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Solarisation of Agricultural Water Pumps in Rajasthan

S. S. Kalamkar and H. Sharma

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Foreword

A complex set of factors including global warming, competitive land use and lack of basic infrastructure is creating new challenges for India's vast agrarian population. The ever increasing mismatch between the demand and supply of energy in general and electricity in particular, is posing challenges to farmers located in remote areas and makes them vulnerable to risks, especially the small and marginal farmers. Indian farmers and the national and sub-national government both face several challenges with regard to irrigation. Electricity in India is provided at highly subsidized low tariffs, mostly at flat rates, and this has led to widespread adoption of inefficient pumps. Farmers have little incentive to save either the electricity, which is either free or highly subsidized, or the water being pumped, resulting in a wastage of both. Although the government heavily subsidizes agricultural grid connections; grid electricity in rural India is usually intermittent; fraught with voltage fluctuations; and the waiting time for an initial connection can be quite long. Besides, the power shortages, coal shortages and increasing trade deficit, put food security of nation at the risk. Currently, India has 26 million groundwater pump sets, which run mainly on electricity that is primarily generated in coal-fired power plants; or by diesel generators. Irrigation pumps used in agriculture account for about 25 per cent of India's total electricity use, consuming 85 million tons of coal annually, and 12 per cent of India's total diesel consumption, i.e. more than 4 billion liters of diesel. The scarcity of electricity coupled with the perpetual unreliability of monsoon is forcing farmers to look at alternate fuels such as diesel for running irrigation pump sets. However, the costs of using diesel for powering irrigation pump sets are often beyond the means of small and marginal farmers. Consequently, the lack of water often leads to damaging of the crop, thereby, reducing yields and income. In this scenario, environment-friendly, low-maintenance, solar photovoltaic (SPV) pumping systems provide new possibilities for pumping irrigation water. Solar powered pumps are emerging as an alternative solution to those powered by grid electricity and diesel. Diesel and electric pumps have low capital costs, but their operation depends on the availability of diesel fuel or a reliable supply of electricity. It is estimated that saving of 9.4 billion liters of diesel over the life cycle of solar pumps is possible if 1 million diesel pumps are replaced with Solar Pumps.

The Ministry of New & Renewable Energy (MNRE) has been promoting the Solar-Off Grid Programme since two decades. The programme size has increased many folds with the advent of Solar Mission, giving much impetus to various components of the programme in which solar pumping is one of the major component. Solar Pumping Programme was first started by MNRE in the year 1992. From the year 1992 to 2015, 34941 solar pumps have been installed in the country. This number is minuscule, if we compare this with the total number of pumps in agricultural sector. High costs of solar modules during these years resulted in low penetration of solar pumps. However, in recent times the module costs have started decreasing and are presently hovering around one fourth of the price in those days. As a result, the programme has become more viable and scalable. Therefore, there was a need to study the important issues concerning large scale adoption of solar irrigation pumps, its economics/feasibility and problems in adoption of same. In view of above, the present study was entrusted to us by the Ministry of Agriculture and Farmers Welfare, Government of India. The results of the study provide useful insights to understand the socio-economic profile of adopter households. The study came out with suitable policies.

I am thankful to authors and their research team for putting in a lot of efforts to complete this excellent piece of work. I also thank the Directorate of Economics and Statistics, Ministry of Agriculture, Government of India for the unstinted cooperation and support. I hope this report will be useful for policy makers and researchers.

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Team Leader

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List of Abbreviations

AD	Accelerated Depreciation
Approx.	Approximately
Av.	Average
BEN	Beneficiary farmer households
C.I.	Cropping Intensity
CEEW	Council on Energy, Environment and Water
CFA	Central Financial Assistance
CII	Confederation of Indian Industry
DC	Direct Current
DISCOMs	Distribution Company (In India)
FGD	Focus Group Discussion
GCA	Gross Cropped Area
GCF	Green Climate Fund
GDP	Gross Domestic Product
GIA	Gross Irrigated Area
GOR	Government of Rajasthan
GOI	Government of India
GTNfW	Grassroot Trading Network for Women
GVA	Gross Value Added
GW	Giga Watt
ha	hectare
HH/hh	Household

HP	Horsepower
I.I.	Irrigation Intensity
INR	Indian Rupees
IREDA	Indian Renewable Energy Development Agency
IRENA	The International Renewable Energy Agency
IWMI	International Water Management Institute
JNNSM	Jawaharlal Nehru National Solar Mission
kg	kilograms
KUSUM	Kisan Urja Suraksha Evam Utthan Mahaabhiyan
kW	kilowatt
kWh	kilowatt-hour
kWp	kilowatts peak
LEDS GP	Low Emission Development Strategies Global Partnership
m	meter
mha	Million hectares
MIS	Micro Irrigation System
MNRE	Ministry of New and Renewable Energy
MOA & FW	Ministry of Agriculture & Farmers Welfare
MOP	Ministry of Power
MoWR	Ministry of Water Resources, River Development & Ganga Rejuvenation
MPCE	Monthly Per Capita Expenditure
mt	Metric Tonnes
MW	Megawatt
NABARD	National Bank for Agriculture and Rural Development, India

NCA	Net Cropped Area
NGO	Non Government Organisation
NIA	Net Irrigated Area
NITI	National Institution for Transforming India
NONBEN	Non-beneficiary Farmer Households
NRREP	National Rural and Renewable Energy Programme
NSA	Net Sown Area
NSSO	National Sample Survey Organisation
NSUSER	Non-Solar User Household
NTPC	National Thermal Power Corporation
O&M	Operation & Maintenance
OBC	Other Backward Classes
PPA	Power Purchase Agreement
RBI	Reserve Bank of India
REC	Renewable Energy Certificates
RKVY	Rashtriya Krishi Vikas Yojana
SEWA	Self-Employed Women's Association
SIP	Solr Irrigation Pump
SKY	Surya Shakti Kisan Yojana
SLDC	State Load Dispatch Centre
SPaRC	Solar Power as Remunerative Crop
SPDI	Solar Powered Drip Irrigation
SPIS	Solar Powered Irrigation Systems
SPV	Solar Photo Voltaic
SREA	State Renewable Energy Agencies

