AERC REPORT 174

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,
Sardar Patel University, Vallabh Vidyanagar, Gujarat (India)

Agro-Economic Research Centre
For the states of Gujarat and Rajasthan
(Ministry of Agriculture and Farmers Welfare, Govt. of India)
Sardar Patel University,
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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.

Chapter I

Introduction

1.1 Introduction

Energy is a primary driver of economic growth and welfare. Provision of good quality energy is a means to improve the standard of living of the people. India has come a long way since independence in building the capacity to produce quality energy and in making it reach the rural areas as well. Power production is considered to be a core industry as it facilitates growth across various sectors of the Indian economy such as manufacturing, agriculture, commercial enterprises and railways. Thus, it is a key enabler for India's economic growth, and has historically shown growth trends in tandem with the overall growth of the economy, which is also reflected in the strong correlation between the growth rate of GDP/GVA and the growth rate of power generation capacity in the economy.

In spite of recording significant growth over the years, the Indian power sector is facing challenges such as shortages and supply constraints of inputs as well as power supply. Power scenario in the country which had worsened over the years with the deficit at 10.1 per cent and the peak deficit at 12.7 per cent during 2009-10 has now improved somewhat, with a recorded deficit of 0.7 and peak deficit of 2.0 percent in 2017-18[1]. However, it is still not enough, because considering the growth outlook of the economy, it is expected that the demand for electricity would grow in future. Moreover, India imports over 70 per cent of her crude oil needs and demand routinely outstrips supply. All of these, along with the growing concerns about the environmental consequences of fossil-fuel based power-generation; call for an effective and thorough system of energy production, distribution and regulation in India. While power-generation in India is predominantly done with the help of conventional sources such as thermal, hydro and nuclear plants, the country is also emerging as one of the leaders in

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[1] See Annexure I (https://powermin.nic.in/en/content/power-sector-glance-all-india).

renewable energy production (MSSRF, 2007). Efforts are being made to achieve fuel security though renewable fuels. Harnessing clean and green sources of energy on a large scale in the country is a necessity to ensure sustainable economic development without seriously damaging the environment while also addressing the need for energy security (SPRERI, 2014).

1.2 Renewable Energy Resources at Global Level:

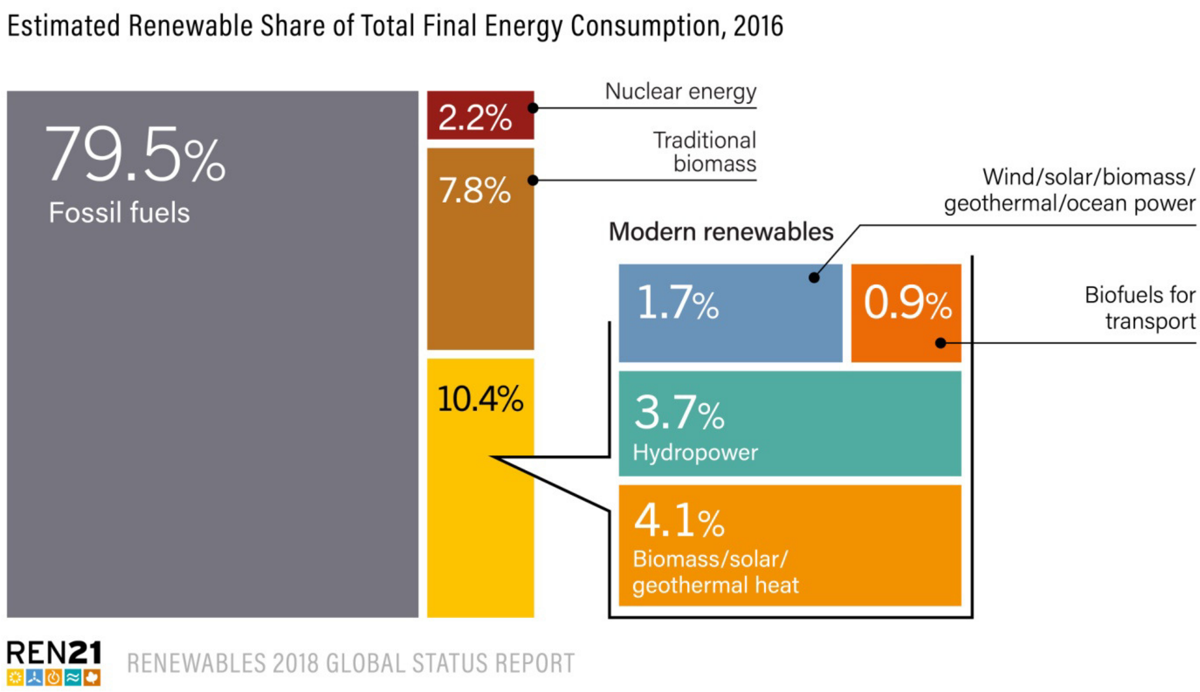
Rising international fuel prices, growing demand for energy and concerns about global warming are the key factors driving the increasing interest in renewable[2] energy sources (Rosegrant et al., 2006). Renewable technologies for power generation, heating and cooling, as well as transportation are considered the key tools for advancing multiple policy objectives including boosting of national energy security and economic growth; creating jobs; developing new industries; reducing pollution from carbon emissions; and providing affordable and reliable energy for all citizens instead of having to rely on costly and ever-depleting fossil fuels (REN21, 2018). Renewable energy is defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat (Omar et al., 2014). The shifting to renewable energy can help us meet the dual goals of reducing greenhouse gas emissions, thereby limiting future extreme weather and climate impacts; and ensuring reliable, timely, and cost-efficient delivery of energy. Investing in renewable energy can have significant dividends for our energy security (Omar, et.al, 2014). Therefore, there is considerable interest within the international community in the socio-economic implications of moving society towards a more widespread use of renewable energy resources. Renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services (REN21, 2010).

The world over, renewable energy sources are beginning to be accepted not only for their easier availability compared to fossil fuels, but also their positive impact on global warming and climate change. Renewable technologies for power

[2] Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat (Omar et al., 2014).

generation, heating and cooling, and transport are considered key tools for advancing multiple policy objectives of countries going through various stages of economic development. Renewable energy markets have been growing rapidly over the last few years. The deployment of established technologies, such as hydro-power turbines as well as newer technologies such as wind and solar photovoltaic (SPV) plates has spread quickly, which has increased confidence of the users in these technologies; reduced the costs of production of equipment by bringing in the economies of scale; and opened up opportunities for new entrepreneurs in the market. It is estimated that global electricity generation from renewable energy sources could grow by 2.7 times between 2010 and 2035 (Omar et al, 2014).

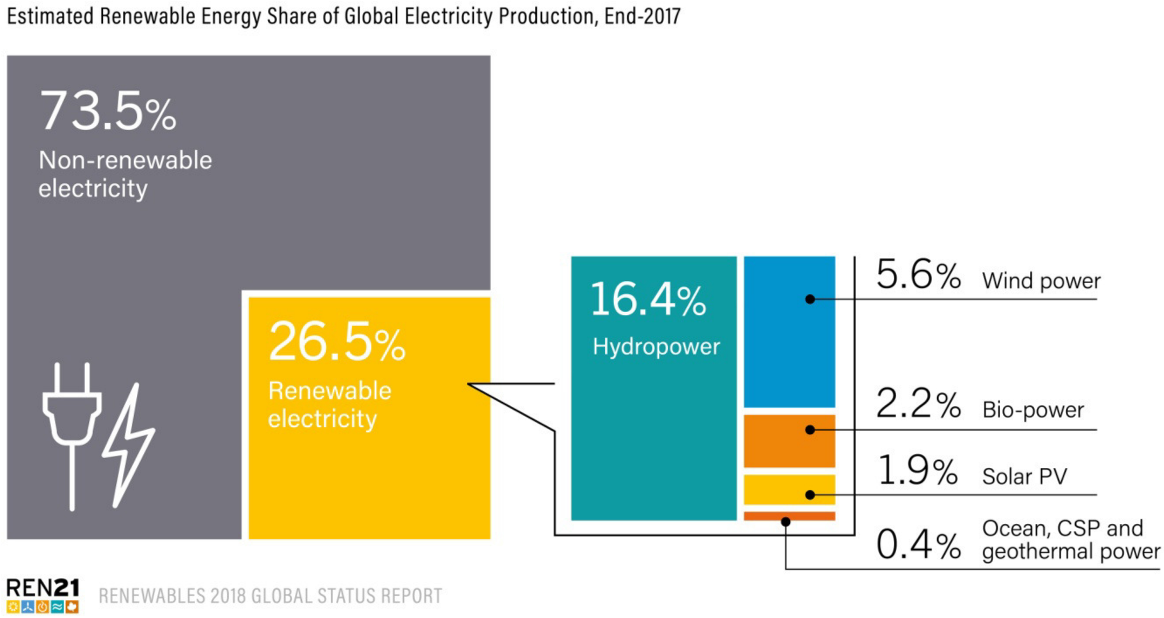
Fig 1.1: Energy Resources of the World (2016)



Source: REN21 (2018).

Renewable energy resources are innovative options for electricity generation. Their potential is enormous as they can, in principle, meet the world's energy demand many times over. Despite rapid expansion of capacity for renewable energy generation as well as the output of equipment such as solar photovoltaic (PV) panels as well as wind turbines, fossil fuels continue to supply an overwhelming proportion of total consumption of energy in the world (REN21, 2018). On the other hand, renewable energy produced from traditional renewable sources of energy such as burning of biomass and large hydropower plants; as well as 'new' renewable sources such as small hydro-power plants, modern 'biomass', wind, solar, geothermal, and biofuels; together supplies only about 11 percent of the total energy consumed in the world (see, Fig. 1.1) while renewable energy share of global electricity production was 26.5 per cent (Fig. 1.2).

Fig 1.2: Renewable Energy share of Global Electricity Production, 2017



Source: REN21 (2018).

1.3 Renewable Energy Scenario in India

Way back in 1980, India was the first country in the world to set up a Ministry of Non-conventional Energy Resources. Over the years, renewable energy sector in India has emerged as a significant player in enhancing the grid-connected power generation capacity. In doing so, it also supports the government's agenda of sustainable growth, while, emerging as an integral part of the solution to meet the nation's energy needs an agent for improving the access to energy for a vast section of the population and the economy. It is evident that renewable energy would have to play a much deeper role in achieving energy security in the coming years as an integral part of the process of planning to fulfill energy needs.

The core drivers[3] for development and deployment of new and renewable energy in India have been as follows:

(a) ***Energy Security***: At present around 69.5 per cent of India's power generation capacity is based on coal. Besides, it faces an increasing dependence on imported oil, which amounts to around 33 per cent of India's total energy needs.

(b) ***Electricity Shortages***: Despite an increase in installed capacity by more than 113 times in the sixty five years since independence, India is still not in a position to meet its peak electricity demand as well as energy requirements.

(c) ***Energy Access***: India faces a challenge to ensure availability of reliable and convenient and good quality of energy supply for all its citizens. Almost 85 per cent of rural households depend on burning of bio-mas for their cooking needs and only 55 per cent of all rural households have access to electricity. However, even with this low access, most rural households face issues with quality and consistency of energy supply. Shortage of supply of electricity gives rise to large-scale use of kerosene which in turn leads to a continuously increasing burden of subsidies on imported crude oil; dependence on imports for the same and consequently, a constant pressure on foreign exchange reserves.

(d) ***Climate Change:*** India has undertaken a voluntary commitment of reducing carbon emissions up to that which prevailed in year 2005 by the year 2030 (a reduction of about 30-35 per cent). In the recently concluded 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) held at Paris, India committed to achieve a target of installing 40 per cent of its capacity of cumulative electricity generation from non-fossil fuel based energy resources by the year 2030 with the help of transfer of technology and low cost international finance; including that from the Green Climate Fund (GCF).

One of India's major advantages today and going forward is that its renewable energy (RE) potential is vast and largely untapped. India has an estimated renewable energy potential of about 900 GW from commercially

[3] https://mnre.gov.in/file-manager/annual-report/2015-2016/EN/Chapter%201/chapter_1.htm

exploitable sources viz. Wind – 102 GW (at 80 meter mast height); Small Hydro – 20 GW; Bio-energy – 25 GW; and Solar power-750 GW, assuming that 3 per cent of wasteland would be made available for this purpose (see, Annexure II).

India is geographically, a very diverse country. Renewable energy sources in India are not equally well distributed. While solar and biomass are distributed more or less evenly and could be harnessed in almost all Indian states; wind energy sources, although abundant, are concentrated only in a few states in southern and western India. Even for solar energy generation and supply of biomass for the generation of power, the availability of land might be a cause of concern for a few states, though not so much for the others.

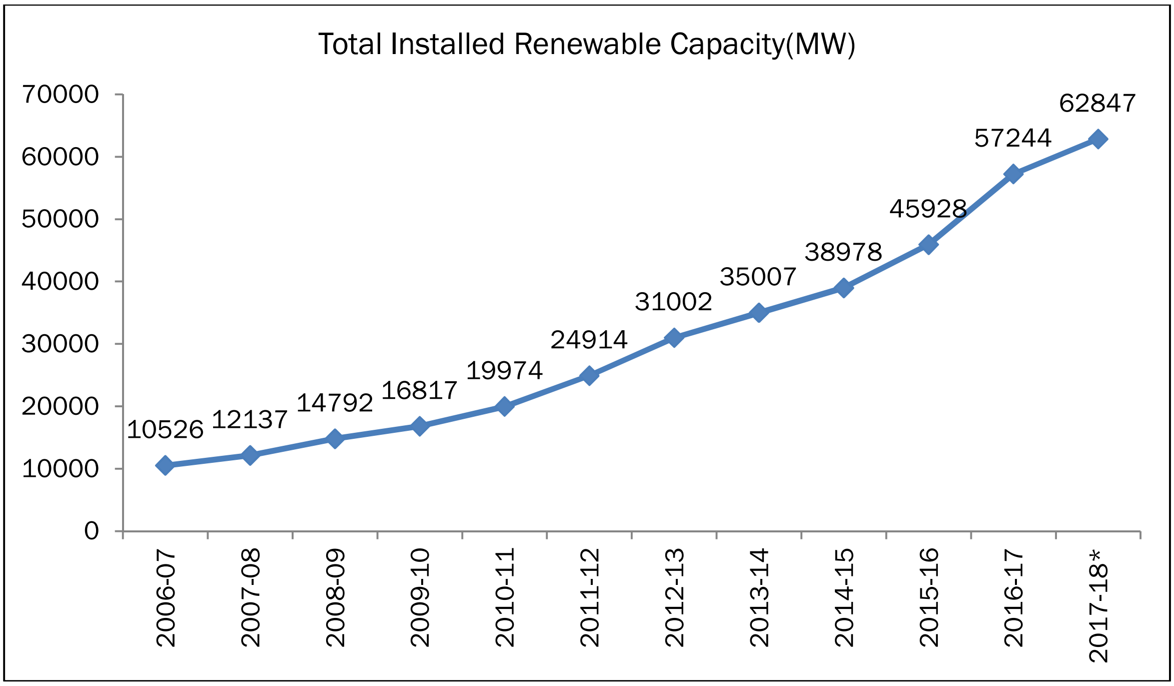
Recent estimates show that India's solar potential is greater than 750 GW and its announced wind potential is 302 GW (the actual could be higher than 1000 GW). The potential of biomass and small-hydro power projects is also significant. India Energy Security Scenarios 2047 show a possibility of achieving a high of 410 GW of wind and 479 GW of solar PV by 2047[4]. Thus, renewable energy has the potential to anchor the development of India's electricity sector. The Ministry of New and Renewable Energy (MNRE), Government of India (GOI) is in-charge of developing sources of renewable energy in India. The Ministry has been facilitating the implementation of broad spectrum programs including harnessing renewable power; promoting the use of renewable energy in rural areas for lighting, cooking and transportation; use of renewable energy in urban, industrial and commercial applications; as well as development of alternate fuels and applications. It has targeted for increasing solar power capacity to almost fifteen times the level of 2016 by year 2022. India is a major participant in the International Solar Alliance of 120 countries of the world that aim to develop solarization in power sector (GoI, 2015-16, "Annual Report, MNRE).

The growth in solar power capacity achieved during 1999-200 to 2015-16 is presented in Figure 1.3. As of October 31, 2018, India's overall installed capacity for power generation has reached 346.048 Giga Watt (GW); of which, renewable energy sources account for 72.013 GW i.e. (20.8 %)[5]. Out of the total

[4] https://niti.gov.in/writereaddata/files/writereaddata/files/document_publication/report-175-GW-RE.pdf
[5] See Annexure III (https://powermin.nic.in/en/content/power-sector-glance-all-india).

power generated through renewable sources, around 49 per cent came from wind, while around 32 per cent was generated through solar energy. It is worth noting that hydro-electricity generation is treated separately and falls under the purview of the Ministry of Power (MOP) and not under the MNRE. In keeping with the stress laid on harnessing and development of renewable energy sources, the Ministry of Power, GoI, has also announced that no new coal-based capacity addition is required after the year 2027. The figures presented in Table 1.1 refer to newer and fast developing renewable energy sources and are managed by the Ministry for New and Renewable Energy (MNRE). In addition, as of 31st March 2018 India had 45.29 GW of installed large hydro capacity which comes under the ambit of Ministry of Power. As mentioned earlier, government of India intends to achieve 40 per cent cumulative electric power capacity from non-fossil fuel sources by 2030 (MNRE, 2017).

Fig. 1.3: Total Installed Renewable Capacity (MW), 2006-07 to 2017-18



With electricity being a concurrent subject, power sector planning occurs at both the Central level and State levels, not always in a cohesive manner. Apart from this, the power distribution utilities (DISCOMS) in various States are already grappling with issues such as power theft and mounting losses, so as to have little inclination for managing the variations associated with the intermittent output of wind and solar power. Renewable energy can offer enormous benefits to the nation as a whole, eventually benefiting the States as well. Sharing of energy resources between States could make things easy, quick and cost-effective for them. It has been well-established internationally, that a smooth integration and management of energy supply reduces to some extent, the overall variability of power supply from renewables. Hence, the energy policy needs to be designed in a manner such that it empowers the States so that they could leverage their investments in the energy sector by multiple times by way of quick, large-scale and planned deployment of renewable energy generation. National Institution for Transforming India (NITI, 2015) in its report highlighted some of the challenges and possible policy interventions (Box 1.1).

Table 1.1: Installed Grid Interactive Renewable Power Capacity (excluding large hydropower) in India as of 31st March 2018 (RES MNRE)

Sr. No.	Source	Total Installed Capacity (MW)	2022 target (MW)
1	Wind power	34,046	60,000
2	Solar power	21,651	100,000
3	Biomass power	8,701	
4	Biomass & Gasification and Bagasse Cogeneration	114.08	*10,000
5	Waste-to-Power	138	
6	Small hydropower	4,486	5,000
	Total	69,022	175,000

Note: * The target is given for "bio-power" which includes biomass power and waste to power generation.
Source: Renewable energy in India - Wikipedia.html accessed on December 20, 2018.

1.3.1 Solar Energy in India

Of all the sources of renewable energy, the most suitable in the Indian context is solar energy. Situated close to the Tropic of Cancer and enjoying sunny days for close to about 300 days in a year in most regions, India could have an obvious opportunity to become the hot-bed of solar energy. With about 300 clear and sunny days in a year, the calculated solar energy incidence on India's land area is about 5000 trillion (kWh) per year (or 5 EWh/yr). The solar energy available in a single year exceeds the possible energy output of all of the fossil fuel energy reserves in India. The daily average solar power plant generation capacity in India is 0.20 kWh per m^2 of used land area, equivalent to 1400–1800 peak (rated) capacity operating hours in a year with available technology that is also commercially viable. The Indian government is aggressively promoting solar energy generation. It had announced an allocation of ₹1,000 crore (US$160 million) for the Jawaharlal Nehru National Solar Mission (JNNSM) and a clean-energy fund for the 2010-11 fiscal year, an increase of ₹ 380 crore (US$60 million) from the previous budget. The budget 2010-11 had encouraged private solar companies by reducing the import duty on solar PV panels by five percent which is expected to further reduce the cost of a rooftop solar-panel installation by 15 to 20 percent. The Union government had reduced the solar PV panel purchase price from the maximum allowed ₹4.43 (6.9¢ US) per KWh to ₹4.00 (6.3¢ US) per KWh, reflecting the steep fall in the cost of solar power-generation equipment. The applicable tariff is offered after applying viability gap funding (VGF) or accelerated depreciation (AD) incentives. At the end of July 2015, the major incentives offered were as follows: i) Scheme of accelerated depreciation under which, if an enterprise installs a rooftop solar power generation system, 40 percent of the total investment could be claimed as depreciation in the first year itself. This would reduce the total tax liability of the firm; ii) Provision of subsidy (initially 30% and subsequently reduced to 15%) on capital expenditure for installing rooftop solar-power plants up to a maximum of 500 kW and iii) Tradeable RECs (Renewable Energy Certificates) provided for every unit of green power generated by the firms as a supplementary source of income for them.

