on-farm energy assurance (Jha *et al.* 2012, Jha 2013). The solar power in India is being promoted through grid connected solar power system, and off-grid solar systems like roof top solar system,

solar lighting system, solar photovoltaic (SPV) irrigation pump. Solar powered pumps represent a growing market as they present a good and viable solution for rural areas.

Solar water pumping minimizes the dependence on diesel, gas or coal-based electricity (Chandel *et al.* 2015). Amalgamation of advances in electronics and production technologies breakthrough reduced the cost of SPV and increased its efficiency considerably. In this context, this paper attempts to provide an overview of solar power potential and schemes in the country with special reference on solar powered irrigation system. This paper also examines the economic feasibility of solar pump over diesel pump based on field survey in Andhra Pradesh.

### MATERIALS AND METHODS

The data on solar powered irrigation and related information were collected from Ministry of New and Renewable Energy (MNRE), Government of India and Central Electricity Authority, New Delhi. The life cycle cost (LCC) analysis of SPV water pump system and that of diesel pump system was compared based on survey data from three districts of Andhra Pradesh, i.e. Kadapa, Ananthpur and Guntur collected during 2019. LCC analysis is an economic appraisal of all present and future cost of a product or process from cradle to grave. For methodological aspects in calculation of LCC, we followed studies by Kolhe *et al.* (2002), Odeh *et al.* (2006), and Kelley *et al.* (2010). The LCC of a SPV water pump or diesel pump system consists of the initial capital investment ( $C_0$ ), the present value of operation and maintenance costs (OM) and replacement cost (R).

Present address: <sup>1</sup>ICAR-Indian Agricultural Research Institute, New Delhi. \*Corresponding author e-mail: gkjha@iari.res.in.

$$LCC = C_o + OM + R$$

The capital cost of PV ( $C_o$ ) is the sum of investment in each part of its system like wiring, support structures, packing, transport, installation and related electronics etc. It is mainly depending on peak power rating of the PV array, i.e.

$$C_o = W_{pv} * U_{pv}$$

$W_{pv}$  – Power rating of the array in Watts

$U_{pv}$  – Unit cost/Watt

Cleaning of solar panels and associated labour charge is the major operation and maintenance cost in solar pump life time. It is generally expressed as some per cent of capital cost solar pump system. In this study we assumed the cost as one per cent of the capital cost of SPV pump. The replacement of controller once in 7 years is the major replacement cost in SPV pump which is calculated by discounting actual component cost. The economic life of solar photovoltaic panel is assumed to be 20 years.

The capital cost of diesel pump is based on generator dealer pricing and associated components like electronics, installation etc. Economic life of diesel pump is assumed to be 6 years. Air filter change, oil and fuel filter change, decarbonisation, are the major operation and maintenance cost in diesel including fuel cost. To calculate fuel cost latest available average price of diesel is being used including fuel delivery cost. The life time fuel cost ( $F_d$ ) is calculated by multiplying diesel price per litre, the number of days in growing season and the operation hours of pumps per day. We have assumed 6 hours of operation per day for an average of 300 days irrespective of the different crop production practices. A two per cent increase in annual fuel cost is assumed while calculating lifetime fuel cost of diesel. The associated structures such as water tank, supporting structures etc. were not included in the cost analysis.

## RESULTS AND DISCUSSION

*Solar power potential and schemes in India:* The potential of solar power in the country has been assessed to be around 750 GW (MNRE 2019). State wise scenario shows that Rajasthan is having the highest potential for solar power generation (19%) followed by Jammu and Kashmir (15%), Maharashtra (9%), and Madhya Pradesh (5%). The solar capacity has mostly concentrated in Southern and Western states which are having favourable conditions like high irradiation, land availability and grid connectivity. As on 31<sup>st</sup> March 2019, total solar power capacity installed is 28 GW in which Karnataka, Rajasthan, Telengana, Andhra Pradesh and Tamil Nadu are front runners (MNRE 2019). The way ahead for India is very challenging for scaling up solar power in country as government envisioned generating 100 GW by the year 2022. Total capacity commissioned in North Eastern states is 37.95 MW against their potential of 62.3 GW. Land availability and hilly terrain pose problems in these states. Rooftop solar system can be better option for these states.