ST	Solar Thermal
SWP	Solar water pump
UNFCCC	United Nations Framework Convention on Climate Change
V	Volt
VGF	Viability Gap Funding
Wp	Watt Peak Capacity
Y	Yield

Executive Summary

Solarisation of Agricultural Water Pumps in Rajasthan

S. S. Kalamkar and H. Sharma[1]

India relies heavily on agriculture and irrigation is used in about 49 per cent of India's cultivated area, while the rest relies on monsoon rain. Thus, sound and expanded irrigation is critical for improving crop production and raising yields. For over 50 years until 2010, India ranked first with the largest irrigated area in the world. Irrigation in India today is almost entirely reliant on electric and diesel pumps. Irrigation pumps used in agriculture account for about 25 per cent of India's total electricity use, consuming 85 million tons of coal annually, and 12 per cent of India's total diesel consumption, more than 4 billion liters of diesel. Of the nearly 30 million irrigation pumps in use throughout the country, about 70 per cent run on grid electricity, 30 per cent are powered by diesel, and only 0.4 per cent are solar. The annual fossil fuel use associated with diesel and electric pumps amounts to more than four billion litres of diesel, and 85 million tonnes of coal for electricity generation. The demand for irrigation far exceeds the available pumping capacity. Rapidly growing population, coupled with unreliable precipitation patterns and extreme temperatures wrought by climate change impose additional pressure on agricultural productivity in the country. Therefore, improving access to irrigation, while reducing greenhouse gas emissions, has become our national priority

A complex set of factors including global warming, competitive land use and lack of basic infrastructure is creating new challenges for India's vast agrarian population. The ever increasing mismatch between the demand and supply of energy in general and electricity in particular, is posing challenges to farmers located in remote areas and makes them vulnerable to risks, especially the small and marginal farmers. Indian farmers and the national government both face several challenges with regard to irrigation. Electricity in India is provided at highly subsidized low tariffs, mostly at flat rates, and this has led to widespread adoption of inefficient pumps. Farmers have little incentive to save either the electricity, which is either free or highly subsidized, or the water being pumped, resulting in wasting both. Although the government heavily subsidies agricultural grid connections, grid electricity in rural India is usually intermittent, fraught with voltage fluctuations, and the waiting time for an initial connection can be quite long. Despite the power shortages, coal shortages and increasing trade deficit, put food security of nation at the risk.

The generation of solar energy and irrigation for agriculture could be intricately related to each other. This is because India is a country that is fret with an irregular and ill-spread monsoon. Hence, irrigation is a pre-requisite for sustaining and increasing agricultural output. This is particularly true for the western states of India and especially Gujarat and Rajasthan, where rainfall is

[1] *Agro-Economic Research Centre, Sardar Patel University, Vallabh Vidyanagar, Gujarat*

often scanty, uneven and irregular; whereas perennial rivers are absent. The role of canal irrigation becomes very crucial in this scenario. However, in the absence of sufficient and reliable canal water supply, the only other option that remains with the farmers is that they irrigate their fields with the help of ground water withdrawn through either electricity or diesel-driven pumps. Provision of power for irrigation and other farm operations therefore, is a high priority area for the States. However, providing farmers reliable energy for pumping is as much of a challenge as is making the availability of water, sufficient. The high operational cost of diesel pump sets forces farmers to practice deficit irrigation of crops, considerably reducing their yield as well as income.

Currently, India has 26 million groundwater pump sets, which run mainly on electricity that is primarily generated in coal-fired power plants, or run by diesel generators. Scarcity of electricity coupled with the increasing unreliability of monsoon forces the reliance on costly diesel-based pumping systems for irrigation. The scarcity of electricity coupled with the perpetual unreliability of monsoon is forcing farmers to look at alternate fuels such as diesel for running irrigation pump sets. However, the costs of using diesel for powering irrigation pump sets are often beyond the means of small and marginal farmers. Consequently, the lack of water often leads to damaging of the crop, thereby, reducing yields and income. In this scenario, environment-friendly, low-maintenance, solar photovoltaic (SPV) pumping systems provide new possibilities for pumping irrigation water. Solar powered pumps are emerging as an alternative solution to those powered by grid electricity and diesel. Diesel and electric pumps have low capital costs, but their operation depends on the availability of diesel fuel or a reliable supply of electricity. Saving of 9.4 billion liters of diesel over the life cycle of solar pumps is possible if 1 million diesel pumps are replaced with Solar Pumps. Using solar power for irrigation pumps can cut a carbon footprint of Indian agriculture and bolster the country's role in the war against climate change.

Solar power could be an answer to India's energy woes in irrigated agriculture. Solar power generation on the farm itself through installation of solar PV (photovoltaic) panels; and using it to extract groundwater could just be the solution for the above concerns. Solar pumps come with a user-friendly technology and are economically viable. They are easy to use, require little or no maintenance, and run on near-zero marginal cost. Solar power is more reliable, devoid of voltage fluctuations and available during the convenient day-time. India is blessed with more than 300 sunny days in the year, which is ideal for solar energy generation, aptly supported by promotional policies of the Government of India.

The Ministry of New & Renewable Energy (MNRE) has been promoting the Solar-Off Grid Programme since two decades. The programme size has increased many folds with the advent of Solar Mission, giving much impetus to various components of the programme in which solar pumping is one of the major component. Solar Pumping Programme was first started by MNRE in the year 1992. From 1992 to 2015, 34941 number of solar pumps have been installed in the country. This number is minuscule, if we compare with the pumps in agricultural sector. High costs of solar modules during these years resulted in low penetration of solar pumps. However, in recent times the module costs have started decreasing and are presently hovering around one fourth of the price in those days. As a result, the programme has become more viable and scalable. Therefore, present study was undertaken with aim to study the important issues concerning large scale adoption of solar irrigation pumps, its economics/feasibility and problems in adoption of same.