Financial incentives are based on the measurement of power produced by way of installed meters on the premises. Besides, the government provides a guarantee of assured Power Purchase Agreement (PPA) to the firms producing solar power. This is done via the power-distribution and purchase companies owned by State and Central governments. The PPAs offer a price equal to that of the peaking power on demand for the solar power. It also has an added advantage of an intermittent yet more reliable source of power supply to the producer firm itself for its own use on a daily basis.

Box 1.1: Major barriers to Mainstreaming Renewables

Despite the obvious benefits, several factors have prevented the mainstreaming of renewable energy.

- Firstly, India lacks a comprehensive national policy and legislative framework for renewable energy. Existing policies and programmes are technology-specific and vary across states restricting strategic intent.
- Secondly, there is an acute shortage of willing and credit-worthy buyers of RE-based electricity. Most of our financially distressed power distribution companies (DISCOMS) and also the bulk purchasers of power have held back from buying expensive power (whether conventional or renewable-based) thus confining power markets. Market risks, clubbed with other economic factors, have led to high interest rates in Indian financial markets up to around 10% - 14% per annum; which is almost three times higher than that in developed economies. These high rates impact RE more than other conventional power or infrastructure. The lack of financing for RE projects is also a result of risks at multiple stages, for example buyers not paying or grid operators curtailing their operations which results in reduced enthusiasm amongst investors in these projects.
- Third major factor, also adding to the risks, is the unplanned and non-facilitated project development environment.
- Finally, inadequate and outdated grid infrastructure and operations have affected not just the renewable energy sector but the overall reliability of power supply. Placing renewables at the center of India's power system will therefore require a paradigm shift in planning and governance practices.

Source: NITI (2015).

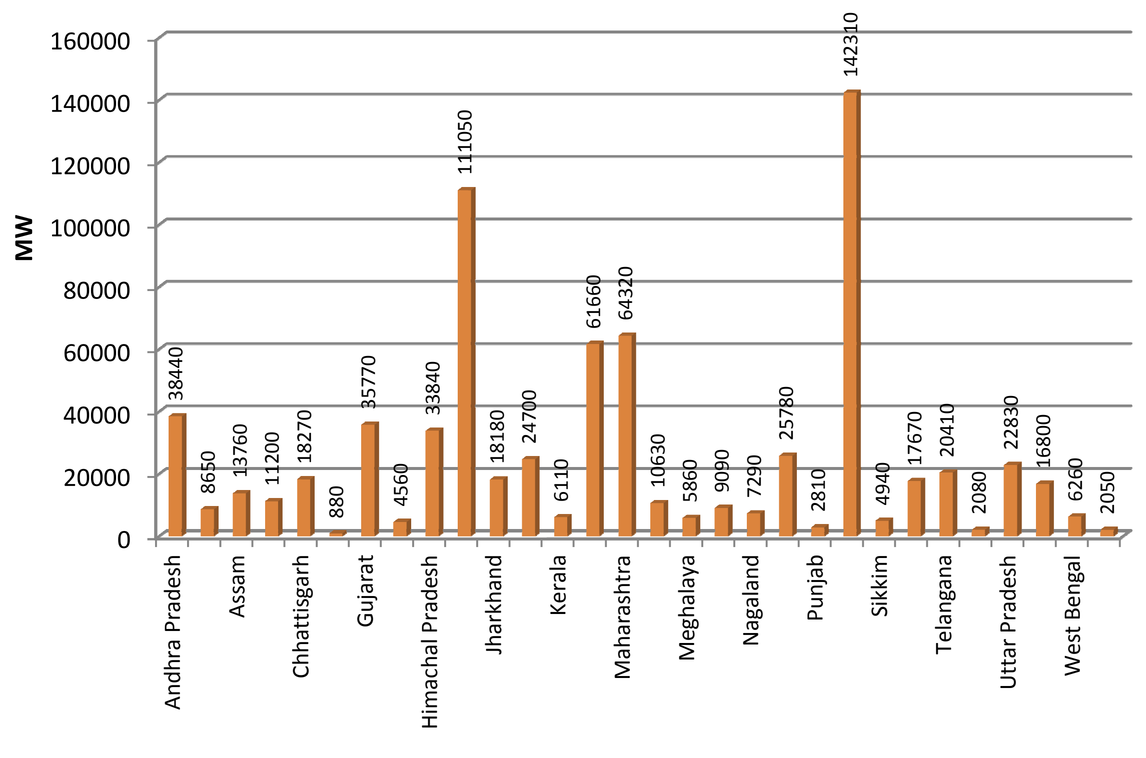
India's solar energy insolation is about 5,000 T kWh per year (i.e. ~ 600 TW), far more than its current total primary energy consumption. In fact, India's long-term solar potential could be unparalleled in the world because it has the ideal combination of a geographical location that affords a high solar insolation as well a vast consumer base of power-deprived population. With a major section of its citizens still surviving off-grid, India's grid system is considerably under-developed. Availability of cheap solar power can bring electricity to these people almost with a minimum time-lag and bypass the need and costs of installation of expensive grid networks. Also, a major factor influencing a region's energy-use intensity is the cost of the energy consumed for controlling high temperatures during the extremely harsh summers. However, this energy use could be turned around for free, if solar power generated during high temperature in the day time itself, could be utilized for cooling load requirements during the same period. Since the harshness of the summer coincides with the generation of solar power and in turn, the requirement of power for cooling; using solar energy for the purpose of cooling could make perfect energy-economic sense.

Installation of solar PV plants requires nearly 2.0 hectares (5 acres) land per MW capacity. This is comparable to coal-fired power plants if one considers the entire life-cycle including land for coal mining, consumptive water storage and area for ash disposal. It is also akin to the requirement of a hydro power plant if the area that is submerged under the water reservoir created on a the site is also accounted for. Solar plants of the capacity of about 1.6 million MW could be installed in India on its 1 per cent land (32,000 square km). There are vast tracts of land suitable for solar power generation in all parts of India exceeding 8 per cent of its total area which is unproductive, barren and devoid of vegetation. Part of waste lands (32,000 square km) when installed with solar power plants can produce 2400 billion kWh of electricity (two times the total generation in 2013-14) with land productivity/yield of Rs. 0.9 million per acre (3 Rs/kWh price) which is at par with many industrial areas and many times more than the best of the productive and irrigated agriculture lands. Moreover, these solar power units are not dependent on supply of any raw material and are self-sustaining. There is unlimited scope for solar electricity to replace all fossil fuel energy requirements (natural gas, coal, lignite and crude oil) if all the marginally productive lands are occupied by solar power plants in future. Thus the solar power potential of India promises to meet perennially, the requirements of its population.

As mentioned earlier, India has an estimated solar energy potential of about 750 GW, the state-wise estimated solar energy potential and installed solar capacity in the country as on 31.12.2016 presented in Figure 1.4 and Table 1.2. It indicates that Rajasthan accounted for the highest potential of 142 GW which is 19 percent of the total national potential followed by Jammu and Kashmir (15 per cent), Maharashtra and Madhya Pradesh (8-9 per cent each), Andhra Pradesh and

Gujarat (around 5 per cent each). These six states together accounted for 60 percent of total solar energy potential of the country.

Figure 1.4: State-wise Solar Energy Potential (in MW) in India 2015-16



Source: MNRE (2016).

The installed capacity of commercial solar thermal power plants which do not have a facility to store power; totals at about 227.5 MW in India; with 50 MW in Andhra Pradesh and 177.5 MW in Rajasthan. However, solar thermal plants with thermal storage are emerging as cheaper (US 6.1 ¢/kWh or Rs 3.97/KWh) and having a clean load, which also bring in more advantage, as they can supply electricity round the clock. They can cater the load demand perfectly and work as base load power plants when the generated solar energy is excessive on a particular day. Hence, a proper combination of solar thermal (storage type) as well as solar photo-voltaic type, could be appropriate to cater to fluctuations in load requirements throughout the day as well as in different seasons; thus limiting the need for procuring batteries for storage of power which are costlier options.

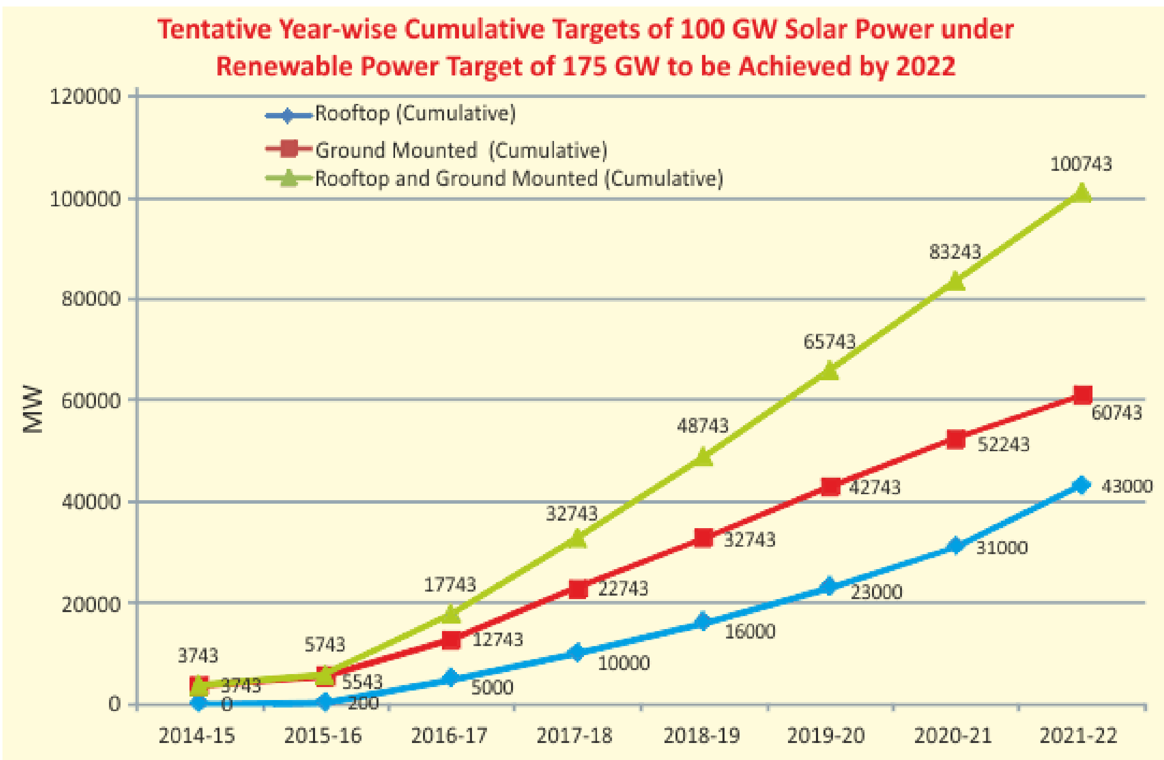
Table 1.2: State-wise estimated Solar Energy Potential vs. installed solar capacity in the Country as on 31.12.2016

Sr. No.	State/UT	Solar Potential (GWp) #		Installed Capacity (MW) as on 31.12.2016		Install capacity to Potential
		GW	% to total	MW	% to total	
1	Andhra Pradesh	38	5.1	979.65	10.9	2.58
2	Arunachal Pradesh	9	1.2	0.27	0.0	0.00
3	Assam	14	1.9	11.18	0.1	0.08
4	Bihar	11	1.5	95.91	1.1	0.87
5	Chhattisgarh	18	2.4	135.19	1.5	0.75
6	Goa	1	0.1	0.05	0.0	0.01
7	Gujarat	36	4.8	1158.5	12.9	3.22
8	Haryana	5	0.7	53.27	0.6	1.07
9	Himachal Pradesh	34	4.5	0.33	0.0	0.00
10	Jammu & Kashmir	111	14.8	1	0.0	0.00
11	Jharkhand	18	2.4	17.51	0.2	0.10
12	Karnataka	25	3.3	327.53	3.6	1.31
13	Kerala	6	0.8	15.86	0.2	0.26
14	Madhya Pradesh	62	8.3	840.35	9.3	1.36
15	Maharashtra	64	8.5	430.46	4.8	0.67
16	Manipur	11	1.5	0.01	0.0	0.00
17	Meghalaya	6	0.8	0.01	0.0	0.00
18	Mizoram	9	1.2	0.1	0.0	0.00
19	Nagaland	7	0.9	0.5	0.0	0.01
20	Odisha	26	3.5	77.64	0.9	0.30
21	Punjab	3	0.4	545.43	6.1	18.18
22	Rajasthan	142	18.9	1317.64	14.6	0.93
23	Sikkim	5	0.7	0.01	0.0	0.00
24	Tamil Nadu	18	2.4	1590.97	17.7	8.84
25	Telangana	20	2.7	973.41	10.8	4.87
26	Tripura	2	0.3	5.02	0.1	0.25
27	Uttar Pradesh	23	3.1	239.26	2.7	1.04
28	Uttarakhand	17	2.3	45.1	0.5	0.27
29	West Bengal	6	0.8	23.07	0.3	0.38
30	Delhi	2	0.3	38.78	0.4	1.94
31	UTs & Others	1	0.1	88.68	1.0	8.87
	TOTAL	750	100.0	9012.69	100.0	1.20

Notes: # Assessed by National Institute of Solar Energy; * includes 100.92 MW from other rooftop systems.
Source: http://mnre.gov.in/file-manager/annual-report/2016-2017/EN/pdf/4.pdf

The Government has up-scaled the target of renewable energy capacity to 175 GW by the year 2022 which includes 100 GW from solar, 60 GW from wind, 10 GW from bio-power and 5 GW from small hydro-power. The capacity target of 100 GW set under the National Solar Mission[6] (JNNSM) will principally comprise of 40 GW Rooftop and 60 GW through Large and Medium Scale Grid Connected Solar Power Projects (See, Figure 1.5 and Annexure IV). With this ambitious target, India will become one of the largest Green Energy producers in the world, surpassing several developed countries. The total investment in setting up 100 GW will be around Rs.6,00,000 crore. The existing solar thermal power plants (non-storage type) in India which are generating costly intermittent power on a daily basis, can be converted into storage type solar thermal plants to generate three to four times more base load power at cheaper cost without the need to depend upon government subsidies. Fig. 1.6 presents the tentative state-wise breakup of sector-wise renewable power target of 175 GW by 2022.

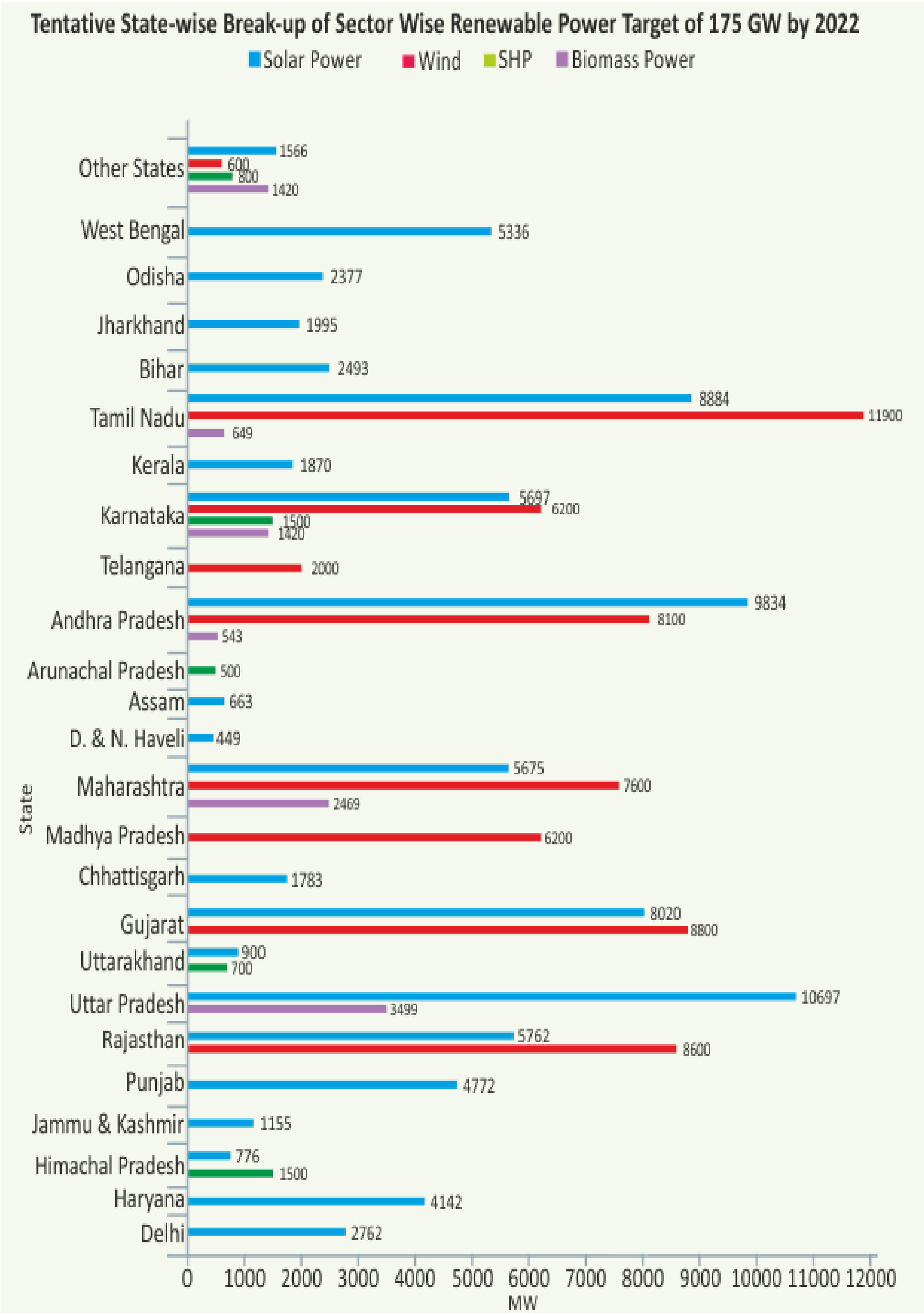
Fig. 1.5: Targeted 100 GW Solar Power under RE 175 GW by 2022



Source: https://mnre.gov.in

[6] https://mnre.gov.in/file-manager/grid-solar/100000MW-Grid-Connected-Solar-Power-Projects-by-2021-22.pdf

Fig. 1.6: Tentative State-wise Breakup of Sector-wise Renewable Power Target of 175 GW by 2022



Source: https://mnre.gov.in

1.3.2. Challenges and Possibilities

There are many challenges to the harnessing of solar energy in India as well. The per-capita land availability is low. Dedication of land for the installation of solar arrays must compete with other needs. The amount of land required for utility-scale solar power plants is about 1 km^2 (250 acres) for every 40–60 MW generated. It would be prudent to use the water-surface area on water-bodies such as canals, lakes, reservoirs, farm ponds and the sea for large solar-power plants. These water bodies could also be a ready source of water in order to clean the solar panels. Similarly, highways and railways may also avoid the cost of land nearer to load centers, thereby minimizing the cost of transmission-lines by deploying solar panels at about 10 meters above the roads or rail tracks. Solar power generated in the area covered by the roads may also be used for in-motion charging of electric vehicles or even trains, which could not only reduce their fuel costs but also waiting time for refueling and congestion on refueling stations as well as rail and road junctions. Solar panels installed on top of highways could also protect them against damage from rain and the summer heat, in turn increasing their life-span and also increasing comfort for the commuters by providing a shaded space to traverse on.

The architecture best suited to most parts of India would be a set of rooftop power-generation systems connected via a local grid. Such an infrastructure, which does not have the economy of scale of mass, utility-scale solar-panel deployment, needs a lower deployment price to attract individuals and family-sized households. Photovoltaic panels are projected to continue their cost reductions, enabling them to compete with the price of fossil fuels.

