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Solarisation of Agricultural Water Pumps in Western India

(Consolidated Report)

S. S. Kalamkar, Sonal Bhatt and H. Sharma

Study Coordinated by
Agro-Economic Research Centre,
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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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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
CII	Confederation of Indian Industry
DC	Direct Current
DGVCL	Dakshin Gujarat Vij Company Limited
DISCOMs	Distribution Company (In India)
DSUUSM	Dhundi Saur Urja Utpadak Sahakari Mandali
FGD	Focus Group Discussion
GCA	Gross Cropped Area
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEB	Gujarat Electricity Board
GEDA	Gujarat Energy Development Agency
GETCO	Gujarat Energy Transmission Corporation Limited
GGRC	Gujarat Green Revolution Company Limited
GIA	Gross Irrigated Area
GOG	Government of Gujarat
GOI	Government of India
GSECL	Gujarat State Electricity Corporation Limited

GTNfW	Grassroot Trading Network for Women
GUVNL	Gujarat Urja Vikas Nigam Ltd.
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
LRK	Little Rann of Kutch
m	meter
MGVCL	Madhya Gujarat Vij Company Limited
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
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
PGVCL	Paschim Gujarat Vij Company Limited
PPA	Power Purchase Agreement
RBI	Reserve Bank of India
REC	Renewable Energy Certificates
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
UGVCL	Uttar Gujarat Vij Company Limited
UNFCCC	United Nations Framework Convention on Climate Change
V	Volt
VGF	Viability Gap Funding
Wp	Watt Peak Capacity
Y	Yield

Solarisation of Agricultural Water Pumps in Western India

S. S. Kalamkar, Sonal Bhatt and H. Sharma[1]

Backdrop:

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 governments 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 the 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. 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 often scanty, uneven and irregular; whereas perennial rivers are few. 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. Currently, India uses 12 million grid-based (electric) and 9 million diesel irrigation pump sets. However, 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. 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.

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

Scarcity of electricity coupled with the increasing unreliability of monsoon forces the reliance on costly diesel-based pumping systems for irrigation. Hence, the farmers look for alternative 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 of solar pumps have been installed in the country. This number is minuscule, if we compare 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, 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 supplement 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 of solarisation of agricultural pumps in Western India covering the states of Gujarat and 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 200 sample farmers who had installed Solar Irrigation Pumps (SIP) with the support of subsidy from the government (beneficiary farmer households). The second group consisted of 9 sample farmers who had installed SIPs on their own without any support in the form of subsidy (non-beneficiary farmers). The third group included 40 sample farmers 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 249 selected farmers (Table 1).

Table 1: Selected States and Number of Sample Households in Western India

Sr. No.	State	Beneficiary Farmers	Non-solar adopter	Non-beneficiary farmers	Total
1	Gujarat	100	20	04	124
2	Rajasthan	100	20	05	125
	Total	200	40	09	249

Case study on first ever cooperative formed by farmers for decentralized solar power generation and usage in irrigation i.e. Dhundi Saur Urja Utpadak Sahakari Mandali or DSUUSM registered in May 2016 by six farmers of Dhundi village of Kheda district of Gujarat State was studied and discussed in this report.

Policies Supporting Solar-Powered Irrigation in India

Among the various renewable energy resources, solar energy potential is the highest in the country. In most parts of India, clear sunny weather is experienced 250 to 300 days a year. The annual radiation varies from 1600 to

2200 kWh/m2, which is comparable with radiation received in the tropical and sub-tropical regions. The equivalent energy potential is about 6,000 million GWh of energy per year.[2] The National Action Plan on Climate Change also points out: "India is a tropical country, where sunshine is available for longer hours per day and in great intensity. Solar energy, therefore, has great potential as future energy source. It also has the advantage of permitting the decentralized distribution of energy, thereby empowering people at the grassroots level". With the objective to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible Government of India launched National Solar Mission. The National Tariff Policy was amended in January 2011 to prescribe solar-specific RPO be increased from a minimum of 0.25 per cent in 2012 to 3 per cent by 2022. CERC and SERCs have issued various regulations including solar RPOs, REC framework, tariff, grid connectivity, forecasting etc. for promoting solar energy. Many States have come up with up their own Solar Policy and among all the states, Rajasthan was at forefront to adopt the supportive policy for solar power adoption.

In view of the ongoing efforts of Central and State Governments and various agencies for promoting solar energy, Ministry of New and Renewable Energy has undertaken an exercise to track and analyze the issues in fulfillment of Solar Power Purchase Obligation and implementation of Solar REC framework in India. This would help various stakeholders to understand the challenges and opportunities in the development of solar power. It would also include monitoring of Solar RPO compliance; analyzing key issues related to the regulatory framework for solar in various states of India.

The Government of India has set ambitious targets for expanding the country's renewable energy generating capacity, and in 2010 launched the Jawaharlal Nehru National (JNN) Solar Mission. In 2014, as part of this mission, the Ministry of New and Renewable Energy (MNRE) outlined the Solar Pumping Programme for Irrigation and Drinking Water, which sought to promote the adoption of solar pumps over five years (MNRE, 2014b). Implementation of the programme involved two financing schemes.

- First, farmers received a central financial assistance (CFA) of 30 per cent of the benchmark cost of the pump, and possible additional subsidies at the state level.
- The second, credit-linked scheme, involved 40 per cent capital subsidy from MNRE, 20 per cent beneficiary contribution, and the remaining amount extended as a loan implemented through the National Bank for Agriculture and Rural Development (NABARD) (MNRE, 2014a).

The initial capital subsidy scheme aimed at supporting 100,000 pumps in 2014, and one million by 2020, and the credit-linked scheme through NABARD targeted an additional 10,000 irrigation pumps by 2016. The number of solar pumps in India is increasing, with about 130,000 pumps installed since 2014

[2] https://mnre.gov.in/solar-rpo

when the scheme started, though progress is well below the goals of the subsidy programme (MNRE, 2017a). In March 2017, MNRE closed the NABARD credit-linked subsidy scheme and set modified capital subsidy rates (MNRE, 2017b). It remains to be seen whether the capital subsidy programme will prove effective in encouraging farmers to buy and use solar pumps in the long run. Demand for sustainable irrigation far exceeds current available pumping capacity, and while the Indian government has announced various initiatives to boost deployment of solar irrigation pumps (Figure 2.1), uptake has been slow. The government, to its credit, is making efforts to encourage farmers to install stand-alone solar-powered off-grid pumps to not only meet their irrigation needs but also to provide an extra source of income from selling surplus power to distribution companies (DISCOMs).