Literature suggests that application of solar energy in irrigation could have myriad benefits. The primary benefit is that it is 'free'. However, the generating apparatus comes with high initial fixed costs like that of capital equipment, costs of installation, depreciation, interest, protection from theft, vandalism etc. Nevertheless, the marginal costs are indeed 'near zero' (operation, maintenance, repairs). The costs of expansion in irrigated area like that of hose pipes for transporting water across fields is also much lesser compared to operating a diesel pump or getting another electricity connection. Hence, solar pumps could not only provide cheaper irrigation but also expand irrigated area and thus increase the returns on agriculture. It could also extend the farming beyond the kharif season (monsoon); by harnessing ground water and thus aid the diversification of crops. Solarization could also unshackle the farmers from the shortage of electricity supply and its inconvenient timings. They would be able to irrigate not only their own land, but also become irrigation service providers to their neighbouring farmers and also supplementing their own incomes in the process. Solarized pumps could promote conjunctive irrigation by promoting ground water extraction in flood-prone regions like north Bihar, coastal Orissa, north Bengal, Assam and eastern Uttar Pradesh. The government has acted positively in this matter and during the last five years, considerable progress ha s been made in installation of Solar Pumps.

In light of the above, this study attempts to study the status and prospects of solarisation of agricultural pumps in selected districts of Rajasthan. The data were collected from three distinct groups of farmers, viz. farmers who had adopted SIPs with the help of subsidy by the government, farmers who had adopted SIPs without any support in the form of subsidy by the government, and the farmers who had not adopted SIPs. The first group was of 100 sample farmers (25 from each of the four districts under study, i.e. Jaipur, Bikaner, Udaipur and Sriganganagar) who had installed Solar Irrigation Pumps (SIP) with the support of subsidy from the government (beneficiary farmer households). The second group consisted of 5 sample farmers from four districts who had installed SIPs on their own without any support in the form of subsidy (non-beneficiary farmers). The third group included 20 sample farmers (5 each from the four districts under study) who had not yet adopted solarized irrigation (non-adopters). They were still using other conventional fuels for powering their irrigation pumps when they were visited by the researchers. Thus, the total sample consisted of 125 selected farmers (Table 1).

Table 1: Sampling Framework in Rajasthan State

Sr. No.	Selected District	Beneficiary farmers	Non-solar adopter	Non-beneficiary farmers	Total
1	Jaipur	25	05	01	31
2	Bikaner	25	05	01	31
3	Udaipur	25	05	01	31
4	Sriganganagar	25	05	02	32
	Total	100	20	05	125

Policies supporting Solar Power Irrigation in Rajasthan

The state of Rajasthan has 10 per cent of India's land, 5 per cent of its population and only 1 per cent of its water resources, a disadvantage by a factor of the for supply of irrigation water vis-a-vis agriculture area. Acute water shortage, erratic rainfall and recurring droughts in every district have exacerbated the situation. Over 60 per cent of the population depends for livelihood on agriculture or horticulture, often marred by low productivity due to unreliable, inadequate or non availability of irrigation. About 70 per cent irrigation is done through wells or tube-wells energized mainly by grid-power or diesel generators. Approximately 60,000 farmers are waiting for grid-based electricity connections for irrigation. Extension of electric-grid is not feasible in far-flung areas; almost 70 per cent area in the State is classified as desert. Moreover, ground water has deteriorated rapidly in the last two decades. Out of 249 blocks, nearly 200 are in the highly critical zone. Almost 90 per cent of groundwater withdrawal in the State is utilized through flood or furrow-irrigation methods with mere 35 to 45 per cent water-use-efficiency.

Rajasthan is blessed with one of the best solar insolation on earth (6-7 kWh/m2/day) combined with maximum sunny days in a year, about 325, which makes it one of the most attractive destinations for harnessing solar energy for various purposes, especially irrigation. It was thus envisaged that an integrated solar water pump scheme formulated by combining various stand-alone government schemes would be indeed beneficial for the region as well as its farmers. Subsidies available under various programs were clubbed and the State committed to grant the total subsidy up to 86 per cent of the capital cost. The departments of agriculture, finance and energy of the State, and Union government's Ministries for Agriculture (MoA) and New and Renewable Energy (MNRE) worked in tandem along with various stakeholders to make it is seamless and successful project.

Rajasthan has been pioneer in promoting solar water pumps by adopting suitable policies with an aim to increase solar pump coverage in the state. The solar pump scheme for irrigation began in Rajasthan in 2010 – a combination of the Jawaharlal Nehru National Solar Mission (JNNSM), Rashtriya Krishi Vikas Yojana (RKVY), the water harvesting structure (WHS) scheme under the National