Greenpeace recommends that India should adopt a policy of developing solar power as a dominant component of its renewable-energy mix. In one scenario India could make renewable resources the backbone of its economy by 2030, curtailing carbon emissions without compromising its economic-growth potential. A study suggested that 100 GW of solar power could be generated through a mix of utility-scale and rooftop solar PV panels, with the realizable potential for rooftop solar PV panels between 57 and 76 GW by 2024. During the 2015-16 fiscal year the National Thermal Power Corporation (NTPC); with 110 MW solar power installations, generated 160.8 million kWh at a capacity utilization of 16.64 percent (1,458 kWh per kW)—more than 20 percent below the claimed norms of the solar-power industry. It is considered prudent to encourage solar-plant installations up to a threshold (such as 7,000 MW) by offering incentives. Otherwise, substandard equipment with overrated capacity may tarnish the image of the industry as well as the resource. Alarmed by the low quality of equipment, India issued draft quality guide lines in May 2017 to be followed by the solar plant equipment suppliers which are confirming to the Indian standards.

1.4 The Energy-Irrigation Nexus & Need of Solarization of Pumps:

India relies heavily on agriculture and irrigation is used in about 48.78 per cent of India's cultivated area, while the rest relies on monsoon rain (GOI, 2018). Thus, sound and expanded irrigation is critical for improving crop production and raising yields. For over 50 years until 2010, India ranked first with the largest irrigated area in the world (Renner 2012; www.fao.org[7]). 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 (Pearson and Nagarajan, 2014). 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 (Upadhyay 2014; SSEF, 2014).

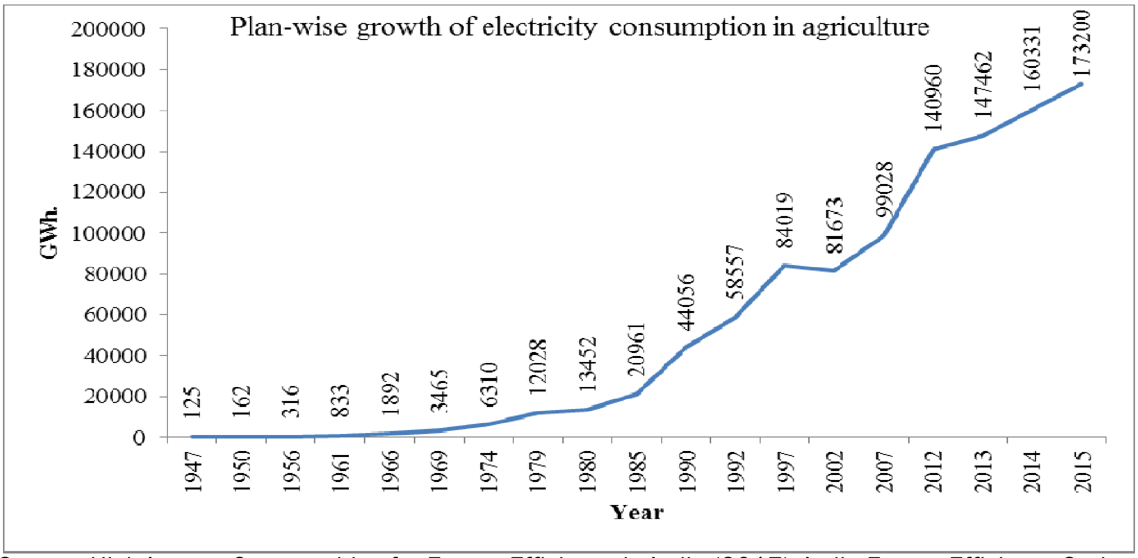
Indian farmers and the national and sub-national government both face several challenges with regard to irrigation. Electricity in India is provided at highly subsidized low tariffs, mostly at flat rates, and this has led to widespread adoption of inefficient pumps (Desai, 2012). Farmers have little incentive to save either the electricity, which is either free or highly subsidized, or the water being pumped, resulting in wasting both. To meet the dual objective, 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. Although the government heavily subsidies agricultural grid connections, grid electricity in rural

[7] http://www.fao.org/nr/water/aquastat/didyouknow/index3.stm

India is usually intermittent, fraught with voltage fluctuations, and the waiting time for an initial connection can be quite long (Banerjee *et.al*. 2015). Solar pumps provide freedom to farmers from these constraints, by giving a reliable access to irrigation on most occasions. However, some of the recent field studies have indicated that solar pumps have not been able to replace the electric or diesel pumps entirely (SKEF, 2018). For a few days in a year, farmers complement other pumps with solar pumps. Looking at the economics, the capital cost of solar pumps is high, but on a life-time cost basis, solar pumps may offer savings for farmers due to their low operating expenses.

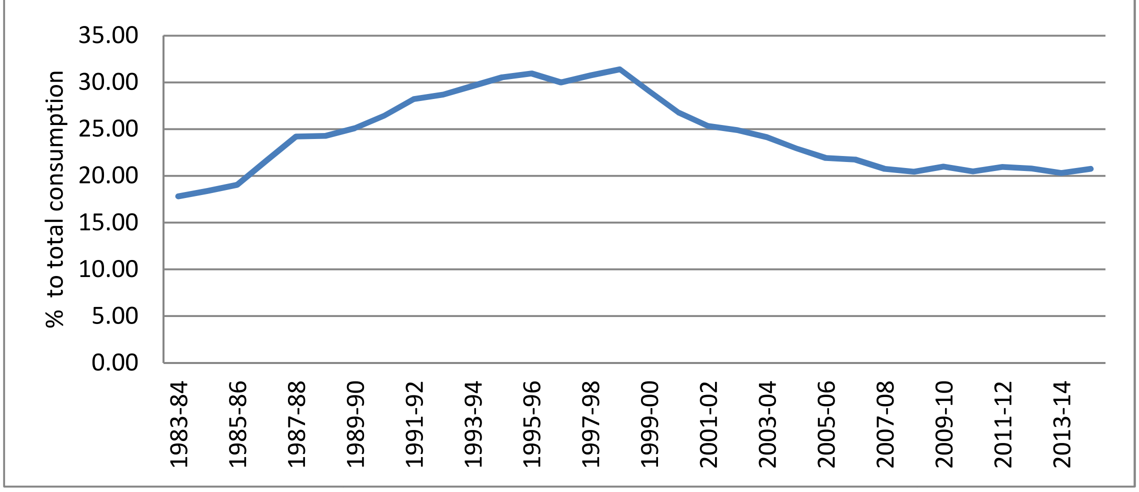
The generation of solar energy and irrigation for agriculture could be intricately related to each other. This is because India is a country that is fret with an irregular and ill-spread monsoon. Hence, irrigation is a pre-requisite for sustaining and increasing agricultural output. This is particularly 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. Agriculture is a State subject in India whereas water and power are on the concurrent list. Hence, along with the scarcity of water, the scarcity of power is another major issue plaguing Indian agriculture. The use of electricity in agriculture has increased significantly over the period of time from about 3 per cent of total electricity consumption in the country at the time of independence to more than 18 per cent in the year 2018 (see, Fig. 1.7 and Annexure V & VI), as availability of electricity has increased. Though share of electricity consumption had increased the highest level of 26.65 percent of total electricity consumption in 1997, it declined thereafter to around 18 per cent which may be due to low availability of electricity in relation to its demand (Fig 1.8). There is a growing demand for electrical energy for irrigation requirements in India. Electricity DISCOMS of many states have been facing acute power shortage which led to unrest among the farmers in many states (Murthy and Raju, 2009). The highest share of use of electricity in agriculture to total consumption during 2013-14 was recorded in the state of Rajasthan (40 per cent), followed by Karnataka and Madhya Pradesh (around 33 per cent), Andhra Pradesh and Haryana (around 30 per cent), while corresponding figure for Gujarat was 22 per cent (Annexure VII).

Figure 1.7: Growth of Electricity Consumption in Agriculture



Source: High Impact Opportunities for Energy Efficiency in India (2017), India Energy Efficiency Series

Fig. 1.8: Share of Agricultural Consumption to Total Consumption



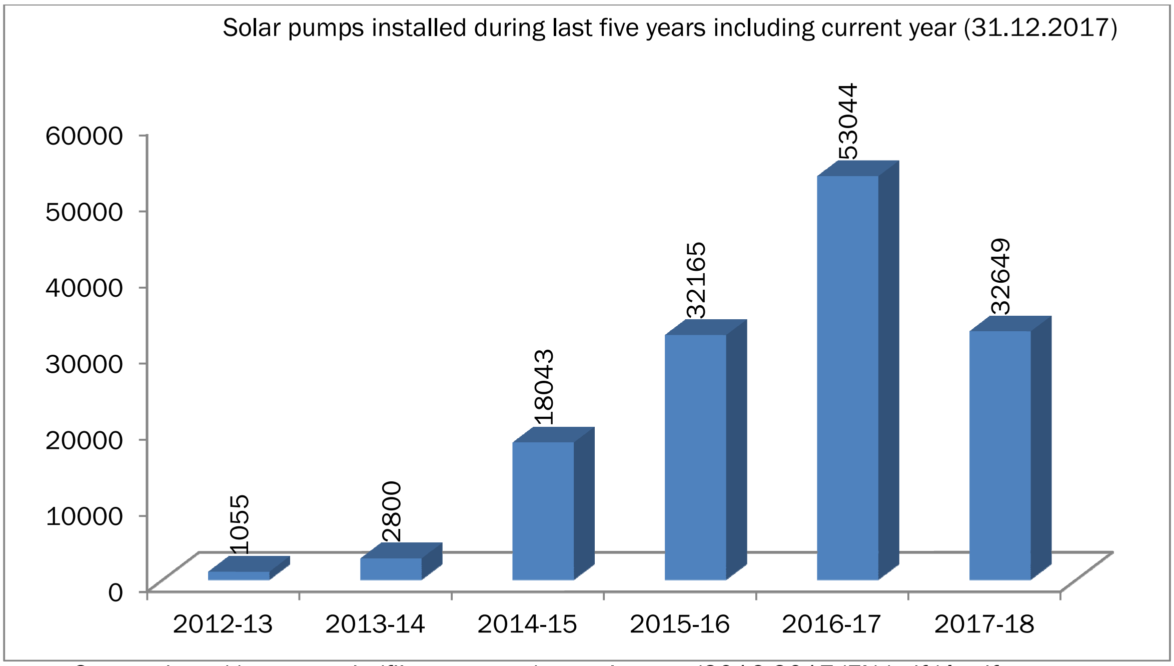
Source: GOI (2018).

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. 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. However, they constitute a rather unknown technical option, especially in the agricultural sector. Up till now, they have not been seriously considered in agricultural planning in the country. Despite inheriting the world's largest canal irrigation network in 1947, India today has become the world's biggest groundwater irrigation economy. However, providing farmers reliable energy for pumping is as much of a challenge as is making the availability of sufficient water. 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.

India currently has about 15 million electrified irrigation tube wells, with an estimated power subsidies on irrigation of about 70,000 crores (Shah *et al.,* 2016) that are responsible for the financial mess in our DISCOMs (Shah, et al., 2016). State governments dare not cut these subsidies owing to their political compulsions. Besides, the existing electricity supply is not far from sufficient, non-reliable, inferior and fluctuating in voltage and available at inconvenient hours. New electricity connections are hard to get, with a waiting list running into lakhs. In eastern India also, in spite of the abundance of ground water, the shortage of electricity supply hampers its harnessing for irrigation. As a result, a large proportion of irrigation is done through diesel-run pumps. About 9 million diesel pumps were currently being used for irrigation in India (Chawla and Agrawal, 2016). This burdens the exchequer with huge subsidies given on diesel; and also generates environmental pollution. In this scenario, 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 (Chawla and Agarwal, 2016).

Solar energy, long considered ideal for home lighting uses, has suddenly become attractive for pumping irrigation water (Shah, et al., 2014). India has already some 20,000 solar irrigation pumps in fields and famers everywhere seem happy with their performance and potential (Kishore et al, 2014; Tewary 2012). Solar water pumping systems constitute a cost-effective alternative to irrigation pump sets that run on grid electricity or diesel. Solar Photovoltaic (SPV) sets constitute an environment-friendly and low-maintenance possibility for pumping irrigation water. Studies estimate India's potential for Solar PV water pumping infrastructure to be between 9 to 70 million solar PV pump sets, corresponding to at least 255 billion liters/year of savings of diesel (HWWI, 2005). The government has acted positively in this matter and during the period 2012-13 to 2016-17 considerable progress ha s been made in installation of Solar Pumps (Fig 1.9).

Figure 1.9: Solar Pumps installation during 2012-13 to 2017-18



Source: http://mnre.gov.in/file-manager/annual-report/2016-2017/EN/pdf/4.pdf

1.4.1 Understanding the Economics of Solar Pumping[8]

The comparison between the solution offered by way of solarized irrigation vis-à-vis the conventional solutions depends on a number of factors, including

1. Initial capital costs (type and size of system, cost of shipping and installation);
2. Recurring costs (e.g. costs relating to operation and maintenance, labour and fuel);
3. Assurance of economic benefits (e.g. fuel savings, yield increase) to the users; and
4. Current expenditure on the provision of energy

A number of studies have assessed the economics of solar irrigation. The comparability of results is limited due to differing contexts, methodologies and cost assumptions. However, across the literature, there is an emerging consensus that solar based irrigation offers substantial economic benefits. In India, several studies point out the competitiveness of solarized irrigation compared to diesel-powered irrigation under a variety of conditions. Similar evidence is also available from Bangladesh, Benin, Chile, Egypt, Kenya, Zambia and Zimbabwe of the about the competitive costs of solarized irrigation as compared to irrigation through conventional sources. Indeed, subsidies offered for electricity and fuel affects their price in such as way that their cost to the consumer is affected, if comparable amount of subsidy were to be offered in solarized irrigation as well. The cost calculations stand to change drastically. While analyzing the economics of solar irrigation, two key aspects need to be examined:

1. Costs and benefits of solarized irrigation vis-à-vis irrigation from other sources should be considered; not only for the farmers but also to the government exchequer (Box 1.2). In the case of grid-connected pumps in particular, non-cost-reflective power tariffs distort the attractiveness of solar pumping solutions for farmers, although governments are increasingly recognizing the long-term economic benefits that can be gained from switching over the existing or new grid-connections for agricultural pumps into solarized irrigation pumps.

[8] Based on *www.energetica-india.net/download.php?seccion=articles&archivo...pdf*

Box 1.2: Cost Benefits of Solar Pumping

Farmers	*Governments*
• Supply of energy and improved access to water for irrigation • Improved crop yields and increased incomes • Reduced manual work and saving of time which could be used more productively • Enhanced crop resilience and food security • More income generating opportunities by combining crops of staple foods with high-value crops • Self-sufficiency in the matter of electricity for household use • Additional benefits for health, education and poverty alleviation; especially with respect to women	• Reduction in electricity and fuel use • Savings of payment of subsidies • Reduced fuel imports; savings of foreign exchange • Creation and development of employment in small or medium land-holdings, trade and businesses across the value chain • Improved reliability of power systems • Increased agricultural output for the population • Reduction in carbon emissions • A step towards resisting climate change

2. Different scales of farming (commercial, smallholder and subsistence) as well as existing irrigation practices (grid-connected, fuel-based and rainfed) need to be considered. The competitiveness of solarized irrigation could vary as farmers with smaller landholdings may adopt smaller, less capital-intensive irrigation options, such as petrol-diesel based pumps or they may also opt to pay for irrigation services purchased from others instead of investing to create the same on their own.

1.4.2 Recognizing the Environmental Impact

India uses more than 4 billion litres of diesel and around 85 million tons of coal per annum to support water pumping for irrigation. Solar irrigation has a substantially lower environmental footprint compared to traditional options. The potential environmental advantages from solar pumping, compared to conventional methods, is impressive. In India, it is estimated that 5 million solar pumps can save 23 billion kilowatt-hours of electricity, or 10 billion litres of diesel. This translates into an emissions reduction of nearly 26 million tonnes of carbon dioxide. Installing 50,000 solar irrigation pumps in Bangladesh could save the country 450 million litres of diesel and reduce emissions by 1 million tonnes of CO per annum. Thus, solarized irrigation offers an opportunity to achieve sustainable development through a reduction in carbon emissions a resilience against climate change (see, Box 1.3). This makes it a preferred contender for financing under the theme of meeting the challenges of climate change. For instance, the solar irrigation programme of Bangladesh IDCOL is supported by the World Bank under the Bangladesh Climate Change Resilience Fund. Similarly, the Nordic Climate Facility has provided funding for solar powered irrigation to farmers in Benin (Nordic Development Fund NDF and Nordic Environment Finance Corporation).

Box 1.3: Summary of Benefits and Impacts of Replacing Conventional Pumps with Solar

Benefits from replacing 1 million diesel pumps with solar pimps		**Impacts**
Reduction of diesel use	9.4 billion liters of diesel use over life cycle of solar pumps	Environmental
Subsidy savings	USD 1.26 billion (INR 84 billion) in diesel subsidy savings[9] over life cycle of solar pumps	Economic
Emission reduction	25.3 million tons of CO_2 emission abatement over life cycle of solar pumps	Environmental
Foreign exchange savings and relief of current account deficit	By reducing diesel imports, USD 300 million savings annually, USD 4.5 billion over pump life	Economic
Benefits from replacing 1 million electric pumps with solar pumps		impacts
Reduction of electricity use	Up to 2,600 million units of electricity, to relieve the overburdened old power grid	Economic and Environmental
Subsidy saving	USD 450-525 million (INR 30-35 billion) savings in farm power subsidies[10]	Economic
Emission reductions	2.5 million tons of CO_2 emission abatement	Environmental
Benefit agricultural output from installing 1 million solar pumps		**Impacts**
Improvement in crop yields[11]	10% increase in crop yields or USD 300 million (INR 20 billion) annually, USD 4.5 billion (INR 300 billion) over the pump lifetimes	Economic
Other Impacts of solar pumps		
Boosting relevant industry	Development of solar pump market and technology advancement	Economic
Job creation	Creation of small businesses/ employment across the value chain	Economic

Source: Shim (2017), Global Green Growth Institute, Seoul.

Looking forward, the global market for solar pumps is expected to reach over 1.5 million units by 2022 compared to approximately just 1,20,000 units in 2014. This means an increase of nearly twelve-fold in the market size. Reaching such a scale of deployment will require substantial efforts in order to develop an enabling environment in terms of policy support as well as fiscal measures that enable the strengthening of forward and backward linkages in the market.

1.5 Brief Review of Literature

Literature suggests that application of solar energy in irrigation could have myriad benefits. The primary benefit is that it is 'free'. However, the generating apparatus comes with high initial fixed costs like that of capital equipment, costs of installation, depreciation, interest, protection from theft, vandalism etc. Nevertheless, the marginal costs are indeed 'near zero' (operation, maintenance, repairs). The costs of expansion in irrigated area like that of hose pipes for transporting water across fields is also much lesser compared to operating a diesel pump or getting another electricity connection. Hence, solar pumps could not only provide cheaper irrigation but also expand irrigated area and thus increase the returns on agriculture. It could also extend the farming beyond the kharif season (monsoon); by harnessing ground water and thus aid the diversification of crops.

Solarization could also unshackle the farmers from the shortage of electricity supply and its inconvenient timings. They would be able to irrigate not only their own land, but also become irrigation service providers to their neighbouring farmers and also supplementing their own incomes in the process. Solarized pumps could promote conjunctive irrigation by promoting ground water extraction in flood-prone regions like north Bihar, coastal Orissa, north Bengal, Assam and eastern Uttar Pradesh (Shah and Kishore, 2012).

The Government of Rajasthan (GoR) began an aggressive promotion of solar irrigation pumps, offering a subsidy of as much as 86 per cent for the adopters. Governments of Bihar and West Bengal also rendered active support for supplying solar pumps to small farmers (Shah and Kishore, 2012).

Solar pumps enable the farmers to make immediate and visible savings on diesel costs (Tewari, 2012). Besides, solar pumps require less monitoring than diesel pump-sets, which makes the former a labour-saving option too. Tewari (2012) attributed the success of solar pumps in northern Rajasthan to the presence of the well-developed canal network, due to which there was already a prevalence of *diggies* (farm ponds) in the area; from which, low-lift pumping could be effectively done through solar pumps.