Kisan Urja Suraksha Evam Utthaan Mahaabhiyan Scheme (KUSUM)

The start of year 2018 saw the announcement of the new solar water pump scheme *Kisan Urja Suraksha Utthaan Mahaabhiyan* (KUSUM) aimed at the betterment of farmers. Under this arrangement, the central government desires to assist as many farmers as possible to install new and improved solar pumps on their farms. The farmers need not pay a hefty fee for this benefit as it comes with government subsidy. The main aim of this scheme is to provide the farmers with advanced technology to generate power. The solar pumps will not only assist to irrigate the farmers, but will also allow each farmer to generate safe energy. Due to the presence of the energy power grid, the agricultural labors can sell the extra power directly to the government. It attempts to provide them with extra income as well. So, this scheme brings double benefits. The features of the scheme are as follows:

1. *For the betterment of the farmers* – The successful operation of this program will be able to help the farmers not only in meeting their power related requirements, but will also be able to earn some extra cash by selling excess energy.
2. *Construction of plants on infertile lands only* – The government has also announced that it will take initiative to construct plants, which will generate solar power. As per the draft, these plants will only be erected on infertile areas, capable of generating a total of 28, 250 MW power.
3. *Distribution of solar powered pumps* – One of the primary aims of this program is to provide interested farmers with solar pumps. The government states that 17.5 lakh solar powered pumps will be provided to agricultural labors.
4. *Power production on small scale* – Apart from the solar power plants, government will work towards the installation of new solar pumps in farms, which have diesel pumps. The capacity of these pumps will be 720 MW.
5. *Power generation from tube-wells* – The government will also work toward the installation of unique tube-wells. Each of these pumps will be able to generate power of 8250 MW
6. *Sale of excess power* – Apart from distribution, the scheme also provides all farmers with the chance to earn more money by installing the solar pumps. The excess amount of energy that the farmers generate can be sold to the grid.

7. *Duration of the scheme* – Current estimates state that for the successful completion of this elaborate scheme, the central government will have to work for at least 10 years.
8. *Subsidy structure of the scheme* – As per the draft, each farmer will get huge subsidy on new and improved solar powered pumps. The agricultural labors will have to tolerate only 10 per cent of the total expenditure to acquire an install a solar pump. The central government will provide 60 per cent cost while the remaining 30 per cent will be taken care of by bank as credit.
9. *Good for the overall environment* – The increased use of solar power and electricity generated from the solar plants, will lower the level of pupation in the area. Dependence on fossil fuel will go down considerably as well.

The components of the scheme are as follows:

1. *Solar pump distribution* – During the first phase of the program, the power department, in association with other wings of the government will work towards the successful distribution of solar powered pumps.
2. *Construction of solar power factory* – The next component will include the construction of solar power plants, which will have the capacity to produce a significant amount of power.
3. *Setting up tube-wells* – The third component of this scheme deals with the setting up of unique tube-wells, under the watchful eyes of the central government, which will also a certain amount of power.
4. *Modernization of present pumps* – Only production of powers is not the aim of the scheme. The final component of this program deals with the modernization of pumps, which are in use, as of now. Old pumps will be replaced by developed solar pumps.

The scheme was elaborated with additional funding for successful implementation. As per the announcement of this program, the Finance Minister and the Power department announced that it will require around Rs. 48, 000 crores. The allocation of funds will be done in four separate segments.

- During the initial stage that involves the solar pump distribution, the central government will dispatch an amount of Rs. 22,000 crores.
- During the second phase of this program, Rs. 4, 875 crores will be provided by the respective department.
- The third phase, wherein all ordinary pumps will be converted into solar powered pumps, the central government will have to tolerate an expense of Rs. 15, 750 crores.
- Lastly, for the successful completion of the fourth phase, the central government will have to spend Rs. 5000 crores.
- The scheme is not only aimed at providing better benefits and added income for the agricultural labors, but will also lower the level of pollution. As the solar pumps take over electricity driven or diesel pumps, it will provide better utilization of resources.

6.3 Policies supporting Solar Power Irrigation in Gujarat

The Gujarat government encourages solar power generation projects as a means of socio-economic development. Gujarat is rich in solar energy resources with substantial amounts of barren and uncultivable land, solar radiation in the range of 5.5-6 kilowatt-hour (kWh) per square meter per day, an extensive power-grid network and DISCOMS with reasonably good operational efficiency. It has the potential for development of more than 10,000 MW of solar generation capacity. State has decided to promote measures for energy efficiency, adopt efficient management techniques and build capabilities for more energy secure future. Government of Gujarat had decided to take the lead in this regard by framing Solar Power Policy in 2009 which spelt out the development of solar power production targets, financing mechanisms and incentives offered for the same. The policy of purchasing solar power from the small producers by connecting them to the grid has also contributed to boost up the interest of producers and investors in this sector. The Solar Power Policy 2009 had aimed to generate 716 MW of solar power. Allocations of 365 MW of SPV and 351 MW of CSP have already been made to 34 developers. Gujarat Energy Development Agency (GEDA) established by the Government of Gujarat disseminates information on opportunities for the generation of solar energy and plays a catalytic role in the development and promotion of renewable energy technologies in the state. It undertakes on its own or in collaboration with other agencies, programmes of research and development, applications and extension as related to various new and renewable energy sources. GEDA plays a key role in facilitation and implementation of the solar power policy 2009. It facilitates and assists project developers through a number of activities. These include identifying suitable locations for solar projects, preparing a land bank, assessing the connecting infrastructure, arranging right of way and water supply at project locations, obtaining clearances and approvals which fall under the purview of state or local governments etc. Gujarat Solar Power Policy 2015 was framed with an aim to scale up the solar power generation in a sustainable manner.