Horticulture Mission (NHM), and various other State resources. Under the scheme, farmers are provided with subsidies from RKVY and the Ministry of New and Renewable Energy (MNRE). In the inception year, a subsidy figure of 86% was arrived at (30% from MNRE and 56% from RKVY), through calculations of a base price for the manufacturing and installation of a solar water pump set. The remaining 14 per cent, equivalent to the cost of just the pump set, was to be paid by the farmer, which would amount to about Rs. 56000-63000. In 2010-11, 50 farmers were targeted, which was scaled up to 500 in 2011-12, and 10,000 in 2012-13, eventually covering all 33 districts of the State. There are three, very transparent eligibility criteria for the subsidy –(1) the farmer should own at least 0.5 Ha of land; (2) the land should have a diggi/farm pond or other water storage structure; (3) drip irrigation system should be installed in a portion of the farm. Progressively, the scheme was amended to include the usage of mini-sprinklers as criteria for areas where land holdings are relatively smaller and diggi construction is unfeasible or impractical. This inclusion widened the scope for the popularization of efficient irrigation methods, increasing the water use efficiency in many regions significantly. On the other hand, the subsidy figure was reduced from 86 per cent to 70 per cent to an even lower 60 per cent over the years, and this reduction in the subsidy amount is presently the major cause for farmers backing out from the scheme. Farmers who already have electric connections for irrigation shall be provided with a smaller figure of subsidy, amounting to about 30% of the total cost of the solar pump set. This calls for a study of the efficacy of the scheme and a detailed evaluation of the impact that these solar water pumps have actually had on farmers already using them, to enable us to ascertain why we should be moving towards this green, efficient, cheap, and emission-free energy source, and/or explaining how the scheme may be further improved for a much wider acceptance and preference among those that require such alternative solutions desperately.

In the year 2008-09, Government of Rajasthan had started scheme of 100 per cent subsidy on solar water pump for government farm then after in 2010-11, pilot project was started and covered only 6 districts to installed solar water pump. To harness the vast amount of energy, the Rajasthan government subsidized 86 percent solar-powered irrigation in 2011-12 and introduced 3 HP DC submersible pumps. MNRE and the Ministry of Agriculture through the financial assistance of the state government had supported. Jawaharlal Nehru National Solar Mission (JNNSM) provides 30 percent of the state government, Rashtriya Krishi Vikas Yojana (RKVY) and the Ministry of New and Renewable Energy offers a 56 per cent subsidy. The solar water pump scheme was scaled up from a mere target of 50 in 2010-11 to 500 (900 per cent increase) in 2011-12; to 2,200 (over 340 per cent increase) for 2012-13; and, to 10,000 (354 per cent increase) for 2013-14. Implementation at large scale was initiated in year 2011-12 when out of 33 districts, 14 districts were covered. Next year i.e. 2012-13 the scheme covered all the 33 districts in the State. In the year 2014-15, all 33 districts were also included, but this time only 2900 solar water pump was kept in the target as the subsidy rate had been reduced, but still achieved a lot of achievement and 242 percent more solar pumps installed than targeted. The good achievement in the next year 2015-16 and 31 percent more installed than the targeted solar pump.

After year 2013-14, Rajasthan has also begun targeting high ROI beneficiaries by prioritizing farmers without electric connections. The state has three subsidy slabs—75 per cent for those willing to give up their place in the queue for electric connections, 60 per cent for farmers without an electric connection, and only the 30 per cent MNRE subsidy for those unwilling to give up their electric connection/place in the queue.

Despite water scarcity, Rajasthan is actively pushing for solar pumps. Its horticulture department provides 86 per cent subsidy on pumps, while the rest is borne by the farmer (Table 2). Government of Rajasthan brought a new momentum in the space of solar irrigation pumps by introducing 3 HP DC submersible pumps in an 86 percent subsidy scheme launched in 2011-12. There was also a 2 HP DC submersible pump option, but there have been few takers for it. The initial estimates of costs at the Rajasthan level 3 were Rs.6.16 lakh for 3 HP pump and almost Rs. 18-20 lakh for a 10 HP pump. Government of Rajasthan's aggressive policy of subsidizing solar pumps is helping to increase the numbers but there is some evidence that the current subsidy is discouraging cost reduction. Farmers are viewing solar pumps as an all purpose solution to their energy needs and government has came out the suitable policy towards same (Table 3). The top five districts having highest coverage of solar pumps are Bikaner, Jaipur, Sri Ganganagar, Hanumangarh and Sikar.

Table 2: Achievements of Solar Irrigation Pump in Rajasthan

Year	Project	No. of District Covered	Target	Achieve-ment	Pump Capacity (WP)	Subsidy (%)	Funding Source
2008-09	Government Farms	7	14	14	1800	100	RKVY
2010-11	Pilot Project	6	50	34	2200/ 3000	86	JNNSM, RKVY
2011-12	First major jump	14	500	1649	2200/ 3000	86	JNNSM, RKVY
2012-13	Second major jump	33	2200	4280	2200/ 3000	86	JNNSM, RKVY State
2013-14	Third major jump	33	10000	10000	2200/ 3000	86	JNNSM, RKVY, State
2014-15	fourth major jump	33	2900	9919	2200/ 3000	30, 60, 75	JNNSM, NCEF, STATE
2015-16	Fifth major jump	33	4702	6170	2200/ 3000	30,60, 75	JNNSM, NCEF, STATE
2016-17	Six major jump	33	7500	n.a.	n.a.	30,60, 75	JNNSM, NCEF, STATE
2017-18	major jump	33	500	n.a.	n.a.	50, 55, 65, 70	JNNSM, NCEF, STATE
2018-19	major jump	33	7500	n.a.	n.a.	50, 55, 65, 70	JNNSM, NCEF, STATE

Note: n.a. Not available.

The solar pump subsidy was only available to farmers who had farm ponds (diggi), did horticulture in at least 0.5 hectare (ha) land and used drip irrigation. The farmer also had to own a minimum of 0.5 ha of land. Further the farmers who owned up to 2 ha of land could apply for 2200 Wp pump and those who had more than 2 ha of land could apply for 3000 Wp pump. The eligibility criterion for solar power pump has been changing every year.

Table 3: Base Rate for SPV Solar Pump Project in Rajasthan (2017-18 and 2018-19)

Sr. No.	Details	DC/ AC Mounting	Head (mtr.)	Base Rate (in Rs. Per set)			
				3 Hp	5 Hp	7.5 Hp	10 Hp
1	2	3	4	5	6	7	8
1	SPV Surface pump	DC Static	20	236250	0	0	0
2		AC Static	20	230492	307999	0	0
3	SPV submersible pump	DC Static	20	252266	344000	509839	650090
4		AC Static	20	230265	306390	465560	593250
5	Additional Cost	Head Over 20 m	50	5412	5412	5412	5412
6			75	9020	9020	9020	9020
7			100	12000	12000	12000	12000
7		Manual Tracker		2706	2706	2706	2706
8		Auto Tracker		8118	8118	8118	8118
9	SPV Domestic Lighting System 37 Wp/ 40 Ah Battery / 9 W x 2 fixture			4681	4681	4681	4681
10	Fencing			6765	9020	11275	13530

Source: GOR, Jaipur.