Shah et al., (2014) studied Karnataka's *Surya Raitha* policy that offers a guaranteed buy-back of surplus solar power from solar irrigation pump (SIP) owners at an attractive price, on the lines of Germany, Japan, Italy and California. Rooftop solar power generation for self-consumption as well as evacuation of the surplus power to the grid is rapidly emerging as a solution for providing electricity for irrigation as done in India (Gambhir et al., 2012). Surya Raitha scheme of Karnataka is to target several goals at one go i.e. improving agrarian livelihoods by providing farmers with a supplementary source of cash incomes for "growing" solar energy much in the same way as any other cash crop; and at the same time conserving the environment through a built-in incentive to conserve groundwater and energy use in pumping. Most importantly, it would enhance the quality of irrigation by providing farmers with a reliable and uninterrupted power supply during the convenient daytimes. It would also have a long term and much larger impact of reducing the carbon footprint of ground water irrigation done with the help of electricity or diesel-run pumps. As a positive side-effect, it could also improve strained finances of the state-run power distribution companies by reducing the burden of agricultural power subsidies. Thus Surya Raitha was expected to produce win-win outcomes for all the stakeholders of the ground water socio-ecology and farm economy. The present policy incentivises farmer against wastage of solar power or overuse of groundwater. The Surya Raitha scheme would pay them for the power produced by them and thus lead to the conservation of both solar power as well as the ground water pumped with it. With a net-metered SIP along with a guaranteed buy-back of surplus solar power, the farmer owning the SIP would now tend to use ground water sparingly, for which he would be encouraged to opt for micro-irrigation technology, At the same time, in order to meet the high costs of installation of SIP as well as micro irrigation system, he would be compelled to choose a crop-mix that brings high returns, i.e, highly productive or high-value crops.

In parts of western and southern India which are not only electricity-scarce but also water-scarce, Shah and Kishore (2012) advocate small farmers to form decentralized cooperative networks of solar power producers. These cooperatives could enable the farmers to not only fulfill their own energy needs through solarized irrigation but also gain supplementary income by selling their surplus in a joint manner. They could become economically viable if the state-owned electricity discom were to guarantee a buy-back of solar power from them. Mishra *et al.,* (2016) also concluded that the off-grid power production in India could be successful only if it is accompanied by policy support, local accountability mechanisms, proper selection of technology and scale of intervention, and capacity building among the communities to subvert local-level conflicts and elite capture.

Apart from the implicit and realized advantages of solarized irrigation, there are concerns also. Bassi (2015) vehemently argued that solar pumps are economically unviable because they are less efficient than diesel pumps and also do not bring any net environmental gain. He also feared an increase in ground water extraction. This is due to the fact that the marginal cost of solarized irrigation is near-zero, with no incentive for farmers to save power and in turn, economize on the use of groundwater. Shah and Kishore (2012) also flag the dangers of solarized irrigation pumps that could encourage completely unrestrained ground water extraction, leading to unprecedented harmful impact on ground water tables and worsen the situation in northern and western India. They advocate the prior formation of an effective demand management regime for ground water before promoting the replacement of diesel pumps with solar pumps. They suggest that instead of allowing the farmers to generate and use solar power freely, they should be organized for collectively evacuating their surplus power into the grid of the power distribution companies. The supplementary income that accrues to them in this manner could incentivize them to economize on their own power use as well as ground water extraction through that solar power. It could also insure them against a failed agricultural season.

Tewari (2012) observed that farmers in Rajasthan did not bother about the possible impact of solar pumps on ground water extraction because energy for irrigation and household needs was their crucial need. Kishore *et al.,* (2014) believe that solar pumps improve productivity of water only by 5-10 per cent; and also do not decrease the total volume of water use. They found that farmers were happy with the performance of solar pumps and the fact that they could get free energy for their domestic needs.

Kishore *et al.,* (2014) found that solar pumps mainly replaced diesel pumps and not electrical ones, with were accompanied by heavily subsidized or often free supply of electricity. Therefore, consumption of state-supplied electricity may not fall with the spread of solar pumps, particularly in those areas where agricultural power was non-metered (carrying a flat charge regardless of the quantum of use) and highly subsidized.

The promotion of solar powered irrigation based on a huge state-supported subsidy regime for the required capital expenditure practiced in states such as Rajasthan has been widely criticized. The Government of Rajasthan had tried to address the possible harmful impact of SIPs on ground water extraction by mandating that the subsidy on the cost of installation of SIPs could be given only to a farmer possessing a drip irrigation system as well as a farm-pond on his land. Kishore *et al.,* (2014) argued against this subsidy regime in Rajasthan by saying that the offer of a huge subsidy to the extent of 86 per cent on solar pumps was inefficient and misdirected. Bassi (2015) also raised a concern against this measure by arguing that the gains from this subsidy would accrue mainly to resource rich farmers who could meet its eligibility conditions with regard to micro-irrigation and possession of a farm-pond. Quite naturally, this would exclude those farmers who did not have the means to meet these eligibility conditions but may still be in dire need of irrigation facility. Besides, the welfare gains of this subsidy would be too little compared to the burden it would entail on the tax payers of Rajasthan State.

Kishore *et al.,* (2014) recommended that pro rata subsidy on purchase of solar pumps from a state-empanelled supplier should be discontinued. With pro-rata subsidy, neither the farmer nor the supplier had any incentive to negotiate the price or cut the costs of production. Hence, the price tended to remain sticky. Instead, if the farmer were given a lump sum subsidy, he would be free to purchase the solar pump-set from the market on the best terms that he could negotiate. There would also ensue a competition amongst supplier firms which could bring down the market price. This could also reduce the transaction costs for the State which would in turn, cut down on the total expenditure on the devolution of the amount of subsidy.

Tewari (2012) notes that empanelled firms charged prices higher than the market, while unregistered suppliers charged much lesser. In fact, if farmers purchased non-subsidized pumps on their own, they would be installed without the need to wait in a queue, go through the cumbersome formalities or bow down to corrupt practices. Moreover, the speedy installation of the SIP would bring an almost instantaneous savings on the costs of diesel costs; compensating for the subsidy that was foregone. Kishore *et al.,* (2014) suggests that if the farmers were given remunerative prices for selling the surplus power to the grid, self-investment on solar pump-sets would increase, resulting in lesser dependence on subsidies in the long run. Shah and Kishore (2012) rightly pointed out that subsidies in solar pumps would be meaningless and contradictory if they enriched supplier firms rather than farmers.

Shah, et.al (2015) estimated that one-hectare farm can generate annual gross revenue of R50,000 from field crops and Rs. 150,000 as an orchard. But if put under solar PV arrays, one hectare can generate over R1 crore/year from solar power. This revenue is free of risk from droughts, floods, pests and diseases. Moreover, growing solar power does not need seeds, fertiliser, pesticides, irrigation and backbreaking labour. All it needs is land, and farmers own half of India's land.

Gupta (2017) estimated the causal effect of solar water pumping program on water consumption, energy consumption, cropping intensity and cropping patterns of farmers in Rajasthan by conducting survey of 430 farmers from 6 districts-Jaipur, Sikar, Jaisalmer, Sriganganagar, Bikaner and Chittorgarh covering the period from 2011-12 to 2015-16. Author found that the solar pump subsidy program has increased energy and water access for solar pump adopters in Rajasthan. This has led to increase in cropping intensity, gross cropped area under fruits and vegetables, and annual profits of solar pump adopters in Rajasthan. Overall, this seems to be a good policy for enhancing food security and incomes of farmers, and reducing fossil fuel consumption of diesel and electricity consumption, which are associated with high degree of carbon emissions. Interestingly, author find that in all diesel using districts (except Chittorgarh) farmers are primarily dependent on canal irrigation and using solar pumps for distribution of water from diggi (water tank which stores canal and rain water). This implies promoting solar pumps in these areas provide win-win solution as farmer profits expand and fossil fuel consumption falls with no impact on ground water extraction. However, there is a evidence of increasing ground water extraction by small and medium farmers who have electric pumps (up to 11-13 HP) or no electric pumps in Jaipur and Sikar. Access to solar pumps enabled them to extract more groundwater and meet some amount of previously unmet irrigation water demand leading to expansion in area under cultivation and area under fruits and vegatables. Almost all solar pumps were of the size 3 HP, which is relatively small compared to the existing average electic capacity of 15 HP in Jaipur and 8 HP in Sikar. However, the extension of subsidy to larger solar pumps such as 5-10 HP could result in over exploitation of ground water in the long run in the ground water using districts as solar is free and farmers have no incentive to save water. Author advocate need 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.

Raymond and Jain (2018) opined that connecting solar pumps to the electric grid is expensive for the government and benefits farmers lesser than subsidies for the purchase of solar pumps. The cost to the government to subsidise a 3HP stand-alone solar pump at 60 per cent, or to provide a grid connection to an existing solar pump and pay the farmer a feed-in tariff for surplus energy over 15 years is approximately equal. However, the farmer's cost under the capital subsidy scenario is 53 per cent lesser than that in the grid-connected case, despite revenues from the feed-in tariff. Connecting solar pumps to the grid may provide some additional revenue to solar pump owners. However, they would prefer selling water using surplus energy, should there be a local demand. Equivalent revenue that a farmer can gain for such pumping service is INR 20 per kWh, which is much higher than the feasible feed-in-tariff. However, not all the surplus energy can be utilised for selling water locally, as the demand is also seasonal and intermittent. Water-as-a-service using solar pumps by village level entrepreneurs is a promising model to improve both the utilisation of solar pumps, and provide irrigation access to marginal farmers. The viability of solar pump sharing and the significance of the revenue from it remain sensitive to the timing of local irrigation needs. In areas with a dominance of diesel pumps for renting or selling water, solar-based water-as-a-service model could have a payback of two to four years. Encouraging pump sharing could be an opportunity for the government to increase the utilisation of solar pumps. It would increase the impact of government support while creating a market-based solution for efficient and judicious use of the ground water.

In light of the above, this study attempts to study the status of solarisation of agricultural pumps in Western India covering two pioneering states in adoption of solar power technology, viz. Gujarat and Rajasthan).

1.6 Objectives of the study:

- To study the coverage of solar irrigation pump in selected states of Western India
- To study the features and relative economics of the use of solar irrigation pumps
- To study the problems faced by the farmer in installation of solar pump
- To suggest suitable policy measures to expand solarization of irrigation.

1.7 Data and Methodology:

The study is based on both, the secondary and primary data. The secondary data pertaining to the data on coverage of solar irrigation pumps across the States and regions, details of implementing agency/cies and various schemes in operation for the promotion of solar irrigation pumps, district-wise coverage of solar irrigation pumps, list of beneficiary farmer households under solar irrigation pump subsidy programme were collected from the nodal agency of State Government, published sources and related websites.

For the study, primary data were collected from randomly selected farmers from four districts from different regions of both the selected states for study, voz. Gujarat and Rajasthan State with the help of structured and pre-tested schedules/questionnaires from the following categories of respondents:

- Beneficiary farmer households (BEN- farmers who had adopted SIPs with the help of subsidy by the government),
- Non-beneficiary farmer households (NONBEN- farmers who had adopted SIPs without any support in the form of subsidy by the government),
- Non-Solar user household (NSUSER- farmers who had not adopted SIPs)

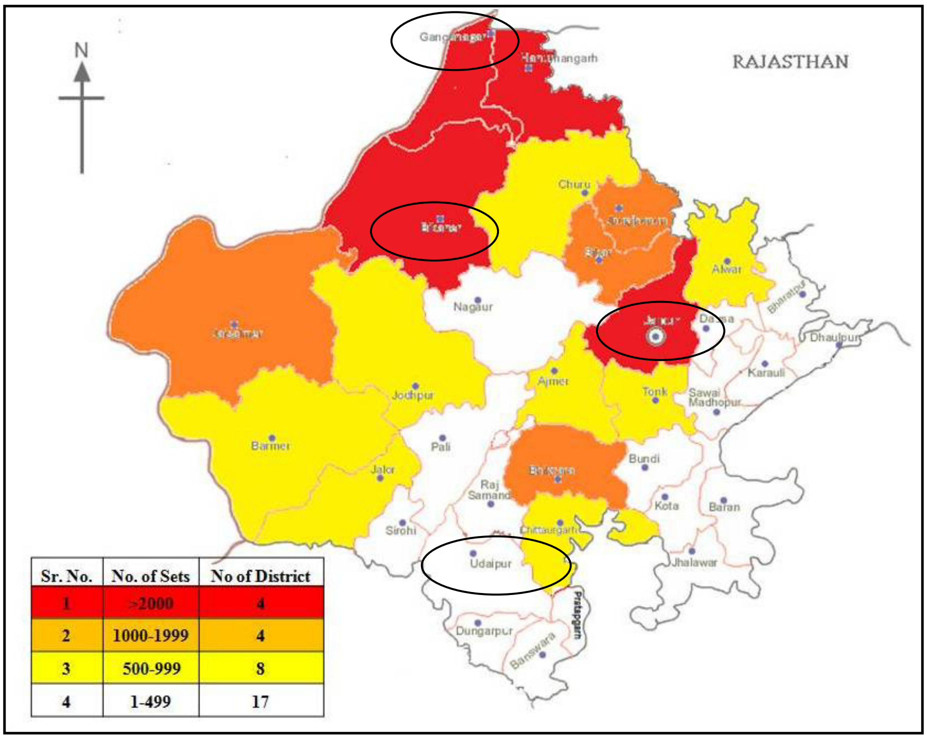
1.7.1 Study Area

The area of study was the State of Gujarat and Rajasthan. The four districts have been chosen from four regions of the each state as they represent the characteristics of that region and are also relevant to research problem under study, i.e. solarisation of irrigation pumps (Map 1.1 and 1.2). The selected four distinct districts in both States in the study area could capture a holistic picture of problem under study at state level. The districts were chosen as the study area as they exhibit a variety of challenges such as a scarcity of electricity connections, falling ground water tables, scarcity of rainfall and surface water structures as well as economic and social backwardness to an extent. On the positive side, these districts also present an interesting opportunity of studying the problem under consideration, since the penetration of solar irrigation technology has reached promising figures and could throw in some important lessons with regard to how could the further expansion of solarised irrigation be done and what could be the constraints for the same. The selected districts in Gujarat state were Sabarkantha, Dahod, Narmada, and Bhavnagar while Jaipur, Bikaner, Udaipur and Sriganganagar districts were selected in Rajasthan State.

Map 1.1: Location Map of Selected States

Map 1.2: Four Agrarian Socio-Ecologies of Gujarat & Location Map of Study Districts

Map 1.3: Solar Map of Rajasthan and Location Map of Study Districts in Rajasthan



1.7.2 Selection of Sample Respondents

All the farmers using solarised irrigation in the selected districts were treated as the universe for this study. There exists a wide variety in the farmers using solarised irrigation in Gujarat and Rajasthan. Firstly, there are the obvious differences unequal land ownership and caste. Further, farmers differ in terms of source of irrigation, i.e. ground water or surface water, method of irrigation i.e. micro (drip and sprinkler), lift or flood irrigation, electric-powered, diesel-powered or purchased irrigation service also, farmers in different regions exhibit different practices. Then there is a variation in terms of the cropping pattern also, across different agro-ecological zones of Gujarat and Rajasthan. Similarly, there is a wide variety amongst adopters of solarised irrigation in both the States as they could use either AC or DC powered solar pumps, submersible or surface pumps; and also use solar pumps in conjunction with or without micro-irrigation on their farms (see, Annexure VIII). With respect to financial costs of SIPs, very few farmers have adopted subsidized solar pumps while there are also those who have purchased them at market rates without availing of government subsidy. This wide variety of beneficiaries, financing models and implementing agencies were taken care of, as much as possible while selecting the sample respondents for the study.

The models of subsidy also differ according to the subsidising tier of government, i.e. whether the subsidy is provided by the State or the Central government, and which is the agency that implements the scheme at the ground level, because agencies are more than one. For instance, there are two agencies to implement the SIP scheme in Gujarat, viz. *Gujarat Green Revolution Company* (GGRC) and *Gujarat Urja Vidhyut Nigam Limited* (GUVNL) (having four GoG-owned electricity companies in Gujarat namely UGVCL, MGVCL, PGVCL and DGVVL- see Annexure X). While Department of Horticulture, Government of Rajasthan, Jaipur is the nodal agency to implement the solar scheme in Rajasthan thorough JNNSM and State Resources.

Sampling Framework

Total sample size for the study was 249 sample households consist of 200 beneficiary households, 40 non-adopters and 9 non-beneficiary households (Table 1.3). As mentioned earlier, primary data were collected from the selected sample households from selected four districts from four regions having highest number of solar pump installations done and then selection of villages therein by adoption same criteria keeping in view service provider and AC/DC pumps. The region-wise selected districts and number of households are presented in Tables 1.4 to 1.5. From each of the selected region and district, villages having highest number of solar pump installations done by the most dominant service provider were selected.

Table 1.3: Number of Selected Sample Households in Western India

Sr. No.	Selected states	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

- Four districts from four regions of the states were selected.
- Four districts were selected from different regions/zones in order to capture holistic macro picture at the state level.

- Accordingly, Sabarkantha, Dahod, Narmada and Bhavnagar districts were selected in Gujarat while Jaipur, Bikaner, Udaipur and Sriganganagar districts were selected in Rajasthan state.
- In Gujarat state, there are two agencies to implement the solar scheme in Gujarat, viz. Gujarat Urja Vidyut Nigam Limited (GUVNL) and Gujarat Green Revolution Company (GGRC). Selection of sample villages was done in such a way that it took cognizance of both the agencies as per their dominance in terms of the number of SIPs installed in a particular village, Thus, villages were selected which had dominance of GVNL and also one village was selected where GGRC was dominant. Total 100 beneficiary households, 1 non-beneficiary households and 20 sample non-adopter households were selected, making total sample of 124 households.
- In Rajasthan, as mentioned earlier, Department of Horticulture, Government of Rajasthan is nodal agency to implement the solar scheme in Rajasthan thorough JNNSM and State Recourses. Total sample size for the study was 125 comprised of 100 beneficiary households, 5 non-beneficiary households and 20 non-solar adopters from four districts of Rajasthan

Table 1.4: Details on Number of Selected respondents in Gujarat

Sr No	*Selected Region and District*	*Selected provider/agency and users*				
		Beneficiary hh		*Non beneficiary hh*	*Non-adopters*	*Total*
		GUVNL	*GGRC*			
1.	South-Narmada	24	1	1	5	31
2.	East- Dahod	24	1	0	5	30
3.	North-Sabarkantha	24	1	2	5	32
4.	West- Bhavnagar	24	1	1	5	31
		96	4	4	20	124

Notes: GUVNL: Gujarat Urja Vikas Nigam Limited (4GEBs/DISCOMs); GGRC: Gujarat Green Revolution Company Ltd.

Table 1.5: Details on Selected Sample Households in Rajasthan state

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

1.7.3 Case Study of First Solar Irrigation Cooperative

In order to get ground reality about solar adoption and power generation, case study on first ever cooperative of farmers for decentralized solar power generation and usage in irrigation formed 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 earlier by the authors are presented and discussed.

1.8 Data Collection and Analysis

Personal visits were undertaken in each village and information from sample farmers was collected with the help of a structured questionnaire. The data was coded, cleaned, edited and tabulated for the purpose of further analysis. The data was analysed with the help of simple statistical measures like calculating the mean, median and mode as well as advanced tools like ANOVA as and where it was found suitable. Conclusions were drawn from the study on the basis of the research findings which were used to make policy recommendations for expanding and the area under solarised irrigation in Rajasthan state and enhancing its efficiency in terms of energy use, water use, agricultural production and productivity as well as and farmer welfare in Rajasthan; in addition to the wellbeing of the society at large through the spread of this renewable technology.

Garrett's ranking technique:

To find out the most significant factor which influences the decision of respondent, Garrett's ranking technique was used. As per this method, respondents have been asked to assign the rank for all factors and the outcome of such ranking have been converted into score value with the help of the following formula:

Percent position = 100 (Rij – 0.5) / Nj

Where Rij = Rank given for the ith variable by jth respondents

Nj = Number of variable ranked by jth respondents

With the help of Garrett's Table, the percent position estimated is converted into scores. Then for each factor, the scores of each individual are added and then total value of scores and mean values of score is calculated. The factors having highest mean value is considered to be the most important factor.

1.9 Limitations of the Study

The primary data were collected from the respondent of beneficiary, non-beneficiary and control group households. As none of the solar pumps has fitted with meter to record solar power generation and uses system, thus exact amount of energy generated and used for irrigation could not be estimated. Also very few farmers have installed solar pumps on their own cost and list of such farmers is not readily available. Thus though we wanted to include more number of non-beneficiary respondents, difficulty was faced in tracing/identifying them, which restrict our sample size of non beneficiary households to total nine only.

1.10 Structure of the report

The present study report is divided into six chapters including this introductory chapter. Chapter I discuss in brief about the renewable energy resources at global level, renewable and solar energy scenario in India, energy-irrigation nexus & need of solarization of pumps, brief review of literature, data and methodology, limitations of the study and organsiation of report. The second chapter presents the status of solar irrigation pumps in Gujarat and Rajasthan highlighting the policies adopted by the government towards same. The results on case study conducted by authors in May 2016 and lesson from a novel solar irrigation cooperative started in Gujarat state covering the aspects of inception of Dhundi Solar Irrigation Cooperative, financial arrangements and functioning of DSUUSM, potential Benefits from and impact of DSUUSM, interventions by IWMI and sustainability of DSUUSM is discussed in Chapter III. Chapter IV presents the findings from the field survey data from Gujarat while results from field survey data from Rajasthan were discussed in Chapter V. Last chapter presents summary and conclusions of the study.