Gujarat is one of India's most solar-developed states, with its total photovoltaic capacity reaching 1,262 MW by the end of July 2017. Gujarat has been a leader in solar-power generation in India due to its high solar-power potential, availability of vacant land, connectivity, transmission and distribution infrastructure and utilities. The state has commissioned Asia's largest solar park near the village of Charanka in Patan district. The park is generating 2 MW of its total planned capacity of 500 MW, and has been cited as an innovative and environment-friendly project by the Confederation of Indian Industry (CII). The Gujarat government has also tried to encourage urban roof-top solar power generation in the capital city of Gandhinagar. Under the scheme, it is planned to generate 5 MW of solar power by putting solar panels on about 50 state-government owned buildings and 500 private buildings in Gandhinagar. In another innovative project, the government of Gujarat put solar panels along the branch canals of the Narmada river. As part of this scheme, the state has commissioned the 1 MW Canal Solar Power Project on a branch of the Narmada Canal near the village of Chandrasan in Mehsana district. Not only is this project expected to generate solar power, but also prevent about 90,000 liters of canal water from evaporating. In addition to the existing solar power policy, the Gujarat government has also come up with solar-wind hybrid policy.

Government has successfully implemented pilot projects of solar power generation which is gaining traction at several grassroots-level interventions. Grassroot Trading Network for Women (GTNfW), an initiative by Self-Employed Women's Association (SEWA), is in the process of implementing one such project by setting up a unique solar park of 2.7-megawatt (MW) capacity. The project has roped in saltpan workers from Little Rann of Kutch (LRK) for solar power generation. Around 1,100 saltpan workers in LRK have been using solar-powered pumps for drawing saline water used for extracting salt. As salt production season typically runs from October to March, the solar panels remain unused for the remaining part of the year. To enable saltpan workers to optimally use solar panels round the year, a plan has been made to set up a solar park in the vicinity of the LRK, where solar panels could be mounted for the remaining part of the year to generate power. A petition for this has already been filed with Gujarat Urja Vikas Nigam Limited (GUVNL) recently. GTNfW is in the process of identifying land to set up the solar park and aims to begin generating power by April 2019. Currently, only 1,100 out of 35,000 salt farmers in the LRK region, own close to 8,500 solar panels. These collectively produce around 2.7MW power. The potential to generate power will only go up as more saltpan workers begin using solar panels. Looking at the cost savings by using solar pumps, more saltpan workers are inclined to use solar pumps. By using solar pumps, saltpan workers are not just adopting clean energy, but also saving 40% - 100% of their expenditure on diesel. Conservative estimates indicate that the solar park will help generate an additional income of around Rs 40 lakh during the off-season for the saltpan workers.

Suryashakti Kisan Yojna (SKY) :

Gujarat has considerable deployment of irrigation pump sets. Taking this into consideration, the State Government, in collaboration with the Central Government/ MNRE/ MoP/ Multilateral Agencies undertook measures to provide solar powered pump sets through subsidy support.To enable farmers generate their own power for captive consumption and make an extra buck by selling the surplus power, Gujarat government has launched Suryashakti Kisan Yojna, popularly known as SKY. According to this scheme, which is the first of its kind in the country, farmers having existing electricity connections are given solar panels according to their load requirements. Of the total cost of installing solar system, farmers have to bear only 5 per cent cost and rest comes through state and central government subsidy (60%) and affordable loan (35%). The government estimates suggest that a farmer with metered connection of 5 horsepower (HP) earns Rs 11,612 per annum during the loan period of seven years. After that, the amount goes up to Rs 26,900 every year. With an outlay of Rs 870 crore, the pilot project will cover 12,400 farmers and have a connected load of 175 MW. As many as 137 separate feeders are planned to be set up under the pilot for agriculture energy consumption. The first feeder has already been commissioned at Pariaj in Bharuch and 10 farmers have joined in. For the first 7 years, farmers will get a per unit rate of Rs 7 (Rs 3.5 by GUVNL and Rs 3.5 by state government). For the subsequent 18 years they will get the rate of Rs 3.5 for each unit sold.

Gujarat government is also giving subsidy for solar pumps. As many as 12,742 solar water pumps have been installed so far. A provision of Rs 127.50 crore has been made for installing 2,780 solar pumps in the current year. The state government has also allocated Rs 20 crore for converting existing agricultural electricity connections to solar-based irrigation pumps. By the end of 2016-17, the total number of installed solar pumps in Gujarat through GGRC and GVNL was 7739.

Table 2: Subsidy Norms with Cost and Types of Solar Water Pumps in Gujarat

Sr. No	Type of Pumps	For Banaskantha and Kutch Districts			For Other Districts of the State		
		Total Cost	MNRE (Govt. of India) subsidy amount	Farmer Contribution	Total Cost	MNRE (Govt. of India) subsidy amount	Farmer Contribution
01	3 HP DC Surface	3,03,000	1,21,500	1,81,500	3,01,000	1,21,500	1,79,500
02	3 HP DC Submersible	2,84,449	1,21,500	1,62,949	2,84,449	1,21,500	1,62,949
03	5 HP DC Submersible	4,01,449	2,02,500	1,98,949	4,00,449	2,02,500	1,97,949
04	3 HP AC Surface	2,69,000	97,200	1,71,800	2,66,000	97,200	1,68,800
05	5 HP AC Surface	-	-	-	3,49,000	1,62,000	1,87,000
06	3 HP AC Submersible	2,65,000	97,200	1,67,800	2,63,000	97,200	1,65,800
07	5 HP AC Submersible	3,43,000	1,62,000	1,81,000	3,46,000	1,62,000	1,84,000

Notes: * for AC pump the subsidy is Rs.32,400/- per HP; ** for DC pump the subsidy is Rs.40,500/- per HP. Solar water pump system cost inclusive of installation, commissioning, transportation, insurance, 5 years maintenance and taxes wherever applicable.
Source: GGRC.

The Gujarat Green Revolution Company Limited, Gujarat as per the directions of Ministry of New and Renewable Energy (GoI), has implemented the installation of 1400 numbers of solar water pumps for irrigation under "Solar Water Pumping Programme for Irrigation and Drinking Water" in the state of Gujarat with the following types of pumps and subsidy norms (Table 2). As per subsidy Norms for Solar Powered Irrigated Pumps in Gujarat State as per the Energy & Petrochemicals Department, Government of Gujarat, Gandhinagar GR No. BJT-2014-1447-K1 dated 25th September, 2014, subsidy norms per hp irrigation pump is Rs. 1000/- for SC&ST households and Rs.5000/- for general category. To avail the benefit of installation of SPY water pumps for irrigation under this scheme, beneficiary farmers normally should have drip irrigation under MIS scheme implemented by GGRC in the state of Gujarat. The Government of Gujarat has released general resolutions (GRs) from time to time in order to spread the coverage of solar irrigation pumps in the state.