Farmers have to apply to the Horticulture department along with a demand draft for Rs.10000, land ownership record, a tri-partite agreement among the farmer, preferred empanelled supplier and the horticulture department, a quotation from the selected empanelled firm, and a technical drawing of the structure. Once all the applications are collected at Tehsil level, these are verified for compliance with the eligibility criteria. If the applications are more than the quota, a lottery is conducted in the presence of District Collector. A seniority/waiting list is created. If a farmer's name features in the lottery list, he/she has to deposit his 14 percent share minus Rs.10000 with the select firm. Based on the confirmation of the receipt of farmer's share work orders are issued by the Horticulture Department of the state government.

Findings from Field Survey Data

- Data were collected from 125 sample households comprised of 100 households those who have installed solar irrigation pump with support of subsidy (beneficiary farmer household), 5 sample households who have installed solarizied irrigation pump on their own (without any subsidy non-beneficiary farmer household) and 20 sample households who have not yet got subsidy nor installed solar irrigation pumps on their farm (non adopters-control group).
- It was observed that except few respondents from beneficiary category, all other selected households from all groups (beneficiary, non-beneficiary and non-adopter category respondents) were male. This indicates farming decisions

and adoption of new technology on farm related decision were taken by the male, thus dominance of male could be seen despite of the fact that female contribution is highly significant in the farming and dairying.

- The average age of all the respondents of selected respondents was around 50 years while average family size of household was relatively larger in case of beneficiary households (6.91 person), than non-beneficiary and non adopters households (5.4 and 5.3 members respectively). Out of total adult family members in the family, more than 70 per cent were actively participating in the farming.
- The education status of selected respondents indicate the average education level up to 8 years, while non beneficiary households were relatively more educated (around 11 years) than other groups. The figures on average level of education of respondents indicate that lower level of education among selected respondents.
- The religion-wise distribution of selected respondents indicate that out of total selected households, about 94 per cent households belongs to hindu religion while remaining were from Muslim and Sikh religions. Among the three groups of respondents, same trend was observed except relative high share of Sikh religion among non-beneficiary households as about one fifth of non-beneficiary households were from Sikh religion. In case of social caste distribution, on an average, dominance of other backward class category households was observed followed by households from general category and scheduled caste category. The other backward caste followed by open category comprised beneficiary household group, while opposite composition of households was observed in case of non beneficiary households. Besides, Open and OBC category households, scheduled caste households were also among selected households under non-adopters group. Thus, at overall level, backward class category respondent dominated the sample followed by general category and then scheduled caste, while very meager share was of Scheduled Tribe respondents
- The details on economic characteristics of the selected households indicate that more than 90 per cent of total beneficiary and non-adopter households were having farming as their principal occupation while three fourth of total non-beneficiary households had service as their principal occupation. Animal husbandry and dairying followed by agriculture labour was subsidiary occupation of beneficiary and non-adopters, while crop cultivation followed by agriculture labour was subsidiary occupation of non-beneficiary households. The main occupation of the selected households was agriculture comprised of cultivation of land as a farmer along with supportive allied activity of animal husbandry and dairying.
- The average years of farming experience of the respondents was around 29 years, which shows that most of the respondents were in farming business since their young age. The income level of both beneficiary and non-beneficiary households as around 98 percent and 50 per cent non-adopter of households are categorized above poverty line. The trend was observed in case of dwelling

structure where about 98 per cent households of beneficiary member have pucca structure while in non- beneficiary and non adopter category only 60 per cent and 45 per cent household has pacca house structure.

- On an average, land holding size of selected beneficiary households was 1.21 ha categorizing them as small land holders' group, while non-adopters had much lesser land holing of 0.91 ha as marginal land holders, While corresponding figure for non-beneficiary households was 6.10 ha, indicating larger size of holdings as medium size land holders. Moreover, we also found that the who were having solar water pump had taken land on leasing-in while none of them leasing out the land. Non-beneficiary farmer households had taken larger size of land on leased-in (0.75 hectare) as compared to beneficiary households (0.01 ha), this might be because the non beneficiary farmers are comparatively wealthy farmers and have more capital than the other two groups.
- Out of the total operational land holdings with selected households, almost all land under operation of non-beneficiary household was under irrigation, while in case of beneficiary households, about 80 per cent land was under irrigation coverage. The non-adopter households could irrigated their three fifth of total operational holdings with available sources of irrigation. Thus, despite of having the large size of land holdings, non-beneficiary had sufficient water and sources of irrigation to irrigate the crop. Due to such sound background of having all land coverage with irrigation, the assured returns must have pushed the farmers to invest in installation of solar pumps on their farm with their own expenditure, i.e. without any subsidy.
- After solarisation, changes in cropped and irrigated area were observed in case of selected beneficiary households. Area under cropped as well as irrigated area was increased by around 17 percent, despite of same cropping intensity was constant. The share of area sown to gross cropped area during kharif and summer season has shown meager increase. Area under irrigation by type of irrigation method has shown some changes after solarisation as compared to situation prevailed during pre-solarisation period of beneficiary farms. The area irrigated by flood method of irrigation has declined by about 30 per cent which must have due to adoption of sprinker and drip method of irrigations. The area under rainfed condition has also shown declined trend. Overall the total gross cropped area has increased about 17 per cent after solarisation. The transformational impact of irrigation is evident in solar water pump Scheme, where solar pumps were used to expand the coverage of the scheme from 40 to 50 hectares. More than 50 per cent beneficiary household area transformation from gravity-fed irrigation to sprinkler and drip irrigation with additional solar booster pumps have been deployed to pump water into a storage reservoir.
- The changes in net sown area, gross cropped area and cropping intensity of sample non-beneficiary households indicate that after solarisation, after solarisation, significant growth in gross irrigated area and gross cropped area was recorded, that to increase in irrigated area was more than cropped area. Due to which cropping intensity has changed by around 13 per cent points

after solarisation as compared to before solarisation year. The increase in area under irrigation may be due to assured and quality power supply through solar during convenient timings during day time for irrigation.