The next chapter presents status of solarisation in India with focus on Gujarat and Rajasthan state.

Chapter II

Policies Supporting Solar-Powered Irrigation in India

2.1 Introduction:

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.[1] 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

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

of Solar RPO compliance; analyzing key issues related to the regulatory framework for solar in various states of India.

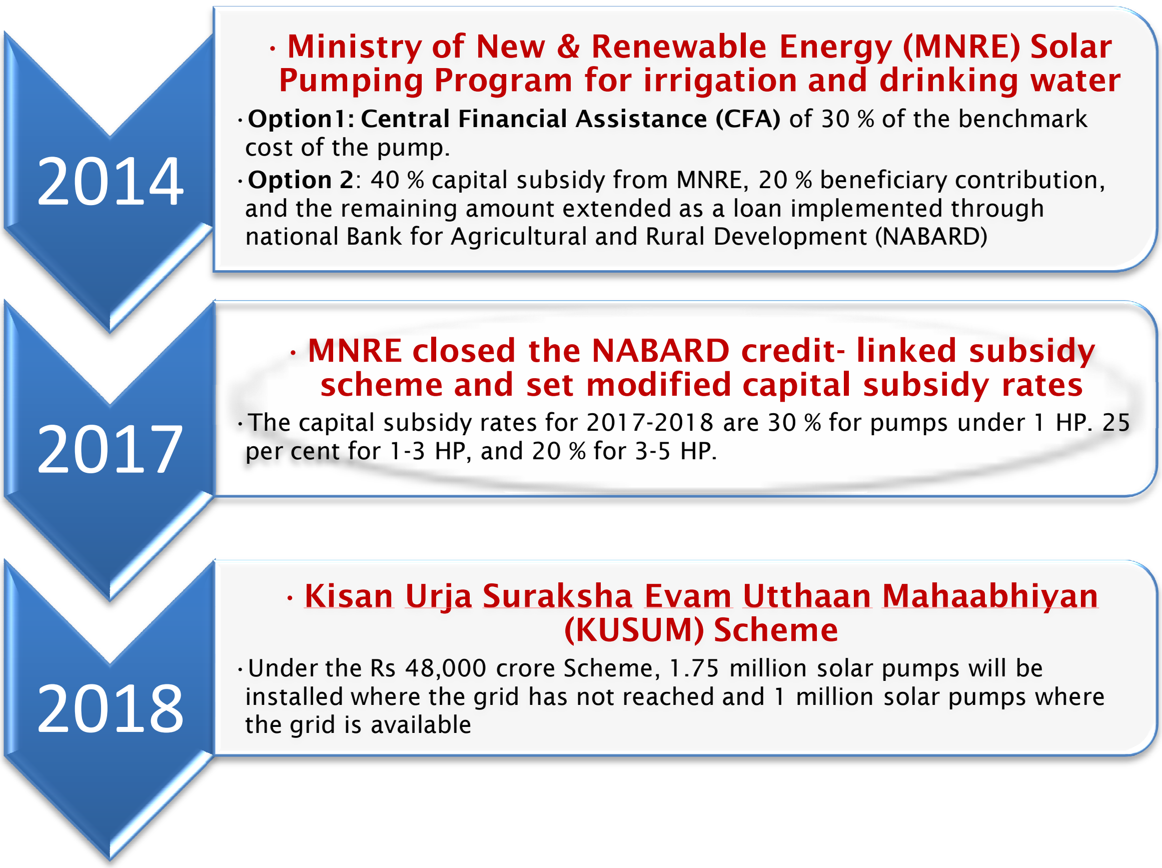
2.2 Policies Supporting Solar-Powered Irrigation in India

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 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).

Figure 2.1: Policies Supporting Solar-Powered Irrigation in India



Source: Ministry of New and Renewable Energy, GOI.

2.2.1 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.

2.3 Status of Solarisation of Agricultural Pumps in Gujarat

Gujarat state has made rapid strides in its agriculture sector including the agribusiness sub-sector during recent past. The spectacular agricultural growth in Gujarat in recent times has been a result of a well thought out strategy, meticulously planned and coordinated scheme of action, sheer hard-work and sincerer implementation of programme, political will to take bold decisions and commitments to economic policy reforms by the state government. Agriculture in Gujarat has been transforming over time from traditional crops to high value added commercial crops which can be seen from a shift in its cropping pattern from food grains to cash crops. The trend in shifting of cropping pattern paved a way for many ancillary industries in the areas of processing, packing, storage, transformation, etc. Agricultural growth in the state is favored by the variety of soli and climatic conditions prevalent in its eight agro-climatic zones, the enterprising culture amongst the farming community, policy support from the government, wealth of livestock population, long and extended coast line as well as the contribution by the agricultural scientists in the field of research and development of modified crops and a vibrant and dedicated group of NGOs working in the field of agricultural progress. The Gujarat government has aggressively pursued an innovative agriculture development programme by liberalizing markets, inviting private capital, reinventing agricultural extension (with initiatives such as Krishi Mahotsav, ikisan portal), improving rural connectivity through provision of roads and other infrastructure such as electricity (with initiatives such as Jyotigram Scheme for providing guaranteed electricity to farmers for eight-hours per day through dedicated feeders). The mass-based water harvesting and farm power reforms in the dry and arid areas of Saurashtra, Kachchh, and North Gujarat have helped energise Gujarat's agriculture. In this chapter, the status of solaristaion of agricultural pumps in Gujarat is discussed in detail.

2.3.1 Energy Overview of Gujarat

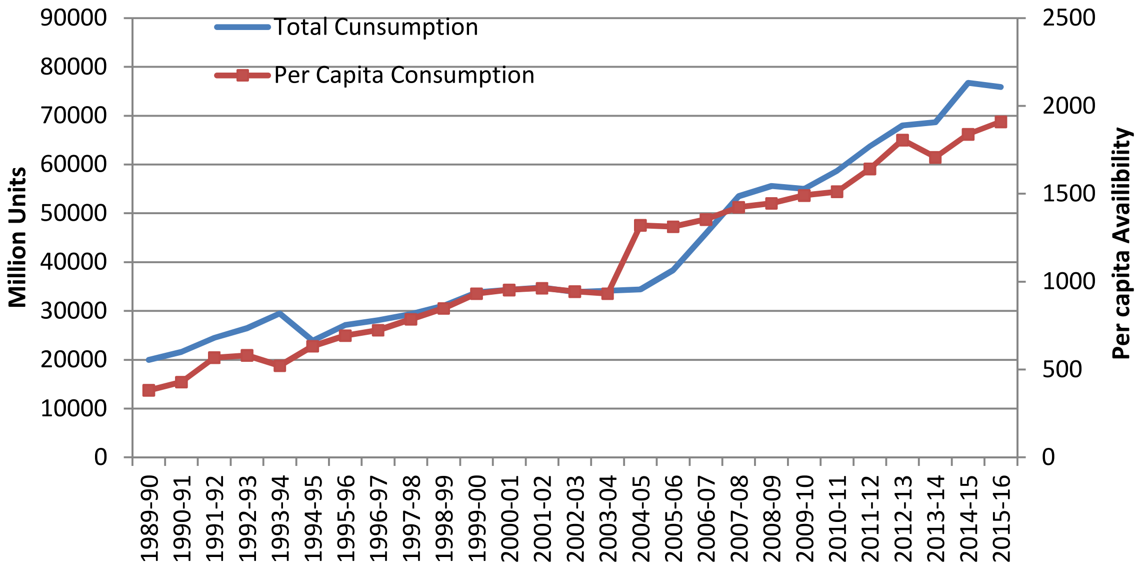
Gujarat has recorded significant economic growth over the past decade. Gujarat leads the country in the per capita consumption of electricity[2].Power is a key factor for the overall growth of the economy and the state of Gujarat has attracted a large number of private players in the sector in recent past. Installed capacity of the State has increased from 315 MW in 1960-61 to 27200 MW up to October 31, 2018[3]. Per capita consumption of power in the State of Gujarat in 2016-17 was 1717 kilowatt per hour. Out of total installed capacity of the State, 6152 MW is developed by the State, 8121 MW by private sector and 4227 MW by the Central sector. The State of Gujarat accounts for around 9 per cent of total energy requirement in India. Gujarat has been power surplus since 2009. Currently Gujarat's peak demand is 15,142MW. For agricultural consumers 8 hours 3 phase supply is given. Extended hours of supply are also provided to farmers to safeguard the standing crops as per the farm requirements. Total consumption of electricity has increased significantly over the period of time and same the case with use of electricity in agriculture. However, share of electricity use of agriculture to total consumption which was around 26 percent in 1989-90 had reached to highest figure of around 45 percent in 2000-01 and has now declined to around 23 percent in 2015-16 (Fig 2.1 and 2.2).

The state aims to become a hub for power generation activities with its focus on doubling the power generation in order to keep pace with the rising energy demand, which is poised to grow at a rate of 10 per cent every year. In the all-India scenario where in almost every state, the power-generation companies and electricity boards of various States are incurring huge losses, Gujarat is the shining exception. It has successfully converted losses to the tunes of Rs.2500 Crores in to profits to the tune of Rs. 400 Crores. Gujarat has separated the power grids for each of the three clusters of users such as industrial, residential and

[2] http://www.gidb.org/power-sector-gujarat
[3] https://guj-epd.gujarat.gov.in/webcontroller/page/project

agricultural consumers which was done under the Jyotigram scheme[4], making it unique state where power producing private sector companies could have a seamless power evacuation. Gujarat has highest number of power substations of 66kv and above in India. All the 18245 villages of Gujarat are getting uninterrupted electricity-supply of good quality i.e. two-phase power without voltage fluctuations. The coming years will witness Gujarat emerging as a hub not only for power generation from conventional sources but also from the more environmentally friendly renewable sources. Looking ahead with concerns about the carbon footprints, the State is proactively considering development of renewable energy sources. For this, the State has also declared a separate Solar Power Policy so as to encourage solar power generation projects as a means for socio-economic development of backward regions through livelihood creation for the local population.

Fig. 2.2: Growth in Total Electricity Consumption and Per Capita Availibility in Gujarat



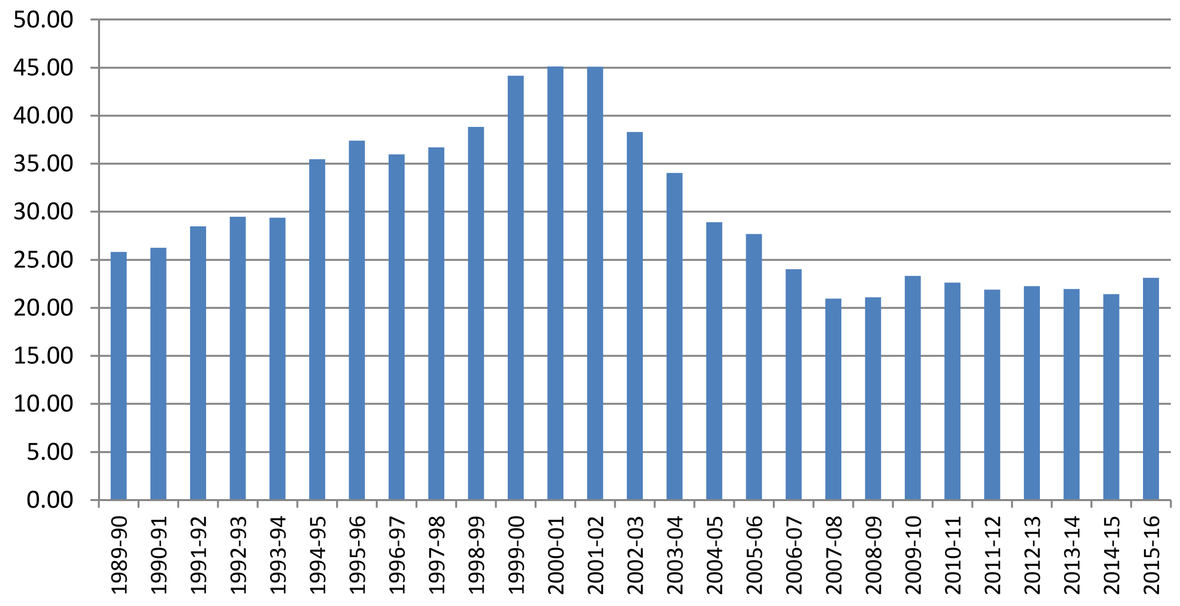
2.3.2 Solar Power Policy of Gujarat State

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

[4] http://guj-epd.gov.in/epd_jyotiyojna.htm

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.

Fig. 2.3: Share of Electricity Use in Agriculture to total consumption in Gujarat



Solar Power Policy in 2009

Gujarat has been in the forefront of industrial development in India and has shown significant leadership in other spheres of economic and social development too. It has sustained this leadership through regulatory and other value-added interventions with an aim to reduce the spread and depth of negative externalities and reduce vulnerability of various classes and sector in multiple spheres of economic development. In view of same, the State had 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[5]. 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.

Solar Power Policy in 2015

Gujarat's Solar Power Policy 2009 was framed to establish and jumpstart utility-scale solar power generation not only in the State but also in the whole country, Gujarat Solar Power Policy 2015 aims to scale up the solar power generation in a sustainable manner. The objectives of 'Gujarat Solar Power Policy 2015[6]' are as follows:

- To promote green and clean power and to reducethe State's carbon emission;
- To reduce dependency on fossil fuels for energy security and sustainability;
- To help reduce the cost of renewable energy generation;
- To promote investment, employment generation and skill enhancement in the renewable energy sector;
- To promote productive use of barren and uncultivable lands;
- To encourage growth of local manufacturing facilities in line with the 'Make in India' programme;
- To promote research, development and innovation in renewable energy.

[5]TERI (2012).
[6]Energy and Petrochemicals Department, G.R. No. Slr-11-2015-2442-B, Sachivalaya, GOG, Gandhinagar, dated 13.08.2015. This policy shall remain in operation up to 31.03.2020.

2.3.3 Status of Solar Power Generation

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 with DISCOM. According to a report by the Low Emission Development Strategies Global Partnership (LEDS GP), these attributes are complemented by political will and public investment. 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.

Solar Park

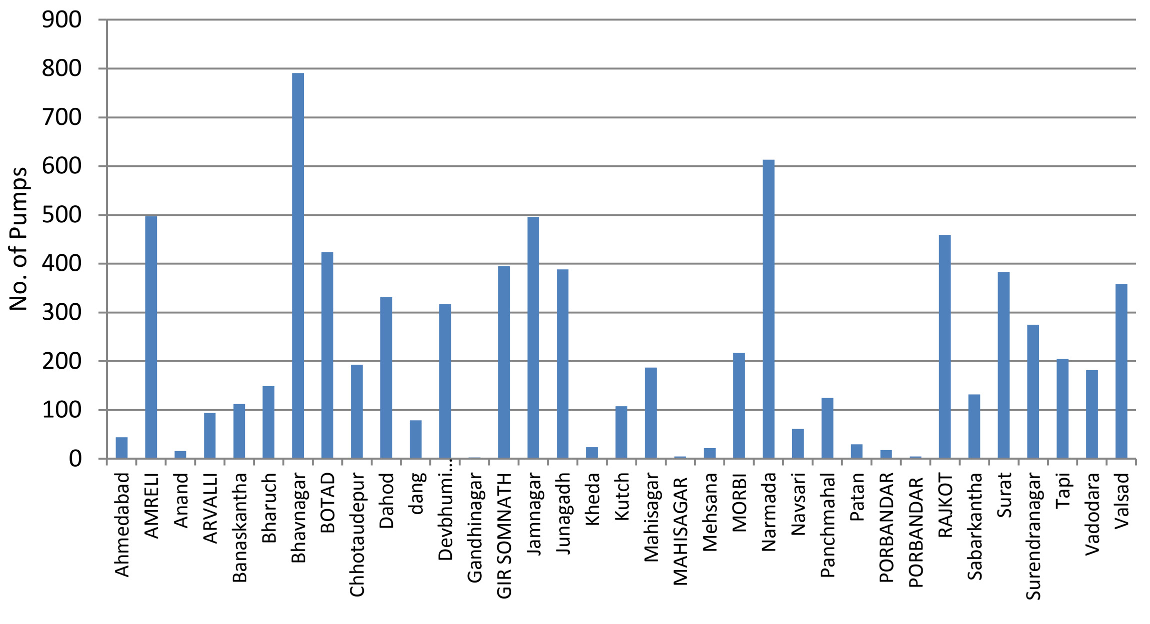
Government has successfully implemented pilot projects of solar power generation which is gaining traction at several grassroots-level interventions. Grassroot Trading Network for Women (GTNfW), an initiative by Self-Employed Women’s Association (SEWA), is in the process of implementing one such project by setting up a unique solar park of 2.7-megawatt (MW) capacity. The project will ropein 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 planhas 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.

2.3.4 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 (Fig. 2.3 and see Annexure X).

Fig. 2.4: District-wise Coverage of Solar Pumps in Gujarat



The GGRC Limited, Gujarat as per the directions of MNRE (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 Gujarat with the following types of pumps and subsidy norms (Table 2.1). As per subsidy norms for Solar Powered Irrigated Pumps (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.

Table 2.1: Subsidy Norms with Cost and Types of Solar Water Pumps in Gujarat (in Rs.)

Sr. No.	Type of Pumps	For Banaskantha and Kutch Districts			For Other Districts of the State		
		Total Cost	MNRE (GOI) subsidy amount	Farmer Contribution	Total Cost	MNRE (GOI) 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.

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 success story of solar with MIS is presented in Box 2.1. 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 (see, Box 2.2). The recent announcement of Government of Gujarat related to expansion of coverage of solar with target is presented in Box 2.3.

Gujarat also provides subsidy for solar rooftops and surplus power that could be injected into the grid for by farmers to earn income from the same. So far, solar systems aggregating 208 MW have been commissioned across different categories. The state ranked second in solar rooftop installations in India as on July 2017. State-run GUVNL has already sought Gujarat Electricity Regulatory Commission (GERC) approval to an arrangement for procuring power from the salt-pan workers.

Box 2.1: Solar with Micro Irrigation Success Story (Case Study) in Gujarat

Name of Farmer	Harshadbhai Ambalal Patel
Registration Number	156-And-144
Mobile No	9714108520
Crop	Banana
Area Under Micro Irrigation(Ha)	0.46
Crop Production before adopting micro irrigation	38000-40000 Kg. (Area 0.40 Ha.)/1500 Plants
Crop Production After Adopting Micro Irrigation	55000-60000 Kg. (Area 0.40 Ha.)/1500 Plants
Profit Before Adopting Micro Irrigation	Appr. Rs.1,50,000/- To 1,80,000/- (Area 0.40 Ha.)/
Profit After Adopting Micro Irrigation	Net Profit Is Rs.2,50,000/- (Area 0.40 Ha.)/
Farmer's Experience About Micro Irrigation & Production	1. Farmer is adopting solar pump with drip irrigation, therefore electricity & water saving is possible. Extra Irrigation Facility Is Available For Other Fellow Farmers.
	2. Weeding is reduced when drip irrigation is available in the irrigation system, so labor costs are also saved and due to low depletion, the disease are also gets reduced
	3. In the drip system, fertilizers are saved and fertilizer can be given to the fixed area in low quantity. Due to the availability of fertilizers in the liquid form, it has a good effect on the quality and also production of the crop.
	4. Any kind of pesticide/fungicide can be given through drip irrigation.
	5. Solar pump facilitates easy and longer maintenance of electricity.
	6. No Fuel Is Required To Operate A Solar Irrigation Pump.
	7. Due to drip irrigation method, the farmer gets good income from the qualitative production in the year, as a result, the farmer has paid the cost of solar and drip irrigation system in the current year only.

Source: Office of GGRC, Vadodara.