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 3). 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 (Table 4). The top five districts having highest coverage of solar pumps are Bikaner, Jaipur, Sri Ganganagar, Hanumangarh and Sikar.

Table 3: 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.

Table 4: 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.

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. 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.

Case Study of First Solar Irrigation Cooperative

A novel solar irrigation cooperative is started in Gujarat state in India; where solar power is generated and used at the farm level for irrigation. It is the first ever cooperative of farmers for decentralized solar power generation and usage in irrigation formed in 2015 in Gujarat, India. It is the World's first Solar Pumps Irrigator's Cooperative Enterprise (SPICE) i.e. Dhundi Saur Urja Utpadak Sahakari Mandali or DSUUSM was registered in May 2016 by six farmers of Dhundi village of Kheda district of Gujarat State. The farmers of the village were earlier harvesting only crops, now they are harvesting solar energy. The members of the DSUUSM use solar energy to run their own irrigation pumps and the surplus energy generated by them is sold to Madhya Gujarat Vij Company Ltd (MGVCL), under a power purchase agreement (PPA) for 25 years. The solar cooperative in Dhundi is a model that not only discourages farmers from overdrawing underground water using free solar power, but also rewards them for diverting the surplus energy into the grid. Taking the Dhundi model further, 11 farmers of Mujkuva village of Anklav taluka in Anand district of Gujarat have foregone their power subsidy and instead, began using solar power.

The DSUUSM could be termed successful model in reducing the dependence and costs of diesel or electricity for irrigation. It also provides the farmer with another avenue for earning supplementary income. However, the sale of solar power to the MGVCL is not attractive for the members at the tariff offered at present, which is why they choose the more profitable option of selling ground water to their neighbouring farmers. This has resulted in an upsurge in ground water extraction, decreasing its price and expanding the water market to a great extent. Although it brings cheer to members of DSUUSM and their neighbouring farmers in the short term, in the long term it threatens a fall in the ground water table. The MGVCL needs to revisit its power purchase price to discourage this phenomenon. It could also explore the possibility of redesigning the Power

Purchase Agreement (PPA) with DSUUSM to enforce a large amount of solar power which is made obligatory to be supplied to MGVCL. Thus, DSUUSM could be an economically viable model of decentralized solar power generation. This makes it a replicable model for nations similarly endowed with ample sunlight and ground water tables. However, it is necessary to devise a policy which not only encourages solar pumps but also manages to regulate ground water extraction through them. Only then, would it become a sustainable solution for energy needs in irrigated agriculture.

Findings from Field Survey in Gujarat

- Except 9 percent households in beneficiary group, all other respondents were males, which indicates the dominance of males in the decision making regarding adoption of the new technology.
- On an average, the respondents in beneficiary households were relatively older having an average age of 51 years as compared to the respondents from non-beneficiary group who were younger as their average age was just 33 years. This is in keeping with the usual trend that younger people are more enthusiastic about lapping up a new idea compared to the older ones, as the non-beneficiaries had adopted SIPs even without benefitting from subsidy, which reflected their belief in this novel technology. However, the third group, i.e. the non-adopter respondents showed a mean sample age of about 44 years, which is lower than the mean age of subsidized adopters but higher than the mean age of non-subsidized adopters. Hence, one could conclude that age is not an important deciding factor in the decision-making about adopting the SIP, either subsidized or otherwise.
- As far as the educational attainment of the sample respondents is concerned, it could be observed that the respondents of the non-beneficiary households were comparatively highly educated having taken education up to post-graduation level; whereas beneficiary adopters as well as non-adopters has a majority of respondents who had received education up to just the primary level. Here again, non-beneficiary households exhibit a higher receptivity to the novelty of solarization which enabled them to take the risk of investing in SIPs without any government subsidy. Their higher educational level and better awareness may have had to play a part in this decision.
- The average size of sample households was found to be 7.11 persons. It was found that the sample beneficiary households were relatively larger in size with around 9.4 persons per family; followed by about 8 persons in the group of non-adopters, while small size of household was noticed among the non-beneficiary group. However, in case of number of members working in agriculture, it was about 4 persons per family on an average, for all the three groups. Hence, the size of the family or the number of persons of a family employed in agriculture do not appear to be having a bearing upon the adoption of SIPs in the study districts.
- The religion-wise distribution of selected respondents indicates that out of total selected households, about 94 per cent households belong to Hindu religion while remaining were from Muslim and other religions (Table 4.2). Among the

three groups of respondents, around 94 percent of beneficiary adopters and non-adopters were Hindu, while corresponding figure for non-adopters was 75 per cent. Thus, about one- fourth of non-beneficiary households were from Muslim religion. Thus, the penetration of SIPs amongst Muslims was found to be lower amongst sample households.

- In case of caste distribution, dominance of scheduled tribe (ST) households was observed to be highest amongst beneficiary adopters followed by households from other backward castes and general category farmers. Amongst the non-beneficiary adopters, the highest proportion was that of other backward castes (OBCs), whereas the non-adopters were also primarily from the STs followed by those from OBC and general category farmers. Thus, the caste of the farmer was not found to have a major impact upon the adoption of SIPs in the study area.
- More than 90 per cent of beneficiary as well as non-adopter households were having farming as their principal occupation while 75 per cent of non-beneficiary households had trading as their principal occupation. Hence, SIP is an attractive option for sample respondents who are primarily engaged in cultivation, while those who could afford to install an SIP without subsidy were the ones who had an income from trading as well.
- Animal husbandry and dairying followed by agricultural labour was the subsidiary occupation of beneficiaries as well as non-adopters, while cultivation followed by agricultural labour was the subsidiary occupation of non-beneficiary households. Thus, all the three groups of respondents were found to be intricately linked to agriculture or its allied occupations.
- From the field data, it was found that on average, selected households had around 21 years of experience in farming. Across groups, beneficiary households were more experienced in farming (about 30 years) followed by 21 years of experience by non-adopters while the non-beneficiary respondents hardly had 14 years of experience in farming. Thus, a longer experience with farming attracts the farmers towards SIPs, but this may not be a significant factor for seeking subsidy for the same.
- It was found that all the non-beneficiary sample households were from APL category, while almost half each of selected households from beneficiary as well as from non-adopter groups were from APL and BPL category. Few of the beneficiary households were also from AAY category. It follows that the beneficiaries of subsidy belong to disadvantaged groups as they are the ones who may have been specifically favored according to the policy norms. On the other hand, non-beneficiary adopters may not have received subsidy, but have still adopted solarisation because one, they could perhaps afford it and two, because they were convinced about its benefits. The house structure of a majority of beneficiaries was found to be kaccha type, while that of all 100 per cent of the non-beneficiary adopters was found to be ‘pucca’ type, hinting at a higher economic strength of the latter.
- The average land holding size of selected beneficiary households was 3.25 ha and non-adopters was 2.95 ha respectively, while the corresponding figure for non-beneficiary households was 10.34 ha, indicating the large land holdings