- In case of non-beneficiary households, area irrigated by flood method of irrigation has declined by about 28 per cent. Also rainfed area has declined by 43 per cent after solarisation. While area irrigated through the use of micro irrigation equipments such as sprinkler and drip has recorded significant increase. Overall the total gross cropped area has increased about by 26.04 per cent after solarisation. As increase in gross cropped area was higher for non-beneficiary than the beneficiary may to due to the fact that non beneficiary farmers are economically strong and diesel pump owners, had shifted to solar pumps to avail benefits such as zero operational costs, ease of use throughout the day and cost savings on diesel.
- In case of non-adopter, cropping intensify was 166 per cent mainly because of more than four fifth of total cropped area having irrigation coverage.
- Before solarisation of irrigation pumps, out of selected solar water pumps users, only 37 percent of beneficiary household had grid connection facility available on their farm while all the non-beneficiary farmers had grid connectivity to their irrigation pumps on farm. In case of rate charged towards use of electricity, almost two third pumps of beneficiary households were metered and remaining were charge in flat rate basis. While in case of non-beneficiary households, all irrigation pump had meter and were charged on meter use basis. Average irrigation expenditure per household per year was estimated to be between Rs. 3200-3500/-. Despite of the fact that agriculture require more hours of electricity supply to carry out agricultural operations (irrigation, threshing, etc), selected respondents households reported that they used to get hardly 6 hours of power supply in a day, which indicate the pressure built on respondents to make use of new technology of solar energy.
- The selected households had multiple sources of water available for irrigation and also used multiple method of irrigations such drip and sprinkler irrigation. The average water depth was estimated to around 200 feet and water was lifted through making use of diesel and electric pumps. The average distance of canal/river water was about 1 kms from the field. Around two third of the selected households had water storage facility on the farm, while no one has made attempt to recharge the groundwater through adoption of any innovative technique or practice. The main problem was observed with the availability of electricity to farm connection which is hardly made available though grid for eight hours in a day that to at inconvenient times, irrespective of season. Thus, in order to irrigate the crop during day time with uninterrupted power supply, the solar irrigation pump is the most suitable option available which selected households have installed on their farm.
- Changes in cropping pattern of sample beneficiary households indicate that due to about 17 per cent increase in gross cropped area after solarisation, area under fruits and vegetables, wheat and maize crop has significantly increased during rabi and summer season. The change in cropping pattern was

relatively in favor of irrigated crops. During kharif season, major crops grown were paddy, maize, groundnut, cotton, soybean while wheat and gram were sown during rabi season. Due to availability of irrigation facility, crops such as maize, moong, vegetables and fruits were grown during summer season.

- Most of the households, who were previously growing little more than subsistence crops of bajra, maize, soybean in kharif and wheat, gram and mustard in rabi, could grow feed crops, earn income and benefit. After solarisation, the numbers of crops grown have also increased. During survey, respondents have reported that farm yields have increased to an average of 2 to 4 quintal per hectare. Irrigation enables farmers to grow three crops per annum and rotate crops to grow a diversity of nutritious and cash crops, such as vegetables and fruit crops and flowers also. This indicates that solarisation helps to increase the area under cultivation during the summer season or under the perennial with commercial crops like vegetables.
- While in case of non-beneficiary households, kharif season was the major season. Crops were grown in all three seasons (kharif, rabi and summer) before solarisation as well because of the fact that they are economically sound and thus can make full use of water through diesel and electricity pump. While after solarisation, the share in area of traditional crops such as jowar, moong, moth, guar and bajra has decreased and area under other horticulture crops like vegetables and fruits crops has increased. After solarisation, gross cropped area of the non-beneficiary households has increased by 25 percent. It was also observed that after solarisation, the numbers of crops grown during year has been increased, as seen in case of beneficiary households. In kharif season, the major crops grown were cotton, soybean and bajra while during rabi season, wheat, gram and rapeseed & mustard crops were grown. The fodder and vegetables crops were grown by the non beneficiary farmers during summer season. The increase in share of the area under commercial crops, fruits and vegetables and perennial crops indicate the benefit of solar energy availability with selected non beneficiary households for irrigating the crops.
- In case of non-adopters (control group) households, major crops grown during Kharif season were bajra, moong, moth, groundnut, guar and other minor crops while wheat, gram, rapeseed and mustard were major crops grown during rabi season. It was very pleasant to note here is that significant area during summer season was allotted under fodder crops indicates the scarcity of fodder in the selected area. The distribution of area under irrigation by type of irrigation method used by all non adopter farmers adopted flood irrigation system.
- The details on possession of irrigation pumps of selected households indicate that Solar pumps essentially are a collection of solar PV panels, AC or DC pumps and the associated electronics that have been optimized for high efficiency operations. All non-beneficiary households have used submersible DC pumps while in case of beneficiary households, 54 per cent households had DC pumps on their farm. As a technology, while AC technology is now catching up, DC technology is considered to be more suitable given the wider operating range and higher efficiencies reported by beneficiary.