Box 2.2: Government of Gujarat Resolutions regarding Solar Irrigation water pumps (by Energy & Petrochemicals Department, Government of Gujarat, Gandhinagar)

Date	Resolution No.	Subject
25-09-2014	GR No.:BJT-2014-1447-K1	Regarding the plan to make solar energy powered irrigation pump sets available to the farmers in the state
26-11-2014	GR No.:BJT-2014-1447-K1	Correction in Resolution regarding plan for providing solar energy powered irrigation pump sets to the farmers in the state.
09-12-2014	GUVNL/Tech/AKF/Solar/2033	Procedures initiated at DISCOM level
02-02-2015	GR No.:BJT-2014-1447-B	Correction in Resolution regarding plan for providing solar energy powered irrigation pump sets to the farmers in the state.
19-08-2015	GR No.:BJT/2014/1447/B	Correction in Resolution regarding plan for providing solar energy powered irrigation pump sets to the farmers in the state.
27-05-2016	GR No.:BJT/2014/1447/B	Correction in Resolution regarding plan for providing solar energy powered irrigation pump sets to the farmers in the state.
10-02-2017	GR No.:BJT/2014/1447/B	Correction in Resolution regarding plan for providing solar energy powered irrigation pump sets to the farmers in the state.
27-06-2018	SLR/11/2016/2284/B1	Regarding declaring "SKY Yojana" (Surya Shakti Kisan Yojana) in the state
29-09-2018	SLR/11/2016/2284/B1	Regarding the Correction of the resolution in the state regarding "SKY Yojana" (Surya Shakti Kisan Yojana)

Source: https://guj-epd.gujarat.gov.in/webcontroller/page/government-resolutions.

Box 2.3: Gujarat to add 15,000MW of Renewable Power by 2022

The Gujarat government on 17.01.2019 announced Rs, 1 lakh crore investments in the renewable(RE) sector in the next three years, aimed at adding 15,000 MW capacity. The state government also plans to reduce dependence on thermal power by increasing the share of RE sector in total power generation from the existing 28 % in next three years. Addressing reporters at après conference here on Thursday, state energy minister said that Gujarat has taken a lead in fulfilling vision of Hon PM developing India's RE sector capacity to 175 gigawatts by 2022. Of the 15,000 MW additional powers generation in the state 10,000MW will be from wind power. At Dholera, Special Investment (SIR), 5,000MW of solar power generation capacity will be added. Government of India has decided to establish 1,000MW mid-sea wind power plant with investment of Rs.15,000 crore near Pipvav.Solar parks of 700 MW at Radha-Nesda, and of 500Mw at Harsad will be developed. Government waste land situated close to 66KV substations will be used for developing solar power generation facilities. Total 3,000MW capacity will be developed at 50 sub stations. Gujarat government will purchase renewable energy directly from those who produce 500KW to 4MW. Government will sign agreements for 25 years. State Government aim to produce around 2,000MW by this method. Rates will be based on the tenders Kutch alone has the capacity to produce more than 4,000MW wind power. Gujarat will be first state to have the single largest capacity in one place.

Hybrid Park to be developed:

State government would develop a hybrid renewable energy park. In this park, solar and wind power generation facilities will be developed at the same place. The government will give public waste land for the park on lease of 40 yrs. Private players will develop the park. The government will give them land at the rate of Rs.15, 000perhectare perannum as rent for a period of 40 yrs. The land will be considered as –non-agricultural land use. Total expected investment is around Rs. 1.20 crore over next 10 yrs. Developers will be chosen for minimum 1,000 MW capacity.

Source: Times of India, January 17, 2019.

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 case study of DSUUSM is discussed in detail in Chapter III. 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.

Box 2.4: Harvests Changing Lives in Gujarat

How Clean Energy Adoption by grassroots-level workers is driving the shift towards solar power in Gujarat is traced by TOI's Niyati Parikh, Kalpesh Damor and Prashant Rupera

In June 2015, Raman Parmar, 48, a farmer of Thamna village in Gujarat's Anand district had become the country's first solar power farmer. By connecting a solar powered irrigation pump to an electricity grid, Raman had received the first payment for his 'solar crop' in the form of a cheque of Rs 7,500 from the International Water Management Institute (IWMI).

Inspired by Raman, six farmers from Dhundi village in Kheda district of Gujarat, formed what was known as the country's first solar irrigation cooperative – Dhundi Saur Urja Utpadak Sahakari Mandali (DSUUSM), in December 2015. These six farmers began drawing water using solar-powered pumps. Three more farmers joined the DSUUSM later.

"Until three years ago, we used diesel pumps to draw irrigation water. I had to shell out Rs 1,000 per day to buy diesel," said Pravin Parmar, secretary, DSUUSM.

"Apart from selling excess power, we were in a position to sell surplus irrigation water to neighbouring farmers as well, at Rs 250 per bigha per irrigation. Both of these were additional sources of income. Till date, DSUUSM has made Rs 10 lakh by selling power and nearly Rs 6 lakh by selling water," he added.

Source: TOI (2018), December 2, 2018.

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 success stories of Dhundi are presented in Box 2.4 and 2.4 and story about Mujkuva village of Anklav taluka in Anand district is presented in Box 2.5.

> Box 2.5: Further Push for Solar Power Generation through Solar Cooperative
>
> IWMI, working closely with MGVCL and the Gujarat Energy Research and Management Institute estimated that a solar pump can generate 13,000 units of power per year worth Rs 65,000 on just 1/25th of a hectare. Accordingly, 10 million solar farmers can 'grow' 130 billion units of solar power and earn upto Rs 65,000 crore per year net of input costs, they estimated.
>
> Taking the Dhundi model further, 11 farmers of Mujkuva village of Anklav taluka, in Anand district, have foregone their power subsidy and instead, began using solar power.
>
> This has been done through the Mujkuva Solar Pump Irrigators Cooperative Enterprise (SPICE) India's first grid-connected solar enterprise which Prime Minister Narendra Modi launched during his visit to Anand on September 30.
>
> Farmers of Mujkuva village have formed Mujkuva Saur Urja Utpadak Sahakari Mandali Limited with assistance from the Anand-headquartered National Dairy Development Board (NDDB).
>
> NDDB, with assistance of the Rajasthan Electronics and Instruments Limited (REIL) and IWMI have helped these farmers create their own micro grid which enables them to sell the surplus solar energy produced in their fields to MGVCL.
>
> Source: TOI (2018), December 2, 2018.

2.4 Policies for Solar Pump 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 tHn 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. The project goals are as follows:

- Enhancing irrigated area in the State
- Increasing productivity of the irrigated area
- Enabling farmers to diversify to remunerative high-value horticulture crops
- Conserving water by utilization of efficient irrigation methods
- Narrowing the gap between grid-power demand and supply in the State Reducing the queue of aspirant farmers for grid connection for irrigation
- Harnessing solar-energy resources available in abundance in the State
- Replacing the expensive and polluting diesel pump-sets
- Providing irrigation facility to farmers living in remote locations where grid is less likely to be extended in near future
- Saving farmers from the drudgery of night or erratic irrigation schedule
- Making environment sustainable and reducing the State's carbon footprint

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 per cent 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/-. There are three, very transparent eligibility criteria for the subsidy;

(a) the farmer should own at least 0.5 Ha of land;

(b) the land should have a diggi/farm pond or other water storage structure;

(c) 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, 3 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 per cent 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.

2.4.1 Progress in Solarisation of Irrigation Pump in Rajasthan

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. 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. 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 now state has three subsidy slabs, as follows:

(a) 75 per cent for those willing to give up their place in the queue for electric connections,

(b) 60 per cent for farmers without an electric connection, and

(c) only the 30 per cent MNRE subsidy for those unwilling to give up their electric connection/place in the queue.

The district wise solar irrigation pumps installed in Rajasthan during 2011-12 to 2015-16 are given in Table 2.1 and Fig. 2.2 and year-wise target, achievement of solar irrigation pump, etc., are depicted in Table 2.2. The top five districts having highest coverage of solar pumps are Bikaner, Jaipur, Sri Ganganagar, Hanumangarh and Sikar.

Table 2.2: Year Wise Solar Water Pump Installed in Rajasthan

Sr. No.	District	Solar water Pump Installed in Rajasthan					
		2011-12	2013-12	2013-14	2014-15	2015-16	Total
1	Ajmer	0	90	251	211	228	780
2	Alwar	14	188	246	53	115	616
3	Banswara	0	44	76	44	38	202
4	Baran	0	21	62	14	4	101
5	Barmer	0	42	99	193	338	672
6	Bharatpur	0	11	61	8	13	93
7	Bhilwara	34	241	516	212	134	1137
8	Bikaner	381	556	1360	1314	732	4343
9	Bundi	0	34	63	54	51	202
10	Chittorgarh	24	118	289	232	129	792
11	Churu		31	100	243	371	745
12	Dausa	0	83	114	37	27	261
13	Dholpur	0	21	33	17	2	73
14	Dungarpur	0	14	67	35	27	143
15	Hanumangarh	260	247	792	678	347	2324
16	Jaipur	80	439	1489	894	798	3700
17	Jaisalmer	31	109	334	485	144	1103
18	Jalore	0	51	149	233	470	903
19	Jhalawad	0	161	96	3	14	274
20	Jhujhunu	27	139	310	366	277	1119
21	Jodhpur	51	118	201	190	148	708
22	Karoli	0	37	26	4	3	70
23	Kota	20	54	90	18	24	206
24	Nagour	34	35	95	60	31	255
25	Pali	0	61	194	157	71	483
26	Pratapgarh	0	41	224	64	72	401
27	Rajsamand	0	91	259	94	53	497
28	Sikar	44	272	1028	264	73	1681
29	Sirohi	0	27	95	122	92	336
30	Sri Ganganagar	612	658	1032	911	480	3693
31	SwaiMadhopur	37	97	19	31	281	465
32	Tonk	0	102	122	195	444	863
33	Udaipur	0	47	108	112	139	406
	Grand Total	1649	4280	10000	7548	6170	29647

Source: Office of the Department of Horticulture, GOR, Jaipur.

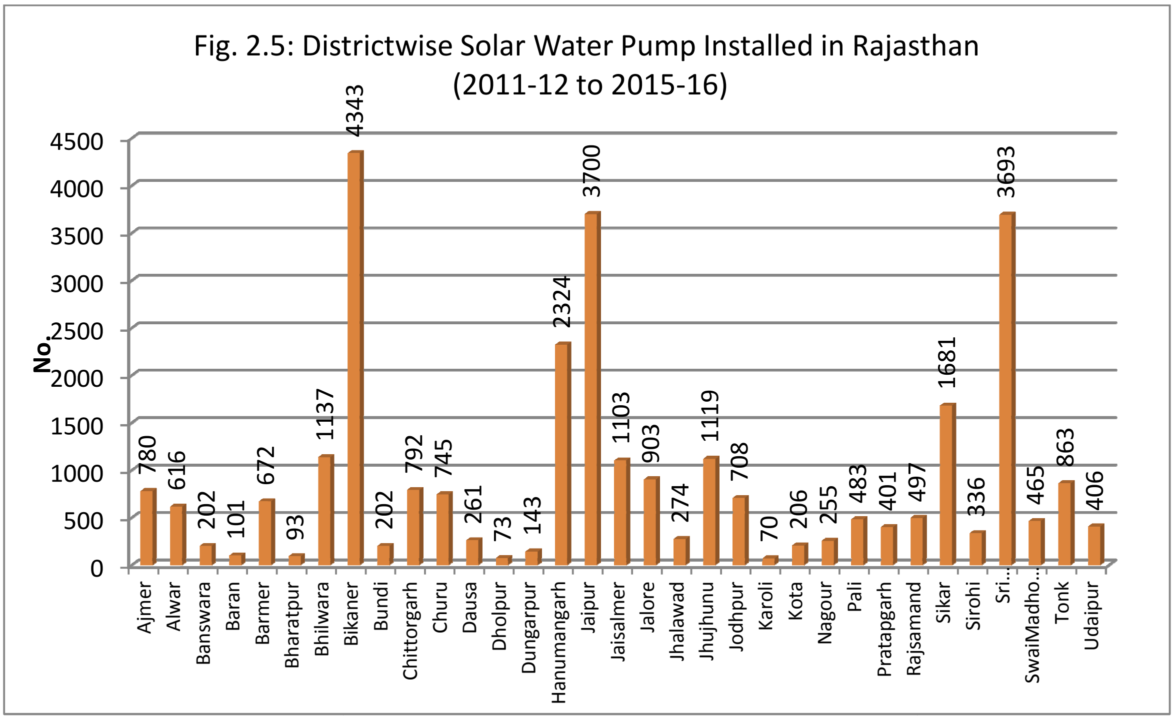


Table 2.3: Year wise Target & Achievements of Solar irrigation pump in Rajasthan

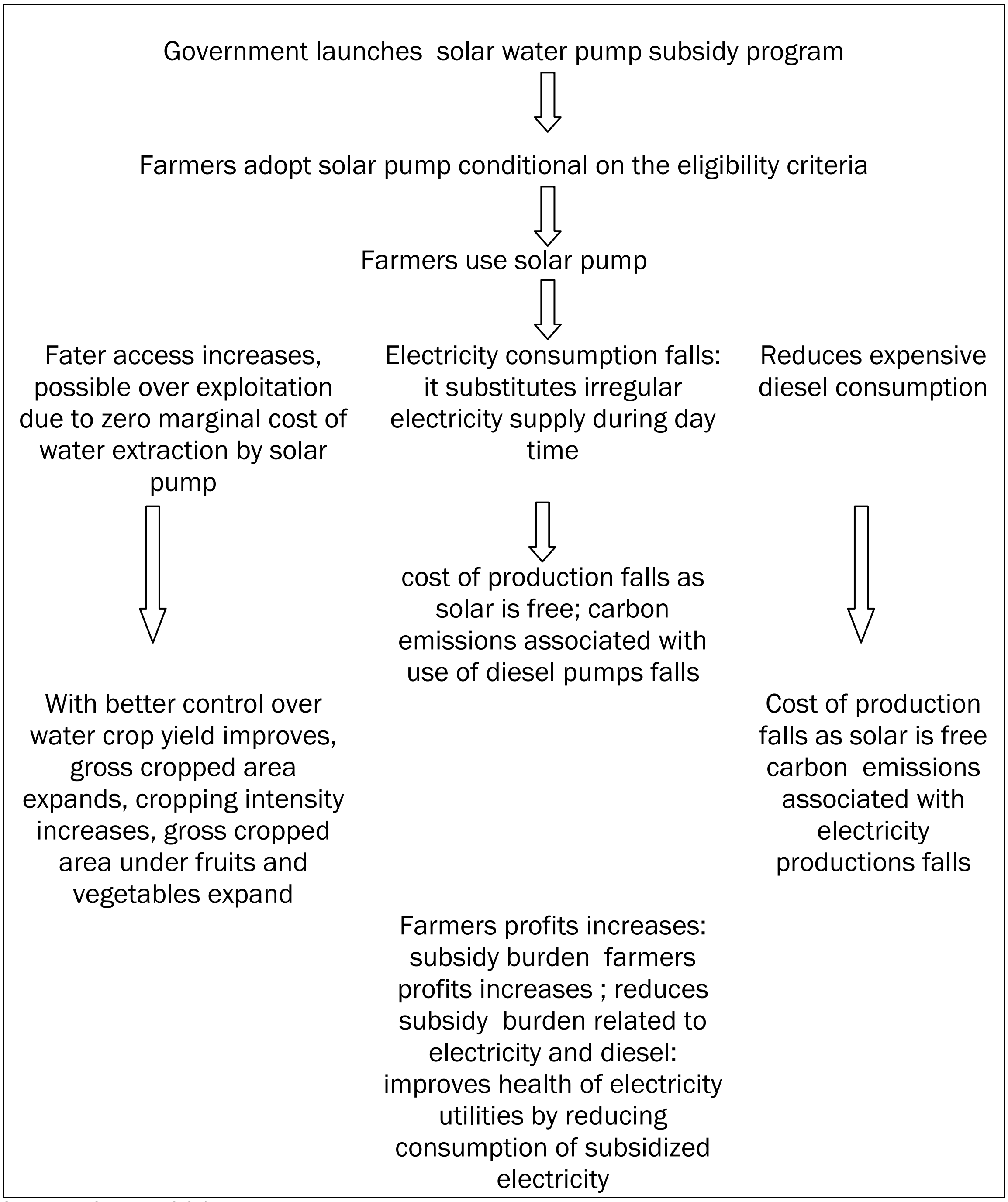
Year	Project	No. of District Covered	Target	Achieve-ment	Pump Capacity (WP)	Subsidy (%)	Funding Source
2008-09	Government Farms	7	14	14	1800	100	RKVY
2010-11	Pilot Project	6	50	34	2200/ 3000	86	JNNSM, RKVY
2011-12	First major jump	14	500	1649	2200/ 3000	86	JNNSM, RKVY
2012-13	Second major jump	33	2200	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
Source: Goyal (2013) and GOR.

2.4.2 Theory of Change in Adoption

The main motivation of the policy makers for promoting Solar Water Pumping Program, in water constrained and solar abundant Rajasthan, is to increase water and energy access of farmers to improve agricultural output and income of farmers. Figure 2.3 explains underlying theory of change associated with the adoption of solar water pumps.

Fig. 2.6: Theory of Change of Solar Water Pump Subsidy Program in Rajasthan



Source: Gupta, 2017.

2.4.3 Solar Power Pump Subsidy

Tables 2.3 to 2.6 provide an indication of the cost for different solar pump alternatives in Rajasthan during 2011-12 to 2013-14. 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. 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 2.4: Rate for SPV Solar Pump Project in Rajasthan (2011-12 to 2013-14)

Type of pump	Mounting Structure	Head (meter)	2011-12 (Rs./set)		2012-13(Rs./set)		2013-14 (Rs. Per set)			
							DC Pump		AC Pump	
			2200Wp	3000Wp	2200Wp	3000Wp	2200Wp	3000Wp	2200Wp	3000Wp
SPV Surface pump	Static	20			3,28,000	4,25,700	3,25,788	4,00,000	3,21,790	4,10,000
	Manual	20	3,76,500	5,37,000	3,36,000	4,48,800	3,29,838	4,04,050	3,25,840	4,14,050
	Auto Tracker	20	4,14,500	5,70,000	3,86,500	4,62,000	3,43,288	4,17,500	3,39,290	4,27,500
SPV Sub-mersible pump	Static	20			3,60,000	4,29,000	3,55,000	4,68,000	3,54,910	4,25,000
		50			3,61,100	4,38,900	3,61,500	4,74,500	3,61,410	4,31,500
		75			3,63,300	4,48,800	3,66,000	4,79,000	3,65,910	4,36,000
	Manual	20	3,89,900	5,60,300	3,74,300	4,48,800	3,59,050	4,72,050	3,58,960	4,29,050
		50	3,95,800	5,62,300	3,80,000	4,65,300	3,65,550	4,78,550	3,65,460	4,35,550
		75			3,95,100	4,75,200	3,70,050	4,83,050	3,69,960	4,40,050
	Auto Tracker	20	4,18,000	5,70,000	3,99,300	4,68,600	3,72,500	4,85,500	3,72,410	4,42,500
		50	4,18,000	5,70,000	4,05,000	4,81,800	3,79,000	4,92,000	3,78,910	4,49,000
		75			4,11,300	4,85,100	3,83,500	4,96,500	3,83,410	4,53,500
SPV Domestic Lighting System 37 Wp/40Ah Battery/9W×2 Fixture						8,090				8,000

Source: GOR, Jaipur.