size with non-beneficiary households. Thus, the non-beneficiaries had the largest land holding amongst the sample respondents.

- Further, 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 the coverage of irrigation. The non-adopters irrigated about 60 per cent of their operational land holdings with available sources of irrigation. Thus, despite having a large size of land holdings, non-beneficiaries had sufficient water and sources of irrigation to irrigate their crops. Due to the security afforded by way of irrigated land, the assurance of returns on agriculture is invariably higher, which may have encouraged these farmers to opt for investing in the installation of SIPs on their farms even without availing any subsidy, i.e. by making expenditure from their own funds. The same is not the case with non-adopters who had a considerable amount of unirrigated land, due to which; adopting SIP may not be their priority.
- In case of selected beneficiary households, gross cropped was increased by about 37 per cent after solarisation while gross irrigated area was increased by 57 percent. The area under irrigation of selected beneficiaries increased by about 11 per cent (to GCA), which is reflected in an increase in the cropping intensity to 181 per cent from 145 per cent previously. After solarization, proportion of gross cropped area during rabi and summer crops registered a significant increase. Also, the coverage of irrigation by selected beneficiaries registered an increase of almost ten per cent, even as the gross cropped area (GCA) in the kharif season had declined. Thus, solarization has resulted in the expansion of irrigated area, cropping intensity and GCA of beneficiary sample farmers.
- In case of non-beneficiary households, it surprisingly to note that despite of 76 per cent increase in gross cropped area and gross irrigated was increased by 34 per cent, cropping intensity after adopting solarisation has declined indicate increase in area during Kharif season.
- While the cropping intensity of beneficiaries sample adopters of SIP is the highest, the non-beneficiaries recorded the lowest cropping intensity amongst the three groups. On the other hand, the non-adopters of SIPs showed the highest cropping intensity. Thus, it could be concluded that the position of non-adopters could be further strengthened if they were to adopt solarization of their irrigation pumps.
- For beneficiary SIP users, in the Kharif season under rainfed cultivation, the cropping of vegetables had increased, while on irrigated land during Kharif, they increased the cropping of paddy and soyabean. In the rabi season, the cropping of irrigated crops like gram, wheat, maize and potato showed an increase. Similarly, in the summer season, due to availability of reliable power through the SIP, the cropping area of almost all crops such as bajra, moong, maize, maize, lemon and fodder and fruit crops increased. Thus, the change in the cropping pattern was relatively in favour of irrigated crops in the study areas.

- In case of non-beneficiary households, major crops grown during Kharif season were cotton, groundnut and urad while wheat and onion were major crops grown during rabi season. In fact, land under kharif crops has showed an increase after solarization, of which significant increase (as a percentage of gross cropped area) was recorded in groundnut under rainfed conditions.
- In case of non-adopter households, major crops grown during Kharif season were castor, cotton, paddy, maize and pulses; while wheat and gram along with fodder crops were the major crops grown during rabi season. A significant portion of the area under cultivation during the summer season was allotted under fodder crops which indicates the importance laid on the supply of fodder in the study area, as also the non-availability of irrigation during the summer season which does not permit the cultivation of crops that are irrigation intensive. Hence, the non-adopters miss out on the opportunity to earn more by a flourishing cultivation of crops such as bajra, fodder, maize, moong, lemon and vegetables as done by the beneficiary adopters of SIPs.
- All the beneficiary and non-beneficiary households owned submersible pumps for drawing out water for irrigation. Out of the total, three fourths of the beneficiary households owned a submersible AC pump while the remaining owned submersible DC pumps. However, in case of non-beneficiary households, the ownership of AC and DC pumps was both fifty per cent each. It was observed that 60 per cent of the non-adopters owned surface AC pumps while remaining households had submersible AC pumps. In total, two-thirds of the selected households owned submersible AC pumps; 40 per cent of the households had submersible DC pumps while the remaining had surface AC pumps.
- Out of the total selected sample households, three-fourths were not having grid connection on their farm indicating that they would have adopted solarization for availing SIPs to meet the irrigation needs of their crops. On an average, the per unit rate paid by the selected households was around Rs. 0.80 with an average bill of about Rs. 5100/- per annum while in case of non- beneficiary households, a flat rate of tariff was being paid entailing an annual expenditure of Rs. 6267/. However, notwithstanding the comparative expenditure, the greater problem was observed with the availability of farm electricity connections which is available only with the greatest difficulty; and there is a large waiting list for getting new connections. Even if the connection is available, the supply is intermittent with a maximum of eight hours in a day and that too at inconvenient times, irrespective of the season. Thus, in order to irrigate the crop during day time with uninterrupted power supply, the SIP is the most convenient option available which selected households have installed on their farms.
- The average depth of ground water reported by beneficiary households was around 110 feet while for the non-beneficiary households, the ground water depth was reported to be five times more. Even then, they were found to have installed an SIP from their own funds which indicates that they found the SIP to be useful even under conditions of a greater depth of ground water.