The objective of National Solar Mission (NSM) launched under the National Action Plan on Climate Change (NAPCC) is to establish India as a global leader in solar

energy, by creating the policy conditions for solar technology diffusion across the country as quickly as possible. Through NSM, a target for development and deployment of 20 GW solar power in the country by 2022 was envisaged in three phases (Phase I: 2010–13, Phase II: 2013–17, Phase III: 2017–22). Later, in 2015, the Government had revised the target of grid connected solar power projects from 20 GW to 100 GW by the year 2021–22. Major solar programmes under NSM are divided into grid connected and off-grid schemes. Under grid connected solar power scheme, creation of solar parks and ultra-mega solar power projects in collaboration with the states for generating electricity are being developed. The viability gap funding is provided by solar energy corporation of India (SECI) for developing grid connected solar power projects. In addition, the rooftop PV and small solar power generation programme (RPSSGP) was commissioned through state nodal agencies, SECI, public sector undertakings and other multi government agencies, private developers etc.

Under the off-grid and decentralized solar PV programme, ministry is providing central financial assistance (CFA) to implementing agencies for deployment of solar PV home lighting systems, solar street lights, solar pumps, stand-alone power plants and other solar applications to meet out the electricity and lighting needs of the individual in the rural areas. Around 6.59 lakhs solar streetlights, 17.89 lakhs home lighting system, 44.04 lakhs solar lantern, 2.37 lakhs solar pump sets, 1.9 lakhs power plants were installed (MNRE 2019). For financial support, Reserve Bank of India has included renewable energy projects under priority sector lending for which bank loans up to ₹15 crore is available to borrowers for renewable energy projects including grid connected solar rooftop systems. For individual households, the loan limit is ₹ 10 lakh per borrower. Ministry of Finance has advised all Public Sector Banks to encourage loan seekers for installing grid connected rooftop solar systems in their home proposal. Multilateral grant from ADB (\$ 5 million), USAID (\$1.8 million) and World Bank (\$ 28.8 million) has also been approved for solar rooftop programme.

*Schemes for solar powered irrigation system:* Application of solar energy in agriculture is important to meet the ambitious target of 100 GW by 2022 in the country. The MNRE had introduced solar pumping programme for irrigation during 2014–15 in coordination with Ministry of Agriculture through state nodal agencies and NABARD. The MNRE provides central financial assistance of 30 % as capital subsidy to the states for installation of solar pumps. State wise subsidy structure is varying and covers 45–60% of capital cost through subsidies. Out of 2.37 lakhs solar pumps installed, Chhattisgarh, Rajasthan and Andhra Pradesh stand in first three positions having a share of 26, 20 and 14% respectively. Other major agricultural states like Uttar Pradesh, Gujarat, Madhya Pradesh also have considerable share in the solar pump installation.

In 2018, new scheme Kisan Urja Suraksha evam Uttham Mahabhiyan (KUSUM) was introduced which is having three provisions: first, 10,000 MW of decentralised ground

mounted grid-connected renewable power plants in the rural areas. Under this, farmers, cooperatives, panchayats, or FPOs can install grid-connected solar power plants having capacity starting from 500 kW and up to 2 MW in their land. Second is installation of 17.50 lakh standalone solar powered agriculture pumps of individual pump capacity up to 7.5 hp. Thirdly, solarisation of existing grid-connected agriculture pumps to make farmers independent of grid supply and also enable them to sell surplus solar power generated to DISCOMs and get extra income. In 2020 budget, the coverage under KUSUM scheme was expanded to 20 lakh farmers in setting up stand-alone solar pumps. Another 15 lakh farmers will be benefitted for solarisation of existing water pump sets. The farmers who have fallow or barren land will be helped to set up solar power generation units enable them to sell surplus power to the solar grid so as to make living out of even barren land.

Similar kind of scheme was started earlier in Karnataka with the name Surya Raitha in which farmers can sell their excess power generated from solar to the grid. According to Shah *et al.* (2014) study Surya Raitha has effect on improving agrarian livelihood, effective use of ground water in terms of conserving energy use in agriculture, providing uninterrupted power supply to farmers. This can be regarded as win-win situation for both farmers and government as farmers will gain an extra income from surplus sale and state will add to their minimum percentage of Renewable Purchase Obligation (RPO). Currently RPOs for each states/UTs set as 7.25, 8.75, 10.50% for three years since 2019–20 (Ministry of Power 2018). Up-scaling grid interactive Solar PV pump at the national level should be in cautious manner as higher Feed-in-Tariff (FiT) may cause farmer to use solar pump exclusively for grid supply and diesel or electric pump for irrigation (Shah *et al.* 2014).