- The details about the installation of solar panels and availability of power with selected beneficiary and non-beneficiary households indicate that land area covered by the solar pump installed was around 4.8 ha in case of beneficiary households while same was 4.4 ha in case of non-beneficiary households. All the selected households had solar panels on farm. About two third of installed solar PV panels were with automatic rotation system while remaining were with manually rotation system. On an average 4-6 poles are were installed with mean number of stand poles between 12-15, having average size of panel of 3 feet by 5 feet. Mean area covered by the each stand pole was around 5 feet by 5 feet. No installed solar panel have meter to record the power generated and used. About 37 percent solar plants of beneficiary households and 5 percent of non beneficiary households were connected to grid. None of farmers has installed the solar power storage cell. The solar power generated mostly been sued for agriculture purpose while few of beneficiary households used for household purposes as well. None of the selected households had use solar power to sell irrigation water to neighboring farmer, thus no additional income through sale of water was reported.
- Rajasthan comprises about 10.4 percent of India's landmass in which 60 per cent area are is desert and 5.5 percent of the total population but has only one percent of the nation's water resources. Groundwater is either saline or declining at a fast rate. The grid power supply available for only 5 to 6 hour for form field and its very expensive. In such a scenario, selected households were asked about the reasons for adoption of solar power generation unit on their farm. The selected households have cited multiple reasons for choosing solar on their farm.
- About two third of beneficiary households mentioned that to avoid hassle of irrigating crop irrigation during night hours was the major reason for adoption of solar irrigation pump. More than 50 percent of selected households strongly reported that they adopted the solar water pump due to costly diesel, followed by non-availability of electricity connection, unreliability of electricity supply/ inconvenient grid supply timings, high electric bill. Few of the beneficiary households wanted to try renewable technology as it is environment-friendly while few wanted to take advantage of subsidy being offered for installation of solar pumps on farm. While in case of non-beneficiary households, major three reasons quoted were saving electric bill followed by costly to run electric pumps and inconvenient time of electric supply/costly diesel. Thus, findings about the reasons for adoption of the solar water irrigation pump under different category suggests that high cost of electricity along with inconvenient hours of electricity supply and high cost of diesel has pushed the farmers to adopt pollution free power generation thorugh solar.
- Government of Rajasthan brought a new momentum in the space of solar irrigation pumps by introducing 3 HP DC submersible pumps with 86 percent subsidy scheme launched in 2011-12. There was also a 2 HP DC submersible pump option, but there have been few takers for it. The State government leveraged central financial assistance coming from MNRE and Agriculture Ministry for the same. The state government provides 56 percent subsidy

under Rashtriya Krishi Vikas Yojana (RKVY) and the New and Renewable Energy Ministry of Government of India provides the balance 30 percent under Jawaharlal Nehru National Solar Mission (JNNSM). The project was implemented through the Horticulture Society under the Agriculture department of Government of Rajasthan. The beneficiaries had to pay 30 to 32 per cent of the system cost. The agriculture department of Rajasthan provided 68-72 per cent of total cost as subsidy through JNNMS and RKVY scheme. The cost of 5 HP solar pumps was about 30 to 33 per cent higher than 3 HP solar. It may be noted that, the major sources of institutional credit was commercial banks followed by cooperative banks, for both beneficiary and non-beneficiary farmers. About 50 to 80 per cent amount had taken loan by beneficiary while corresponding figure for non beneficiary household was 45 to 55 with interest rate ranges between to 7 per cent. The cost of documentation incurred by selected households was about Rs. 1111/- per households while in case of non beneficiary households same was Rs. 1848/-. The expenditure of Rs. 1584/- was incurred towards installation by the beneficiary while corresponding figure for non-beneficiary household was Rs. 1848/-.

- The process of installation of solar pump took almost 6-7 days while average number of visits of representative of agency was more in case of non-beneficiary (about 5 visits) compared to beneficiary households (about 3 visits). The company-wise distribution of solar panels indicates that Jain Irrigation Company had supplied major share of pumps (as solar pump supplier) in both groups. The other major suppliers were Shakti, Lubi, Tata Solar, Waaree, etc. More than 95 per cent of selected respondents had received training/ demonstration about operating solar pump from solar water pump through supplier agency while about more than 98 per cent of beneficiary and non beneficiary household had satisfied with support services provided by agency and quality of solar panels. More than 90 per cent responded are insured the solar pump.
- Government of Rajasthan had many times improved the policy and eligibility criteria of receiving subsidy on solar water pump. The solar pump subsidy was only available to the farmers who fulfill the basic criteria fixed for same such as farmer should have farm ponds (diggi), had land at least 0.5 hectare (ha) land and availability of micro irrigation instruments or ready to take solar with micro irrigation and no grid connection. It can be seen in table 3.19 that more than 80 per cent beneficiary had fulfilled these conditions.
- Storage tanks in different sizes are used to store the water that is pumped. The water that is stored in the tank can be used for irrigation when needed. There are different types of agricultural irrigation method used.. More than 90 percent beneficiary households had used solar with MIS while 100 per cent non-beneficiary households have used MIS and Solar pump without subsidy. All solar water pump users advise to others to adopt solarisation of irrigation pumps with the information of the government policies in the solar irrigation sector, particularly solar subsidies regard and economic benefit of solar irrigation pump.