- As far as the ownership of diesel and electric pumps is concerned, more than 75 per cent of sample households reported of owning diesel pumps as well as electric ones, with the latter being more dominant. Besides using their own pumps, they also used the services of rented diesel and petrol-run pumps as and when required to meet the gaps in the grid-supplied electricity. On an average, the selected households owned pumps having a power of around 5 HP. It is noteworthy that almost all the selected households were in the practice of irrigating their crops through flood method instead of drip irrigation; including those that were however having an additional provision for drip irrigation also, while a few households reported to be using sprinkler method for irrigating their crops.
- In the selected villages and specifically from the location of sample households, the average distance of the canal or river was found to be more than 900 meters. Around 20-25 per cent of selected households were having a facility for water storage with them, while around 31 per cent of the beneficiary households had developed a facility for artificial recharge. In case of non-beneficiary SIP users, about 50 per cent households had made provisions for artificial ground water recharge. Thus, ground water recharging was found to be more of a priority with non-beneficiary sample farmers.
- The land area covered by the installed solar pumps was around 1.5 ha in case of beneficiary households and 3 ha for non-beneficiary households. Except two households in beneficiary category those who have solar PV panels installed at their home, all the selected households had solar panels installed on their farms. All the installed solar PV panels were manually rotated systems and none of them was found to have an automatic rotation mechanism. On an average, four poles were installed with a mean number of stand poles between 20-25, having an average size of panel of 2 feet by 5 feet. Mean area covered by the each stand pole varied from as small as 5 feet by 5 feet in case of beneficiary households; and 12 feet by 24 feet in case of non-beneficiary households. Thus, the non-beneficiary sample households were found to have allotted more land area under the coverage of their SIPs.
- None of the installed solar panels had a meter installed in order to record the total power generated and used by the famers. None of the solar PV power generation unit was linked with the grid; due to which there was no contract made with the power DISCOM associated with the *Gujarat Vidyut Nigam Limited*. Hence, the unused surplus solar power generated by the SIP owners was stored in solar storage cells, which were installed by about 79 percent of beneficiary households and all 100 per cent of non-beneficiary households. However, these were used only for field operations and not for commercial purposes.
- The prevailing water rates per hectare of canal irrigation with the help of gravity flow was estimated to be in the range between Rs. 650-700/, per annum while through canal lift, tube-well and purchased water, the same ranged between Rs. 50-100/- per hour. Clearly therefore, canal irrigation was quite cheap, but if water would be purchased from the SIP, it could turn out to be even cheaper.

However, the solar power generated was mostly used for agricultural purposes while a few of beneficiary households used for household purposes as well.

- The selected farmers were asked about the reasons for adoption of solar power generation unit on their farm. About 96 per cent of selected beneficiary respondents mentioned that non-availability of electricity connection or inadequacy of supply of grid power coupled with the opportunity to take the advantage of subsidy being offered by the government were two major reasons for opting for SIPs; followed by high cost of running electric pumps and the opportunity of using environment-friendly renewable technology (86 per cent). More than three-fourths of the respondents also cited other reasons such as the desire to try out a new technology, the recommendation of fellow farmers/friends/relatives, personal relations with the person who marketed solar technology to them, desire to be free of the inconvenience suffered due to odd hours at which electricity was supplied, unreliability of electricity supply, savings on the cost of fertilizers and weeding, savings on electricity bills and the desire to avoid the hassle of irrigating crops during the night hours when electricity was supplied.
- The non-beneficiary households that had installed solar PV panels at their own cost mentioned that the reason for their action was a desire to try out a new technology (100%). However, 75 per cent of them also revealed that their desire sprung from the need to avoid the hassles connected with irrigating at night or other inconvenient hours during the day time. Also, since they did not have an agricultural electricity connection and did not hope to get it in the near future, purchasing an SIP was their chance to meet their irrigation needs in a reliable way, even if the benefit of subsidy was not available.
- About 50 per cent of the non-beneficiary households mentioned that two reasons were behind their decision to go for an SIP. One, they wanted to try out the cheaper (or rather free) alternative of renewable energy because it was an economically sound decision for them; and two, because it was environment-friendly to use solar power. Hence, it could be said that the non-beneficiaries were also aware of the environmental implications of their energy use; and given an option to use renewable energy, were only too happy to use the same.
- Only about 25 per cent of the non-beneficiary SIP owners opined that they chose to solarize their agricultural pumps solely with the objective of availing private benefit for themselves in the form of saving on the costs of using expensive diesel; as well as avoiding the costs of maintenance of electrical pumps that broke down quite often. Other reasons cited for converting to solarized irrigation were the unreliability of the supply of electricity, inconvenient hours of the supply, need to keep up the personal relations with the person who marketed the solar technology to them and the need to respect the strong recommendations given by friends, relatives or fellow farmers.
- These reasons, although influential and decisive, do not undermine the slowly creeping consciousness about the need to use environment-friendly energy solutions amongst farmers, even as they are not beneficiaries of the subsidy provided for this purpose.

- By and large, it could be concluded that ‘push’ factors from farm fuels such as diesel and electricity are more important than ‘pull’ factors of solar power in order to attract farmers towards solarization of their irrigation pumps.
- In order to purchase SIPs, beneficiary households had received support from the Gujarat Urja Vidyut Nigam Limied (GUVNL) and Gujarat Green Revolution Company (GGRC). The cost of an SIP ranges between Rs. 3.30 lakh to 3.99 lakh. Out of this, the selected beneficiary household is required to contribute own investment to the tune of 15 to 27 thousand and the rest would be paid through subsidy by the government agencies. However, the non-beneficiary households are required to spend on an average, an amount of Rs. 5.59 lakh in order to install the same SIP on their farms. Thus, the SIP turns out to be cheaper for the beneficiaries than the non-beneficiaries even if we do not consider the subsidy.
- Moreover, the cost of various documentation do be done by beneficiaries added up to a cost of Rs. 388/- per household while the non-beneficiary households were required to show lesser documents for which they also spent lesser to the tune of Rs. 213/- only. Besides the monetary cost, the whole process of documentation to be undertaken by the beneficiaries would also obviously involve the spending of time as well as effort on their part, the opportunity cost of which, may not be easy to calculate, but is nevertheless, present; and does play a role in the decision to avail subsidy for the installation of the SIP or otherwise.
- The process of installation of SIPs were reported to be taking about 19 days on an average for beneficiary households while the same took hardly about 4-5 days as reported by the non-beneficiary farmers. This is but natural, considering the fact the formalities and documentation required for availing subsidy on the SIP would take more time than that required for a private decision to install an SIP and making payment for the same.
- The approach of SIP suppliers which sell the SIPS with and without subsidy was also reported to be starkly different. The representative of the government agency had paid around three visits to the respondents during the process of decision-making and installation of the SIP. Major portion of the time spent was on the completion of necessary official formalities. On the other hand, the non-beneficiary households were visited about the same number of times by the seller’s representative; but the bulk of the time spent was on convincing the farmers of about the benefits of the technology and bring him to spare funds in order to install the SIP with the help of his own resources.
- The company-wise distribution of solar panels indicates that LUBI had supplied a major portion of the total SIPs installed by both groups of adopters. The other major suppliers were Rotosol, Kasol, Goldi Green Technologies Pvt Ltd. and Top Sun. In fact, Top Sun and Bright were the two firms most popular with the beneficiaries whereas Bright and Top Sun were the top two most preferred supplier firms for the non-beneficiaries.
- Almost all the households barring few in the beneficiary group had received instructions, training and demonstration about the method of operating SIPs,