*Solar water pump scheme in Andhra Pradesh:* The state of Andhra Pradesh is bestowed with 300 sunny days in a year with solar insolation of 5.5–6.0 KWh/m<sup>2</sup>, which is next to Rajasthan and Gujarat. The Government of Andhra Pradesh is focusing on the development of solar energy programs including SPV pump in large scale (NREDCAP 2019). The state has launched a major programme for irrigation with SPV pumps during 2014–15. The nodal agency for SPV pump program in the state is New and Renewable Energy Development Corporation of A.P. Ltd (NREDCAP). The Solar PV pumping programme is jointly implemented by NREDCAP along with AP DISCOMs namely Eastern Power Distribution Company of AP Limited (APEPDCL) and Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL), Agricultural Department and Fisheries Department. The beneficiaries are being selected by the concerned departments from the applications for irrigation purpose.

During 2015–16 to 2018–19 NREDCAP had installed 31275 numbers of solar pump sets in the state under central financial assistance scheme. The APEPDCL which covers 5 districts installed 13051 numbers and APSPDCL which covers 8 districts installed 18224 numbers of solar pump

sets. Solar pumps of 3 and 5 Horsepower (hp) capacity are given to the farmers with 30% MNRE contribution and 20–22% beneficiary contribution. The state government share 48–50% of the cost (Table 1).

*Economic feasibility of Solar Photovoltaic pump compared to Diesel pump:* The feasibility of SPV water pump and diesel pump were compared based on the field survey data from Andhra Pradesh. Since the introduction of solar pump sets, there is a sharp reduction in solar photovoltaic costs over the years. Discussion with NREDCAP officials revealed that cost for 5 hp solar pump has been reduced from 4.9 lakhs in 2015–16 to 2.43 lakhs in 2017–18. In our study we assumed two scenarios for capital cost calculation of solar PV, i.e. without subsidy (actual cost of pump ₹ 255000 for 5 hp) and with subsidy (₹ 55000 for 5 hp). The life cycle cost comparison has been done over 20 years which is the economic life of solar panel (Kolhe *et al.* 2002, Odeh *et al.* 2006). Without subsidy, capital cost of solar PV pump per hp is around 8 times higher than that of diesel pump while with subsidy, it is around two times higher than that of diesel pump (Table 2). Operation and maintenance cost of solar is significantly lower than that of diesel in both the scenario accounting more than 100 times. In diesel, fuel cost accounts larger share in operation and maintenance cost. Again, replacement cost for SPV pump system is also lower than that of diesel pump system. The

Table 1 Subsidy pattern for solar photovoltaic pump in Andhra Pradesh

Model/Capacity	Unit cost (₹)	Beneficiary share (₹)	Funding by DISCOMs/ Agricultural/ Fisheries Dept (₹)	MNRE subsidy (₹)
3 hp – AC Model– Submersible Surface Mounted	201920	40000 (20%)	101344 (50%)	60576 (30%)
5 hp – AC Model– Submersible Surface Mounted	254768	55000 (22%)	123338 (48%)	76430 (30%)

Source: NREDCAP, Andhra Pradesh

Table 2 Feasibility of Solar Photovoltaic pump over Diesel Pump (₹ per hp)

Cost component	Without subsidy		With subsidy	
	Solar	Diesel	Solar	Diesel
Capital investment	51000	6060	11110	6060
Operation & maintenance	17860	2249732	17860	2249732
Replacement	13860	21846	13860	21846
Total	82720	2277638	42830	2277638

Source: Authors estimates based on field survey

life cycle cost of solar based system is around 25 times less than that of diesel system without subsidy. Similar to this, Kelly *et al.* (2010) reported that life cycle cost of PV system is 20 times lower than diesel system. Since high capital cost of SPV pumps are taken care by government by providing subsidy, life cycle cost of solar system is even much lower than that of diesel.

Installation of SPV pump system is economically feasible over diesel system in the long run. Higher capital cost of SPV pump is one of the limitations for its widespread adoption at the farm level. Evidence from Andhra Pradesh shows that capital cost of SPV pump system nearly halved over time. State and central government is already providing subsidy to the farmers in order to reduce the burden of higher capital cost. Also, introduction of scheme like KUSUM will be expected to enable the farmers to tide over the higher cost in future. Life cycle cost analysis suggests that, even without subsidy, SPV pump system is economically viable due to its lower operation and maintenance cost as compared to diesel system. The SPV system has a greater role in meeting energy demand in agriculture in context of depleting fossil fuel, increasing fuel cost. Besides that, installation of SPV pump system will also help the states to achieve their solar power target and India to reach 100 GW solar powers by 2022.

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