- To supplement the intermittent and inadequate canal supply, many farmers have also dug tubewells. It can be seen in table that the depth of water level is was around 210 feet in case of beneficiary households during both the periods, while same has slightly increased to about 235 feet in case of non-beneficiary users. The depth of groundwater was stagnant possibly may be due to farm pond as recharger for ground water on beneficiary farm.
- Diesel was used as fuel to drive the water pump during rabi season. On an average about 4 litre of diesel was used per bigha watering of land by the selected respondents and approximate expenditure of repair of diesel pump was estimated to be between Rs. 8500-10000/- was incurred. Some of the beneficiary and non beneficiary farmers had to incurred expenditure to the tune of amount of Rs. 4581-/ and Rs. 6847/- towards repair of their electric pumps. On an average, about more than two hours time was spent on procuring diesel/petrol per week to fetch diesel from about 10-12 kms away from village/farm. But after solarisation, not only large reduction in operational and maintenance cost was observed but also complete removal of reliance on fuel has been observed. It was surprising to note here is that no selected respondent have commented on the excessive water withdrawal for long run as well as on steps taken to curtail water withdrawal for self use as no one had reported sale of water. Besides, no efforts were made by anyone respondents to recharge water.
- About 20 to 25 per cent respondent have realized that the crop productivity have increased and about 40 to 45 per cent respondent have adopted the crop diversity after adoption of solar which help them to increase the numbers of crops in a season. They are now growing commercial crops and also reported that the after solar, the productivity of traditional crop increased. None of farmers of beneficiary and non-beneficiary has sold the water but the exchange and borrow water from each other. Due to increase in availability of power during convenient timings, farmers have diversified their cropping pattern towards high value crops as well as some of them have noticed positive increase in productivity of crops grown.
- Solar panels are generally self cleaning, but in particularly dry areas or where panel tilt is minimal, dust and other substances such as bird droppings can build up over time and impact on the amount electricity generated by a module. Grime and bird poop doesn't need to cover an entire panel to have an effect. This is where cleaning solar panels may have to be done. As solar electricity generation is depend on the exposure of solar panel surface area which may over time get dusty and with other substances such as bird droppings can build up over time may impact on the amount electricity generated by a module. Therefore, regular cleaning of solar panels need to be carried out by the farmers. It was observed that different time schedules are adopted by the households for cleaning of solar panel surface and no similar pattern observed. Two third of beneficiary households and one fourth of non-beneficiary households has been cleaning the same twice in a week, half of the non-beneficiary households and one tenth of beneficiary households clean solar panel once in a week. The approximate time for cleaning the solar panel

surface is estimated to about 20-22 minutes. On average, 45 per cent of the solar panels users clean the panels in once a week and 25 percent of the respondents are cleaned twice in a week. The estimated time for the cleaning of solar panels is 28 to 30 minutes.

- The experiences with solarized irrigation of selected households indicate that ease of opinion and maintenance along with convenience time for irrigation with output of water were major positive aspect of solarisation. The other supportive factors of solarisations noted by the selected households were reduction in use of fertilizers, use of micro-irrigation method.
- More than 90 per cent beneficiary and non beneficiary farmers had great experience of solar i.e. ease of operation, ease to maintenance, less labour and supervision required and the timing for irrigation are very convenience, used of fertilizer decrease with increase of micro irrigation after solarisation. Some of the selected respondents using electric pumps were dissatisfied with use of electric pump due to its unreliable power supply, depleting water tables and high expenditure on diesel.
- Solar pumping systems allow vital water resources to be accessed in remote rural locations. Solar water pumps require no fuel and minimal maintenance. All selected respondents reported the advantage of no cost of fuel followed by no maintenance cost and quality of power supply. The other advantages reported by respondents were no harassment of irrigating crop in night, saving on labour cost, almost no monthly cost of operation and no harassment of fetching diesel.
- Most of the selected households mentioned the two prominent disadvantages of solar panels such as it require a huge initial investment and only can be used during sunny days. As installation of solar panel requires usually around Rs. 4.5 lakhs to 6.5 lakhs depending on the size of the panel and horse power of solar panel. This is the main reason that discourages people to install solar panels. Unfortunately, sun doesn't shine 24 hours, and solar power relies on it. Since solar electricity storage is not yet fully developed, so it can be used during sunny days.
- About 79 per cent of farmers had given first preference to lack of fund for non adopting water pump followed by hesitation to invest/ lack of confidence/ risk averse (66.05%), less land, unviable for investment on solar pump (57.40%), opposition from family members (56.55%). unviable for investment on solar pump, Subsidy is insufficient, ground water is at great depth, unsuitable for solar and came to know about it much later.
- About 70 per cent non-adopter HH has suggested that the criteria of subsidy should be relaxed and need to increase subsidy rate. About 40 per cent respondents had suggested that the portability of grid connectivity to solar irrigation pumps should be made and awareness about solar irrigation pump Scheme need to be increased.

Policy Implications:

- Both the central and state governments have policies and incentives place to grow the use of solar pumps in the irrigation sector. However there is a felt need for raising awareness among farming community and for putting project delivery mechanism in place.
- Presently, cost of solar pump appears to be high for individual farmer. Large scale adoption and production will lead to cost cutting. Community based projects can reach out to marginal farmers and other low-income group individuals.
- Feasible costing and assistance from state/ central government will encourage more farmers to opt for the technology. With partnership of state energy departments, Vidyut Vitaran Nigams, and private partners, technology can be disseminated at large scale.
- Portability of grid connectivity to solar irrigation pumps should be made and awareness about solar irrigation pump scheme need to be increased.
- Majority of the beneficiary farmers suggested that solarized irrigation could be expanded if the SIPs were made more user-friendly in terms of their requirement of space, technical features as well as financing; including that for insurance.
- Solar cooperative need to established and individual SIPs in group under cooperative structure can be connected with the grid in order to evacuate the surplus power generated there from into the grid, it could not only prevent the wastage of solar power but also provide the farmers with a supplementary source of income by way of selling solar power.
- The farmers were also in need of awareness about insurance and its coverage against risks of damage of SIPs or theft of their solar panels.
- Also, the procedure for availing subsidy should be simplified and the criteria for eligibility should be relaxed so as to include more farmers as beneficiaries
- Clearly, more needs to be done in the direction of convincing the farmers about the advantages of solarized irrigation per se, so that they would come forward to adopt in large numbers, regardless of the subsidy on offer or the initial capital costs thereof.
- There is a need of innovative policies for governing ground water level in a sustainable way. There is a need for metering agriculture water use and total water extraction by farmers using solar, electric or diesel pump.

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