Table 2.5: Base Rate, Subsidy rate & Farmer Share on Solar Water Pump in Rajasthan 2016-17

S.N.	Details	DC/ AC Mounting Structure	Head (meter)	Base Rate (in Rs. Per set)		Subsidy (in Rs. Per set)						Farmer Share (in Rs. Per set)	
				3 Hp	5 Hp	MNRE	SP	3 Hp	MNRE	SP	5 Hp	3 Hp	5 Hp
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Farmer Category having agriculture electric connection** **(As per the guideline of 2015-16)**												
1	SPV Surface pump with Fencing	DC Manual	20	339950	527050	121500	0	121500	202500	0	202500	218450	324550
2		DC Auto Tracker	20	353400	540500	121500	0	121500	202500	0	202500	231900	338000
3		AC Manual	20	351050	538050	97200	0	97200	162000	0	162000	253850	376050
4		AC Auto Tracker	20	364500	551500	97200	0	97200	162000	0	162000	267300	389500
5	SPV Submersible pump with Fencing	DC Manual	20	386050	527050	121500	0	121500	202500	0	202500	264550	324550
6			50	392550	533550	121500	0	121500	202500	0	202500	271050	331050
7			75	397050	538050	121500	0	121500	202500	0	202500	275550	335550
8		DC Auto Tracker	20	399500	540500	121500	0	121500	202500	0	202500	278000	338000
9			50	406000	547000	121500	0	121500	202500	0	202500	284500	344500
10			75	410500	551500	121500	0	121500	202500	0	202500	289000	349000
11	SPV Submersible pump with Fencing	AC Manual	20	354050	502050	97200	0	97200	162000	0	162000	256850	340050
12			50	360550	508550	97200	0	97200	162000	0	162000	263350	346550
13			75	365050	513050	97200	0	97200	162000	0	162000	267850	351050
14		AC Auto Tracker	20	367500	515500	97200	0	97200	162000	0	162000	270300	353500
15			50	374000	522000	97200	0	97200	162000	0	162000	276800	360000
16			75	378500	526500	97200	0	97200	162000	0	162000	281300	364500
17	SPV Surface pump with DLS & fencing	DC Manual	20	347949	535049	121500	0	121500	202500	0	202500	226449	332549
18		DC Auto Tracker	20	361399	548499	121500	0	121500	202500	0	202500	239899	345999
19		AC Manual	20	359049	546049	97200	0	97200	162000	0	162000	261849	384049
20		AC Auto Tracker	20	372499	559499	97200	0	97200	162000	0	162000	275299	397499
21	SPV Submersible pump with DLS & fencing	DC Manual	20	394049	535049	121500	0	121500	202500	0	202500	272549	332549
22			50	400549	541549	121500	0	121500	202500	0	202500	279049	339049
23			75	405049	546049	121500	0	121500	202500	0	202500	283549	343549
24		DC Auto Tracker	20	407499	548499	121500	0	121500	202500	0	202500	285999	345999
25			50	413999	554999	121500	0	121500	202500	0	202500	292499	352499
26			75	418499	559499	121500	0	121500	202500	0	202500	296999	356999
27	SPV Submersible pump with DLS & fencing	AC Manual	20	362049	510049	97200	0	97200	162000	0	162000	264849	348049
28			50	368549	516549	97200	0	97200	162000	0	162000	271349	354549
29			75	373049	521049	97200	0	97200	162000	0	162000	275849	359049
30		AC Auto Tracker	20	375499	523499	97200	0	97200	162000	0	162000	278299	361499
31			50	381999	529999	97200	0	97200	162000	0	162000	284799	367999
32			75	386499	534499	97200	0	97200	162000	0	162000	289299	372499

Table 2.5 continues.........

S.N.	Details	DC/ AC Mounting Structure	Head (meter)	Base Rate (in Rs. Per set)		Subsidy (in Rs. Per set)						Farmer Share (in Rs. Per set)	
				3 Hp	5 Hp	MNRE	SP	3 Hp	MNRE	SP	5 Hp	3 Hp	5 Hp
1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	Farmer Category not having agriculture electric connection (As per the guideline of 2015-16)												
1	SPV Surface pump with Fencing	DC Manual	20	339950	527050	121500	101985	223485	202500	158115	360615	116465	166435
2		DC Auto Tracker	20	353400	540500	121500	106020	227520	202500	162150	364650	125880	175850
3		AC Manual	20	351050	538050	97200	105315	202515	162000	161415	323415	148535	214635
4		AC Auto Tracker	20	364500	551500	97200	109350	206550	162000	165450	327450	157950	224050
5	SPV Submersibl e pump with Fencing	DC Manual	20	386050	527050	121500	115815	237315	202500	158115	360615	148735	166435
6			50	392550	533550	121500	117765	239265	202500	160065	362565	153285	170985
7			75	397050	538050	121500	119115	240615	202500	161415	363915	156435	174135
8		DC Auto Tracker	20	399500	540500	121500	119850	241350	202500	162150	364650	158150	175850
9			50	406000	547000	121500	121800	243300	202500	164100	366600	162700	180400
10			75	410500	551500	121500	123150	244650	202500	165450	367950	165850	183550
11	SPV Submersible pump with Fencing	AC Manual	20	354050	502050	97200	106215	203415	162000	150615	312615	150635	189435
12			50	360550	508550	97200	108165	205365	162000	152565	314565	155185	193985
13			75	365050	513050	97200	109515	206715	162000	153915	315915	158335	197135
14		AC Auto Tracker	20	367500	515500	97200	110250	207450	162000	154650	316650	160050	198850
15			50	374000	522000	97200	112200	209400	162000	156600	318600	164600	203400
16			75	378500	526500	97200	113550	210750	162000	157950	319950	167750	206550
17	SPV Surface pump with DLS & fencing	DC Manual	20	347949	535049	121500	104385	225885	202500	160515	363015	122064	172034
18		DC Auto Tracker	20	361399	548499	121500	108420	229920	202500	164550	367050	131479	181449
19		AC Manual	20	359049	546049	97200	107715	204915	162000	163815	325815	154134	220234
20		AC Auto Tracker	20	372499	559499	97200	111750	208950	162000	167850	329850	163549	229649
21	SPV Submersible pump with DLS & fencing	DC Manual	20	394049	535049	121500	118215	239715	202500	160515	363015	154334	172034
22			50	400549	541549	121500	120165	241665	202500	162465	364965	158884	176584
23			75	405049	546049	121500	121515	243015	202500	163815	366315	162034	179734
24		DC Auto Tracker	20	407499	548499	121500	122250	243750	202500	164550	367050	163749	181449
25			50	413999	554999	121500	124200	245700	202500	166500	369000	168299	185999
26			75	418499	559499	121500	125550	247050	202500	167850	370350	171449	189149
27	SPV Submersible pump with DLS & fencing	AC Manual	20	362049	510049	97200	108615	205815	162000	153015	315015	156234	195034
28			50	368549	516549	97200	110565	207765	162000	154965	316965	160784	199584
29			75	373049	521049	97200	111915	209115	162000	156315	318315	163934	202734
30		AC Auto Tracker	20	375499	523499	97200	112650	209850	162000	157050	319050	165649	204449
31			50	381999	529999	97200	114600	211800	162000	159000	321000	170199	208999
32			75	386499	534499	97200	115950	213150	162000	160350	322350	173349	212149
3	**Farmer Category applied for agriculture electric connection and wants to surrender their application in lieu of solar pumps subsidy (As per the guideline of 2015-16)**												
1	SPV Surface pump with Fencing	DC Manual	20	339950	527050	121500	152978	274478	202500	237173	439673	65472	87377
2		DC Auto Tracker	20	353400	540500	121500	159030	280530	202500	243225	445725	72870	94775
3		AC Manual	20	351050	538050	97200	157973	255173	162000	242123	404123	95877	133927
4		AC Auto Tracker	20	364500	551500	97200	164025	261225	162000	248175	410175	103275	141325
5	SPV Submersible pump with Fencing	DC Manual	20	386050	527050	121500	173723	295223	202500	237173	439673	90827	87377
6			50	392550	533550	121500	176648	298148	202500	240098	442598	94402	90952
7			75	397050	538050	121500	178673	300173	202500	242123	444623	96877	93427
8		DC Auto Tracker	20	399500	540500	121500	179775	301275	202500	243225	445725	98225	94775
9			50	406000	547000	121500	182700	304200	202500	246150	448650	101800	98350
10			75	410500	551500	121500	184725	306225	202500	248175	450675	104275	100825
11	SPV Submersible pump with Fencing	AC Manual	20	354050	502050	97200	159323	256523	162000	225923	387923	97527	114127
12			50	360550	508550	97200	162248	259448	162000	228848	390848	101102	117702
13			75	365050	513050	97200	164273	261473	162000	230873	392873	103577	120177
14		AC Auto Tracker	20	367500	515500	97200	165375	262575	162000	231975	393975	104925	121525
15			50	374000	522000	97200	168300	265500	162000	234900	396900	108500	125100
16			75	378500	526500	97200	170325	267525	162000	236925	398925	110975	127575
17	SPV Surface pump with DLS & fencing	DC Manual	20	347949	535049	121500	156577	278077	202500	240772	443272	69872	91777
18		DC Auto Tracker	20	361399	548499	121500	162630	284130	202500	246825	449325	77269	99174
19		AC Manual	20	359049	546049	97200	161572	258772	162000	245722	407722	100277	138327
20		AC Auto Tracker	20	372499	559499	97200	167625	264825	162000	251775	413775	107674	145724

Table 2.5 continues.........

S.N.	Details	DC/ AC Mounting Structure	Head (meter)	Base Rate (in Rs. Per set)		Subsidy (in Rs. Per set)						Farmer Share (in Rs. Per set)	
				3 Hp	5 Hp	MNRE	SP	3 Hp	MNRE	SP	5 Hp	3 Hp	5 Hp
1	2	3	4	5	6	7	8	9	10	11	12	13	14
21	SPV Submersible pump with DLS & fencing	DC Manual	20	394049	535049	121500	177322	298822	202500	240772	443272	95227	91777
22			50	400549	541549	121500	180247	301747	202500	243697	446197	98802	95352
23			75	405049	546049	121500	182272	303772	202500	245722	448222	101277	97827
24		DC Auto Tracker	20	407499	548499	121500	183375	304875	202500	246825	449325	102624	99174
25			50	413999	554999	121500	186300	307800	202500	249750	452250	106199	102749
26			75	418499	559499	121500	188325	309825	202500	251775	454275	108674	105224
27	SPV Submersible pump with DLS & fencing	AC Manual	20	362049	510049	97200	162922	260122	162000	229522	391522	101927	118527
28			50	368549	516549	97200	165847	263047	162000	232447	394447	105502	122102
29			75	373049	521049	97200	167872	265072	162000	234472	396472	107977	124577
30		AC Auto Tracker	20	375499	523499	97200	168975	266175	162000	235575	397575	109324	125924
31			50	381999	529999	97200	171900	269100	162000	238500	400500	112899	129499
32			75	386499	534499	97200	173925	271125	162000	240525	402525	115374	131974

Notes :

- Basis of MNRE subsidy calculation is Rs. 32400/- per HP for AC pumps and Rs. 40500/- for DC pumps.
- In addition to above State Plan subsidy is 30% of Base rate for farmers not having agriculture electric connection & 45% for farmers who have applied for agriculture electric connection and wants to surrender their application in lieu of solar pumps subsidy.
- As per MNRE guidelines subsidy will be allowed only on manual & auto tracking enabled SPV pumps along with remote monitoring mechanism (RMM).
- The subsidy would be payable on the supply of the solar pumping system by the empanelled firm only. In case of any complaints regarding sub standard/ defective supplies, Directorate of Horticulture must be informed with full details of the case so that necessary action can be taken against the defaulter.

Source: GOR, Jaipur.

Table 2.6: Base Rate for SPV Solar Pump Project in Rajasthan 2017-18 and 2018-19

Sr. No.	Details	DC/ AC Mounting Structure	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.

Table 2.7: Base Rate, Subsidy rate and Farmer Share on Solar Water Pump in Rajasthan 2018-19

SN	Details	DC/ AC Mounting Structure	Head (mtr.)	Base Rate (in Rs. Per set)				Subsidy Amount (in Rs. Per set)					
				3 Hp	5 Hp	7.5 Hp	10 Hp	MNRE	SP	3 Hp	MNRE	SP	5 Hp
1	2	3	4	5	6	7	8	9	10	11 (9+10)	12	13	14 (12+13)
	Subsidy - 3 & 5 HP 60%												
1	SPV Surface pump with Fencing	DC Manual	20	245721	0	0	0	61430	86002	147432	0	0	0
2		DC Auto Tracker	20	251133	0	0	0	62783	87897	150680	0	0	0
3		AC Manual	20	239963	319725	0	0	59991	83987	143978	63945	127890	191835
4		AC Auto Tracker	20	245375	325137	0	0	61344	85881	147225	65027	130055	195082
5	SPV Submersible pump with Fencing	DC Manual	20	261737	355726	523820	666326	65434	91608	157042	71145	142290	213435
6			50	267149	361138	529232	671738	66787	93502	160289	72228	144455	216683
7			75	270757	364746	532840	675346	67689	94765	162454	72949	145898	218847
8			100	273737	367726	535820	678326	68434	95808	164242	73545	147090	220635
9		DC Auto Tracker	20	267149	361138	529232	671738	66787	93502	160289	72228	144455	216683
10			50	272561	366550	534644	677150	68140	95396	163536	73310	146620	219930
11			75	276169	370158	538252	680758	69042	96659	165701	74032	148063	222095
12			100	279149	373138	541232	683738	69787	97702	167489	74628	149255	223883
13	SPV Submersible pump with Fencing	AC Manual	20	239736	318116	479541	609486	59934	83908	143842	63623	127246	190869
14			50	245148	323528	484953	614898	61287	85802	147089	64706	129411	194117
15			75	248756	327136	488561	618506	62189	87065	149254	65427	130854	196281
16			100	251736	330116	491541	621486	62934	88108	151042	66023	132046	198069
17		AC Auto Tracker	20	245148	323528	484953	614898	61287	85802	147089	64706	129411	194117
18			50	250560	328940	490365	620310	62640	87696	150336	65788	131576	197364
19			75	254168	332548	493973	623918	63542	88959	152501	66510	133019	199529
20			100	257148	335528	496953	626898	64287	90002	154289	67106	134211	201317
21	SPV Surface pump with DLS & fencing	DC Manual	20	250402	0	0	0	62601	87641	150242	0	0	0
22		DC Auto Tracker	20	255814	0	0	0	63954	89535	153489	0	0	0
23		AC Manual	20	244644	324406	0	0	61161	85625	146786	64881	129762	194643
24		AC Auto Tracker	20	250056	329818	0	0	62514	87520	150034	65964	131927	197891
25	SPV Submersible pump with DLS & fencing	DC Manual	20	266418	360407	528501	671007	66605	93246	159851	72081	144163	216244
26			50	271830	365819	533913	676419	67958	95141	163099	73164	146328	219492
27			75	275438	369427	537521	680027	68860	96403	165263	73885	147771	221656
28			100	278418	372407	540501	683007	69605	97446	167051	74481	148963	223444
29		DC Auto Tracker	20	271830	365819	533913	676419	67958	95141	163099	73164	146328	219492
30			50	277242	371231	539325	681831	69311	97035	166346	74246	148492	222738
31			75	280850	374839	542933	685439	70213	98298	168511	74968	149936	224904
32			100	283830	377819	545913	688419	70958	99341	170299	75564	151128	226692
33	SPV Submersible pump with DLS & fencing	AC Manual	20	244417	322797	484222	614167	61104	85546	146650	64559	129119	193678
34			50	249829	328209	489634	619579	62457	87440	149897	65642	131284	196926
35			75	253437	331817	493242	623187	63359	88703	152062	66363	132727	199090
36			100	256417	334797	496222	626167	64104	89746	153850	66959	133919	200878
37		AC Auto Tracker	20	249829	328209	489634	619579	62457	87440	149897	65642	131284	196926
38			50	255241	333621	495046	624991	63810	89334	153144	66724	133448	200172
39			75	258849	337229	498654	628599	64712	90597	155309	67446	134892	202338
40			100	261829	340209	501634	631579	65457	91640	157097	68042	136084	204126

Source: GOR, Jaipur.

Table 2.7 coninues...

SN	Details	DC/ AC Mounting Structure	Head (mtr.)	Farmer Share (in Rs. Per set)						
				3 Hp	5 Hp	3 / 5 Hp	3 / 7.5 Hp	3 / 10 Hp	5 / 7.5 Hp	5 / 10 Hp
1	2	3	4	15	16	17 (6-11)	18 (7-11)	19 (8-11)	20 (7-14)	21 (8-14)
	Subsidy - 3 & 5 HP 60%									
1	SPV Surface pump with Fencing	DC Manual	20	98289	0	0	0	0	0	0
2		DC Auto Tracker	20	100453	0	0	0	0	0	0
3		AC Manual	20	95985	127890	175747	0	0	0	0
4		AC Auto Tracker	20	98150	130055	177912	0	0	0	0
5	SPV Submersible pump with Fencing	DC Manual	20	104695	142291	198684	366778	509284	310385	452891
6			50	106860	144455	200849	368943	511449	312549	455055
7			75	108303	145899	202292	370386	512892	313993	456499
8			100	109495	147091	203484	371578	514084	315185	457691
9		DC Auto Tracker	20	106860	144455	200849	368943	511449	312549	455055
10			50	109025	146620	203014	371108	513614	314714	457220
11			75	110468	148063	204457	372551	515057	316157	458663
12			100	111660	149255	205649	373743	516249	317349	459855
13	SPV Submersible pump with Fencing	AC Manual	20	95894	127247	174274	335699	465644	288672	418617
14			50	98059	129411	176439	337864	467809	290836	420781
15			75	99502	130855	177882	339307	469252	292280	422225
16			100	100694	132047	179074	340499	470444	293472	423417
17		AC Auto Tracker	20	98059	129411	176439	337864	467809	290836	420781
18			50	100224	131576	178604	340029	469974	293001	422946
19			75	101667	133019	180047	341472	471417	294444	424389
20			100	102859	134211	181239	342664	472609	295636	425581
21	SPV Surface pump with DLS & fencing	DC Manual	20	100160	0	0	0	0	0	0
22		DC Auto Tracker	20	102325	0	0	0	0	0	0
23		AC Manual	20	97858	129763	177620	0	0	0	0
24		AC Auto Tracker	20	100022	131927	179784	0	0	0	0
25	SPV Submersible pump with DLS & fencing	DC Manual	20	106567	144163	200556	368650	511156	312257	454763
26			50	108731	146327	202720	370814	513320	314421	456927
27			75	110175	147771	204164	372258	514764	315865	458371
28			100	111367	148963	205356	373450	515956	317057	459563
29		DC Auto Tracker	20	108731	146327	202720	370814	513320	314421	456927
30			50	110896	148493	204885	372979	515485	316587	459093
31			75	112339	149935	206328	374422	516928	318029	460535
32			100	113531	151127	207520	375614	518120	319221	461727
33	SPV Submersible pump with DLS & fencing	AC Manual	20	97767	129119	176147	337572	467517	290544	420489
34			50	99932	131283	178312	339737	469682	292708	422653
35			75	101375	132727	179755	341180	471125	294152	424097
36			100	102567	133919	180947	342372	472317	295344	425289
37		AC Auto Tracker	20	99932	131283	178312	339737	469682	292708	422653
38			50	102097	133449	180477	341902	471847	294874	424819
39			75	103540	134891	181920	343345	473290	296316	426261
40			100	104732	136083	183112	344537	474482	297508	427453

Source: GOR, Jaipur.

Table 2.7 coninues...

SN	Details	DC/ AC Mounting Structure	Head (mtr.)	Base Rate (in Rs. Per set)				Subsidy Amount (in Rs. Per set)					
				3 Hp	5 Hp	7.5 Hp	10 Hp	MNRE	SP	3 Hp	MNRE	SP	5 Hp
1	2	3	4	5	6	7	8	9	10	11 (9+10)	12	13	14 (12+13)
2	Subsidy - 3 & 5 HP 75%												
1	SPV Surface pump with Fencing	DC Manual	20	245721	0	0	0	61430	122861	184291	0	0	0
2		DC Auto Tracker	20	251133	0	0	0	62783	125567	188350	0	0	0
3		AC Manual	20	239963	319725	0	0	59991	119982	179973	63945	175849	239794
4		AC Auto Tracker	20	245375	325137	0	0	61344	122688	184032	65027	178825	243852
5	SPV Submersible pump with Fencing	DC Manual	20	261737	355726	523820	666326	65434	130869	196303	71145	195649	266794
6			50	267149	361138	529232	671738	66787	133575	200362	72228	198626	270854
7			75	270757	364746	532840	675346	67689	135379	203068	72949	200610	273559
8			100	273737	367726	535820	678326	68434	136869	205303	73545	202249	275794
9		DC Auto Tracker	20	267149	361138	529232	671738	66787	133575	200362	72228	198626	270854
10			50	272561	366550	534644	677150	68140	136281	204421	73310	201603	274913
11			75	276169	370158	538252	680758	69042	138085	207127	74032	203587	277619
12			100	279149	373138	541232	683738	69787	139575	209362	74628	205226	279854
13	SPV Submersible pump with Fencing	AC Manual	20	239736	318116	479541	609486	59934	119868	179802	63623	174964	238587
14			50	245148	323528	484953	614898	61287	122574	183861	64706	177940	242646
15			75	248756	327136	488561	618506	62189	124378	186567	65427	179925	245352
16			100	251736	330116	491541	621486	62934	125868	188802	66023	181564	247587
17		AC Auto Tracker	20	245148	323528	484953	614898	61287	122574	183861	64706	177940	242646
18			50	250560	328940	490365	620310	62640	125280	187920	65788	180917	246705
19			75	254168	332548	493973	623918	63542	127084	190626	66510	182901	249411
20			100	257148	335528	496953	626898	64287	128574	192861	67106	184540	251646
21	SPV Surface pump with DLS & fencing	DC Manual	20	250402	0	0	0	62601	125201	187802	0	0	0
22		DC Auto Tracker	20	255814	0	0	0	63954	127907	191861	0	0	0
23		AC Manual	20	244644	324406	0	0	61161	122322	183483	64881	178423	243304
24		AC Auto Tracker	20	250056	329818	0	0	62514	125028	187542	65964	181400	247364
25	SPV Submersible pump with DLS & fencing	DC Manual	20	266418	360407	528501	671007	66605	133209	199814	72081	198224	270305
26			50	271830	365819	533913	676419	67958	135915	203873	73164	201200	274364
27			75	275438	369427	537521	680027	68860	137719	206579	73885	203185	277070
28			100	278418	372407	540501	683007	69605	139209	208814	74481	204824	279305
29		DC Auto Tracker	20	271830	365819	533913	676419	67958	135915	203873	73164	201200	274364
30			50	277242	371231	539325	681831	69311	138621	207932	74246	204177	278423
31			75	280850	374839	542933	685439	70213	140425	210638	74968	206161	281129
32			100	283830	377819	545913	688419	70958	141915	212873	75564	207800	283364
33	SPV Submersible pump with DLS & fencing	AC Manual	20	244417	322797	484222	614167	61104	122209	183313	64559	177538	242097
34			50	249829	328209	489634	619579	62457	124915	187372	65642	180515	246157
35			75	253437	331817	493242	623187	63359	126719	190078	66363	182499	248862
36			100	256417	334797	496222	626167	64104	128209	192313	66959	184138	251097
37		AC Auto Tracker	20	249829	328209	489634	619579	62457	124915	187372	65642	180515	246157
38			50	255241	333621	495046	624991	63810	127621	191431	66724	183492	250216
39			75	258849	337229	498654	628599	64712	129425	194137	67446	185476	252922
40			100	261829	340209	501634	631579	65457	130915	196372	68042	187115	255157

Source: GOR, Jaipur.