while around 73 per cent households reported that they were satisfied with the support services provided by the agency or the supplier firm.

- As regards the insurance against the risk of theft of the solar PV panels, it is very worrisome that while all the solar PV panels purchased under the subsidy scheme are supposed to be insured by the government agency by default, while farmers were not aware of same. Only 17 per cent of the beneficiaries and 25 per cent of the non-beneficiaries reported to have had their solar PV panels insured against theft or other risks. All 100 per cent of the non-beneficiary households mentioned that they were satisfied with the quality of solar panels while the corresponding figure for beneficiary households was around 71 per cent only.
- When the beneficiary respondents were asked about the conditions for the eligibility of receiving the subsidy, it was mentioned that the subsidy was available under multiple conditions as per scheme guidelines.
- For instance, households falling under a particular caste or category; households which were devoid of a grid connection for electricity; farmers owning a specified size of landholding; farmers having availability of a tank or *diggi* on the farm itself; female land-owners; farmers belonging to the income group of Below Poverty Line (BPL) category etc. were some groups that were given a priority in the disbursal of subsidy for installation of an SIP.
- Out of the total selected beneficiary respondents, 86 percent had installed SIPs without micro-irrigation system (MIS). This is of crucial importance because MIS could serve as a means to economize on water use, given that solar power with which ground water is withdrawn through the SIP is 'free'. However, it is sad to note that so far, only 14 per cent of the beneficiaries reported to have installed MIS attached with the SIP. It is however, interesting to note that 75 per cent of the non-beneficiary sample households (who were not bound by the norms for receiving subsidy) had installed SIPs attached with MIS facility on their own initiative (Table 4.18).
- The use and sale of water 'before' and 'after' solarization of irrigation pumps is presented in Table 4.19. It can be seen that the mean depth of groundwater till the present time had remained almost unchanged, i.e. about 110-115 feet as reported by beneficiary sample households and about 450-500 feet as reported by the non-beneficiary sample famers. On an average, during rabi season, it took around 6-6.5 hours to irrigate one bigha of land whereas the same was irrigated in about 8-9 hours during the summer. Before solarization, the average use of diesel during *rabi* season was reported to be around 15-18 litres per bigha, while the same increased to around 20-22 litres per bigha during the irrigation of summer crops.
- Besides, on an average, an expenditure of Rs. 6,533 and Rs. 10,375 per anum was incurred respectively by the beneficiary and non-beneficiary households on repairs of electric pumps. They also reported to be spending Rs. 3,988 and 6,250 per annum respectively on the repairs and maintenance of diesel pumps. The expenditure on irrigation with the help of electric pumps which was about Rs. 4,287 in case of beneficiary households and Rs. 2,500 for non-beneficiary households; was reported to have come down to Rs. 1,228/- for

beneficiary households and no expenditure for non-beneficiary households after solarization.

- The mean distance travelled by the beneficiary respondents for procuring fuel was quite far at about 12.5 kms as compared to 8.5 kms. traversed by the non-beneficiary sample households. The time taken for procuring fuel for each group was also different as it was reported to be about 2.2 hours in case of beneficiary households compared to 1 hour reported by non-beneficiary sample households. Also, 77 per cent of beneficiary sample households and 4 per cent of non-beneficiary households had faced various issues with respect to grid electricity supply; which compelled them to opt for SIPs.
- Around 71 per cent of beneficiary households and 4 per cent of non-beneficiary households believed that excessive withdrawal of water may have harmful impact on water table in the long run, while 12 per cent of beneficiary households and 4 per cent of non-beneficiary households had taken steps for artificial recharge of ground water table.
- After solarization of irrigation pumps, crop diversification was observed in case of almost half of the selected beneficiary households, while no such difference were reported in case of the cropping pattern followed by non-beneficiary households. Positive change in productivity post the installation of SIP was reported by most of households. About 74 per cent of beneficiary households an 4 per cent of non-beneficiary households mentioned that crop productivity has changed with solar pumps. They ascribed this to the adequate availability of power to irrigate their crops as and when required as SIPs were a reliable source of irrigation for them.
- Due to increase in availability of power during convenient timings, farmers also reported to have diversified their cropping pattern in favour of high value crops and a majority of the beneficiary respondents reported that there has been a positive impact of SIPS on the productivity of crops grown.
- Solar electricity generation depends on the exposure of the surface area of solar panels to sunlight. Over time, the surface may get dusty and tainted with other substances such as bird droppings. If not cleaned properly, this dirt could build up over time and reduce the amount of electricity generated by a module. Therefore, regular cleaning of solar panels needs to be carried out by the farmers.
- It was observed that households adopted different time schedules as per their convenience for cleaning the surface of solar PV panels. Most adopters cleaned the panels twice a week while a lesser proportion of adopters cleaned them once a week. The approximate time taken for this job was reported to be around 20 minutes.
- The experiences of selected households with solarized irrigation indicate that they were happy with the ease of operation of SIPs and found them easy and inexpensive to maintain. Apart from this, they provided the convenience of timings for irrigation and the output of water from the SIP was also reported to be quite good.

- The advantages of SIPs as mentioned by the selected households were many, such as i) near-zero maintenance cost, near-zero cost of operation, iii) good quality of power supply i.e. absence of frequent outages or fluctuations as before, iv) savings on the cost of labour, v) availability of power for 'free', vi) freedom from the hassle of having.
- One important observation from the field survey was that none of the sample beneficiaries or non-beneficiaries reported sale of water withdrawn through the SIP to any other farmers in their vicinity or a neighbouring village. In other words, water markets in selected study villages were reported to have zero impact due to the onset of SIPs. The adopters of SIPs also did not report a single instance of renting out power cells which they used in order to store solar power generated on their farms. Hence, they were in no position to generate supplementary income by using the surplus solar power for ground water withdrawal and sale of irrigation service. Hence, apart from achieving self-sufficiency in the matter of farm power for irrigation purposes, there was no added advantage of SIPs rendered to the adopters, either beneficiary or non-beneficiary.
- The disadvantages of SIPs were sought to be identified by the selected adopter households. Most of them opined that the solar PV panels needed to be placed at a greater height so that the land underneath could be used for cultivation instead of going waste. They also desired that service centers would be available at nearby locations in order to address occasional break-downs or problems occurring in the SIPs.
- They also reported a dearth of technical staff delegated by the supplier firms for handling installations or occasional snags in the systems. Even though the problem may not be very complicated, it was troublesome for the adopters because they needed to halt their irrigation if the SIP broke down. If this was a crucial period of watering the crops and the SIP was not repaired well in time, crop productivity could suffer a great deal. Moreover, the SIPs came with the feature of manual rotating system, which was found inconvenient. The adopters preferred to have an automatic rotating system pre-installed in the SIP. They also suggested that while aggressively promoting SIPs to farmers, the government must also keep in mind the need for counselling the farmers in terms of proper space management while installing the SIP on the farm as also giving information and financial assistance to them for protecting their SIPs by way of proper fencing as well as availing of insurance against theft.
- The non-adopter households were asked the reasons for non-adoption of SIPs. Lack of funds was the major reason for not adopting the SIP; followed by opposition from family members, hesitation to invest such a large amount in a hitherto untested technology, risk aversion, too little land making the purchase of an SIP unviable, prior possession of an electricity connection charging a flat-rate for usage, low confidence in the government agency which promoted SIPs to them; as well as a delayed knowledge and exposure to SIPs.
- Although the non-adopters could not adopt SIPs due to a variety of reasons, they did appreciate the SIP with its many advantages such as near-zero maintenance cost, subsidy offered by the government, free from cost of fuel,

freedom from inconvenience of having to fetch fuel on a recurring basis and most importantly, the good quality and reliability of power supply.

- The non-adopters also obviously realized the disadvantages of the SIPs most likely from their interactions with their fellow farmers who had opted to install SIPs. They expressed that being usable only during the sunlight hours and not before or after that, was the main disadvantage of SIPs. However, more than that, they believed that the high initial capital cost of installation of SIPs was the main deterrent against the wider acceptance of SIPs amongst farmers. They also flagged the concern for the possible negative impact that SIPs could have on ground water withdrawal and result in depletion of the groundwater table in the long run.
- The sample beneficiary and non-beneficiary adopters in the sample were asked about their suggestions for the expansion in solarization of irrigation in Gujarat. A majority of the beneficiary households focused only on making the SIP more user-friendly in terms of their requirement of space, technical features with respect to the position of installation, operation, maintenance and financing; including that for insurance.
- On the other hand, the non-adopters of SIPS focused a lot more on other factors which could expand the coverage of solarized irrigation in Gujarat. They underlined the need to increase the awareness about SIPs amongst farmers through concerted efforts for communicating the same. They also opined that the portability of the solarized engines instead of fixation with irrigation pump at a certain point; would greatly enhance their utility for the users. Further, if the individual SIPs were to be connected with the grid in order to evacuate the surplus power generated therefrom 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. This was already being done in other parts of Gujarat and was touted as a well-thought-out and well-appreciated measure by the government. However, along with a subsidy for installing SIPs and connectivity with the grid, the farmers were also in need of assistance for taking insurance against risks of damage of SIPs or theft of their solar panels. Also, the procedure for availing subsidy should be simplified; the criteria for eligibility should be relaxed so as to include more farmers as beneficiaries; and the amount of subsidy should be increased in order to encourage more adoption of this technology.

Findings from Field Survey in Rajasthan

- 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- Gujarat:

- Majority of the beneficiary farmers suggested that solarized irrigation could be expanded in Gujarat 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.

- Non-adopters of SIPs underlined the need to increase the awareness about SIPs amongst farmers through concerted efforts for communicating the same. They also opined that the portability of the solarized engines instead of fixation at a certain point, would greatly enhance their utility for the users.
- Further, if the individual SIPs were to be connected with the grid in order to evacuate the surplus power generated therefrom 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 assistance for taking insurance 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
- The amount of subsidy should be increased in order to encourage more adoption of this technology.
- SIPs are not accompanied by micro-irrigation systems or efforts to raise the ground water tables as envisaged in the policy. The 'push' factors such as costs and hassles of procuring farm fuels such as diesel and electricity are more important than 'pull' factors of solar power in attracting farmers towards solarization of their irrigation pumps.
- 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.

Policy Implications- Rajasthan:

- 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.

Conclusion

In summation, it could be said that solarisation of irrigation pumps has been a successful experiment in both Gujarat as well as Rajasthan. There is evidence to suggest that both the Gross Cropped Area and the Gross Irrigated Area have increased post solarization. The cropping pattern has also changed in favour of high value crops. The SIPs are found to be user-friendly, particularly for women. However, the cost of SIPs is still found to be high for individual farmers. Community-based SIPs on the lines of cooperative in Dhundi in Gujarat; could be helpful in making this technology accessible to marginal and low income farmers. Also, connecting the SIPs to the electricity grid; and equipping them with solar power storage cells; could enhance their utility as well as provide the farmers with a supplementary source of income through sale of solar power in much the same way as in the cooperative in Dhundi. For large-scale penetration of SIPs, there is a need for increasing awareness amongst farmers about the benefits of solarised irrigation. All in all, solarization of irrigation pumps in Gujarat and Rajasthan is ‘a work in progress’; albeit with promising prospects.