Table 2.7 continues…

SN	Details	DC/ AC Mounting Structure	Head (mtr.)	Farmer Share (in Rs. Per set)						
				3 Hp	5 Hp	3 / 5 Hp	3 / 7.5 Hp	3 / 10 Hp	5 / 7.5 Hp	5 / 10 Hp
1	2	3	4	15	16	17 (6-11)	18 (7-11)	19 (8-11)	20 (7-14)	21 (8-14)
2	Subsidy - 3 & 5 HP 75%									
1	SPV Surface pump with Fencing	DC Manual	20	61430	0	0	0	0	0	0
2		DC Auto Tracker	20	62783	0	0	0	0	0	0
3		AC Manual	20	59990	79931	139752	0	0	0	0
4		AC Auto Tracker	20	61343	81285	141105	0	0	0	0
5	SPV Submersible pump with Fencing	DC Manual	20	65434	88932	159423	327517	470023	257026	399532
6			50	66787	90284	160776	328870	471376	258378	400884
7			75	67689	91187	161678	329772	472278	259281	401787
8			100	68434	91932	162423	330517	473023	260026	402532
9		DC Auto Tracker	20	66787	90284	160776	328870	471376	258378	400884
10			50	68140	91637	162129	330223	472729	259731	402237
11			75	69042	92539	163031	331125	473631	260633	403139
12			100	69787	93284	163776	331870	474376	261378	403884
13	SPV Submersible pump with Fencing	AC Manual	20	59934	79529	138314	299739	429684	240954	370899
14			50	61287	80882	139667	301092	431037	242307	372252
15			75	62189	81784	140569	301994	431939	243209	373154
16			100	62934	82529	141314	302739	432684	243954	373899
17		AC Auto Tracker	20	61287	80882	139667	301092	431037	242307	372252
18			50	62640	82235	141020	302445	432390	243660	373605
19			75	63542	83137	141922	303347	433292	244562	374507
20			100	64287	83882	142667	304092	434037	245307	375252
21	SPV Surface pump with DLS & fencing	DC Manual	20	62600	0	0	0	0	0	0
22		DC Auto Tracker	20	63953	0	0	0	0	0	0
23		AC Manual	20	61161	81102	140923	0	0	0	0
24		AC Auto Tracker	20	62514	82454	142276	0	0	0	0
25	SPV Submersible pump with DLS & fencing	DC Manual	20	66604	90102	160593	328687	471193	258196	400702
26			50	67957	91455	161946	330040	472546	259549	402055
27			75	68859	92357	162848	330942	473448	260451	402957
28			100	69604	93102	163593	331687	474193	261196	403702
29		DC Auto Tracker	20	67957	91455	161946	330040	472546	259549	402055
30			50	69310	92808	163299	331393	473899	260902	403408
31			75	70212	93710	164201	332295	474801	261804	404310
32			100	70957	94455	164946	333040	475546	262549	405055
33	SPV Submersible pump with DLS & fencing	AC Manual	20	61104	80700	139484	300909	430854	242125	372070
34			50	62457	82052	140837	302262	432207	243477	373422
35			75	63359	82955	141739	303164	433109	244380	374325
36			100	64104	83700	142484	303909	433854	245125	375070
37		AC Auto Tracker	20	62457	82052	140837	302262	432207	243477	373422
38			50	63810	83405	142190	303615	433560	244830	374775
39			75	64712	84307	143092	304517	434462	245732	375677
40			100	65457	85052	143837	305262	435207	246477	376422

Source: GOR, Jaipur.

Eligibility Criteria

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. The eligibility criteria specified during the year 2017-18 is presented in Box 2.1 and details are discussed below:

Box 2.6: Eligibility Criteria for Solar Power Pump Subsidy

<table>
<tr><td colspan="2">Eligibility</td><td>Farmer's Eligibility for 3 HP Solar Power Pump Plant</td><td>Farmer's Eligibility for 5 HP solar power pump plant</td></tr>
<tr><td colspan="2">Land tenure</td><td>Minimum 0.5 hectare</td><td>Minimum 1.0 hectare</td></tr>
<tr><td colspan="2">Green House, Shade Net</td><td>1000 Meters</td><td>2000 Meters</td></tr>
<tr><td colspan="2">Lo-Tunnel</td><td>0.5 hectare</td><td>0.75 hectares</td></tr>
<tr><td>Water Storage Structure</td><td rowspan="3">Surface water source</td><td>1000 cubic meters</td><td>1500 cubic meters</td></tr>
<tr><td>Diggi</td><td>400 cubic meters</td><td>800 cubic meters</td></tr>
<tr><td>Farm pond</td><td>1000 cubic meters</td><td>1500 cubic meters</td></tr>
<tr><td colspan="2">Underground Water Source</td><td>Maximum 100m Depth</td><td>Maximum 100m Depth</td></tr>
</table>

Source: Dept of Horticulture, GOR.

Farmers have to apply to the Horticulture department along with a demand draft for Rs.10,000/-, 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.

Farm Pond (Khet talai) (Rashtriya Krishi Vikas Yojana)

- Construction farm pond is a very important and useful activity for harvesting rain water.
- Subsidy: To all category of farmers 50% of cost or maximum Rs 52500/- for earthen farm pond and Rs 75000/- for Farm pond with plastic lining (300 Micron on per BIS Standards), whichever is less Subsidy will be payable for individual beneficiary.
- Eligibility: Farmer should have ownership of minimum 0.5 hectare cultivable land.

Diggi

- Construction of Diggi is very useful activity in Canal Command area to restore surplus water for field crops and other agriculture activity.
- Subsidy :-A subsidy 50% of unit cost or Rs 350 per quvic meter Storage capacity for Pakki Diggi(Masonary work) or Rs 100 per quvic meter Storage capacity with plastic lining Diggi or maximum Rs 2.0 lac. Whichever is less, will be payable to all category of farmers with minimum capacity of four lac liter Storage capacity as an individual beneficiary.
- Eligibility: - Farmer should have ownership on minimum 1.0 ha cultivable land.

Water Tank (Rashtriya Krishi Vikas Yojana)

- Jalhauz construction is a very important and useful activity to store water for timely irrigation as and when required in areas where ground water level is very deep and electric supply is uncertain.
- Subsidy:-To all category of farmers for construction of Jalhauz with minimum one lac liter capacity, 50% of cost or Rs 350 per quvic meter Storage capacity and maximum Rs 75000/- whichever is less subsidy will be payable for individual beneficiary.
- Eligibility: - Farmer should have ownership on minimum 0.5 ha cultivable land.

Irrigation Pipeline (RKVY, NFSM, NMOOP)

- Use of Irrigation Pipeline facility is an important activity for promoting efficient use of irrigation water.
- Subsidy: A subsidy 50% of unit cost or Rs 50/- per meter HDPE pipe or Rs 35/- per meter PVC pipe or Rs 20/- per meter HDPE laminated lay-flat tube pipe or maximum Rs. 15000/- whichever is less, will be payable to all category of farmers as an individual beneficiary.
- Eligibility: Farmer should have ownership on cultivable land, electric / diesel / tractor operated Pumpset. Individual farmer is eligible for separate subsidy having joint and / or separate Pumpset on joint irrigation source. Individual farmer will be eligible for separate subsidy on long distance conveyance pipeline from a common water source.

Sprinkler irrigation and Mobile Raingun (NFSM, NMOOP)

- Sprinkler irrigation and Mobile Raingun facility is provided to farmers for promoting efficient use of irrigation water.
- Subsidy:- Individual beneficiary programme.
- Sprinkler irrigation Programme:-
    - NFSM – Pulses and Wheat: - Subsidy 50% of unit cost or maximum Rs 10000/- per hectare whichever is less, will be payable.
    - NMOOP:- Eligibility:-

Unit cost as per GOI	Area	Farmer Category	Subsidy Payable in %
19600/- per Hectare	DPAP/DDP	Small/ Marginal	60
		Other	45
	Non DPAP/ Non DDP	Small/ Marginal	45
		Other	35

2.4.4 Supportive Programs for Efficient Use of Water

Due to irregular and inadequate rainfall in the state, continuous famine situation remains in some area and water is available for irrigation in limited quantity. Due to rising population and industrialization, increasing demand for water is increasing. In such a situation, it is necessary to preserve this valuable resource, to provide more irrigation in efficient use and to get more profit from the per unit water. Therefore, the following programs are being implemented by the Agriculture Department for proper use of water to attract the attention of the farmers to the protection and efficient use of this limited and valuable resource: -

a) Diggy-Fountain Program
b) Farm Pond (Field Tailieri) Program
c) Water Hog Program
d) Synchy pipeline program

Diggy Fountain Program:

This scheme is quite beneficial in the rural areas for the proper use of water and for irrigation in the irrigated area. When the canal is started, the extra water available in the digestion can be used for irrigation by fountain and drip method. This program is being implemented in the districts of Sriganganagar, Hanumangarh, Jaisalmer, Bikaner, Kota, Baran and Bundi districts. About 50 per cent of the cost or maximum of Rs 3.00 lakh whichever is less, grant is given for the construction of four million liters and a heightened capacity of the dignitaries by the farmers. National Agriculture Development Plan:

- Financial goals of Rs.50.00 crores are proposed for the physical targets of 5000 Diggy constructions and Rupees 150.00 crores in the year 2012-13.
- In the year 2013-14, grants-in-aid of 101.02 crores has been provided to the farmers for the construction of 3453 Digies.
- In the year 2014-15, the financial target of 5000 digit construction and Rs. 100.00 crore financial provision is proposed.

Farm Pond (Farm Tailieri) Program:

This program is very effective for the purpose of collecting irrigation water by collecting rain water in heavy soil and harsh lower surface land. The size of the pond for the grant should not be less than 20x20x3 meters (1200 cubic meters). Farmers subsidy is also payable on the form of various sums of forms (such as 30x30x4, 30x30x3, 25x25x4, 25x25x3 meters) which are more than minimum saris. Small, marginal, scheduled caste, scheduled tribes and women farmers will be given 75 percent of the cost or maximum of Rs 60,000 / - whichever is less, on the construction of various sized forms. Growers will be paid to farmers of general category 50 percent of the cost or maximum Rs 60,000 / - whichever is less.

This program is being implemented in all the districts of the state.

- In the year 2013-14, a grant of Rs. 38.42 crores has been provided to farmers for the construction of 6611 farm pond.
- In the year 2014-15, the physical target of 9000 (8000 raw and 1000 lined) form pond constructions and rupees 49.50 crore financial provision is proposed.

Water Haul Program:

Jawal Hauj is an important plan to ensure the use of irrigation water as per need. The size of the hawk should not be less than 30g 20g 06ft (3600 cubic feet) or less than 1 lakh liters capacity for the grant. All categories of farmers are given 50 percent of the cost or maximum Rs 60,000 / - whichever is less grant in the year 2013-14. This program is being implemented in the districts of Jaipur, Ajmer, Dausa, Sikar, Jhunjhunu, Bikaner, Churu, Jodhpur, Jaisalmer, Barmer, Nagaur, Jalore, Pali, Sirohi and Bundi districts. Financial target of 1,000 water halls construction and financial provision of rupees 6.00 crores in the financial year 2012-13 under National Agriculture Development Plan.

- In the year 2013-14, a grant of Rs 4.82 crore has been provided to the farmers for the construction of 838 water halls.
- In the year 2014-15, the physical target of 1,000 water-havelic building and rupees 6.00 crore is proposed for financial provision.

Synergy Piper Line Program:

By taking raw water available for irrigation through raw drains to the fields, 20 to 25 percent of water is wasted. In order to reduce the wastage and irrigate more area of the water saving area, the farmers of all the categories are asked to take water from the source to the farm on the irrigation pipeline, HDPE / PVC As per their requirement, the farmers will be given subsidy on all types and all-sized pipes to the farmers of 50 percent of the cost or maximum of Rs.15000 / - whichever is less or maximum 25 rupees per meter.

- In the year 2013-14, a grant of Rs 10.21 crore has been made available to farmers for setting up 3729 km pipeline.
- In the year 2014-15, for the Irrigation Pipeline program financial objective of 600 km of NMOP scheme and financial provision of Rs. 150.00 lakh and financial provision of Rs. 4928 crore for the National Food Security Mission and the financial provision of Rs. 1232.00 lakh.

2.4.5 Cost Analysis and Measurable indicators of Solar Pump Programme

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 important government resolutions of State Government of Rajasthan are given in Box 2.7.

Box 2.7: Government Resolutions regarding Solar Irrigation water pumps by, Government of Rajasthan, Jaipur

Date	Resolution No.	Subject
10/15/2014	No.P1() D.H./Solar/GL/2014-15/3255-3479	Guidelines for Solar Energy Operated Irrigation Scheme 2014-15
12/03/2015	No.P1() C.H./Solar/GL/2015-16/4348-4520	Guidelines for Solar Energy Operated Irrigation Scheme 2015-16
07/20/2016	No.P1() D.H./Solar/GL/2016-17/1436-1611	Guidelines for Solar Energy Operated Irrigation Scheme 2016-17
11/1/2017	No.P1() D.H./Solar/GL/2017-18/5401-5526	Guidelines for Solar Energy Operated Irrigation Scheme 2017-18

Source: GOR Office, Jaipur.

The comparative economics of solar pumps and electric system estimated by the State Government in 2013 is presented in Table 2.7. The measurable Indicators - Rajasthan Solar Pump Program up to 2013 is presented in Table 2.8.

Table 2.8: Solar Pump vs Electric System in Rajasthan – Cost Analysis

Sr. No.	Details:	Cost input 25 yr	Per ha/yr
1	**Fixed cost**		
(I)	11 kW Sub Station Structure Cost {Structure, GO & DO and LA	90000	
(II)	25 kVA transformer with meter cost	40000	
(III)	11 KV Line per consumer assuming 5 pole average requirement	55000	
(IV)	Sub total	185000	
(V)	Amount being charged from consumer by Discom for 5 HP Connection @ 2500/- per HP	12500	
A	Net Government financial load for connection:	172500	3450
	Established cost for 25 years @10% per year	431250	8625
2	**Calculation of Indirect Electricity tariff subsidy financial load per consumer on Government:**		
(I)	5 HP Load running 6 Hrs per day for 225 days in a years in a year : 3.75 kW×6 Hrs×225 days=50623 units	5063	
(II)	Electricity being charged for 5062 uni billing @ Rs.1.40 per unit	7088	
(III)	Revenue return possible from the same electricity under Commercial tariff plan @ 6.30 per unit	31894	
(IV)	Net Electricity tariff difference indirect subsidy to consumer per year (c-b)	24806	
B	Total Electricity tariff difference indirect subsidy to consumer in 25 years:	620156	12403
3	**Total Government Investment**		
C1	Total subsidy being provided to consumer on connection as well as indirect tariff subsidy in 25 years period: A+B	1223906	24478
C2	Solar subsidy (86% of cost Rs. 7.48 lac)	643280	12866
4	Benefit of Solar over electricity		
D	Saving of subsidy over electricity/ha/year (C1-C2)		11613
	Saving against Potential per year 100000 ha (5000 pumps) Rs. Lac	29031	1161
	Investment for 5000 pumps @ 5.00 lac/-	25000	

Note: Assumption: 5HP pump covers 2 ha area under irrigation
Source: Goyal, 2013.

Table 2.9: Measurable Indicators: Rajasthan Solar Pump Programme

Sr. No.	*Item*	*Unit*	*Total*
1	MNRE approved rate with DC pump	Rs ./Wp	190
2	MNRE approved rate with AC pump (DC rate minus 15%)	Rs ./Wp	161.50
3	Average solar pump capacity	Wp	3,000
4	No .of pumps in 2012-13	No.	4000
5	Equivalent electric power saved (4000x 3000wp)	MWp	12
6	Duration in hours apump runs/day	Hrs.	6
7	No. of units (KWh) saved per day	KWh	18
8	No. of days a pump runs in a year	Days	200
9	No. of electric units saved per pump per year 18 x 200	KWh	3,600
10	Cost per Kwh of electricity	Rs.	5
11	Monthly saved by solar pump per year 3,600 x 5	Rs.	18,000
12	Conventional grid, distribution capital cost saved(not considered)	Rs.	----
13	Diesel cost saved per year (diesel generation is about twice costly than electric)	Rs.	36000
14	Diesel saved per pump per day	litre	3
15	Diesel saved per pump per year	litre	600
16	Diesel saved total, per year (4000 x 600)	Millon Ltr	2.4
17	Foreign exchange saved per year, crude price@ Rs,20/litre	Rs.million	48
18	Diesel subsidy saved by Govt. per year (24,00,000 x Rs.10/liter)	Rs.million	24
19	Diesel subsidy saved by Govt. in 15 years (Rs.2.4Cr x 15 years)	Rs.million	360
20	Area irrigated per pump per crop	Ha	3
21	Area irrigated total, 2 crops a year (4000 pumps x 2 x3)	Ha	24,000
22	Water required for surface irrigation per Ha	Cubic Mtr	5,000
23	Water saved per Ha due to drip irrigation (40% of 500)	Cubic Mtr	2,000
24	Total water saved, 24,000 x 2,000	MCM	48
25	Additional production value due to irrigation through solar pumps	Rs.	1,00,000
26	Total addl production value due to irrigation through solar pumps	Rs. milion	2,400
27	Co2 emission for one 1kwh electricity produced by diesel	Kg	0.29
28	Total co2 generation avoided, 12,000 KWh x 0.29 kg	Kg	3,480
29	Curtailment in farmers' waitlist for electric connection	Nos.	4,000

Source: Goyal, 2013.

2.5 Chapter Summary:

This chapter presented the status of solar irrigation pumps in Gujarat and Rajasthan highlighting the policies adopted by the government towards same. Success stories of adoption of solar with MIS in Gujarat also highlighted. Rajasthan has been pioneer in promoting solar water pumps by adopting suitable policies with an aim to increase solar pump coverage in the state. Its horticulture department provides 86 per cent subsidy on pumps, while the rest is borne by the farmer. 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. 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.

The next chapter presents the quick results of case study on first Solar Cooperative established in India at Dhundi Village of Thasra taluka of Kheda district in Gujarat, conducted by the authors in May 2016.

Chapter III

Case Study of First Solar Irrigation Cooperative[1]

3.1 Introduction

A novel solar irrigation cooperative is started in Gujarat state in India is the Worlds' first solar irrigation cooperative 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. This chapter presents the details of the study which was done in order to understand and document the formation of Dhundi Saur Urja Utpadak Sahkari Mandali Ltd. (DSUUSM), its functioning and economic benefits as well as the experiences of its member and non-members[1]. Results of the study are presented as follows:

3.2 About Dhundi Village

Dhundi is located in Thasra taluka (Block) of Kheda district in Gujarat (India), about 90 km. east of Ahmedabad. It has a total of 309 families, with a population of 1,473 persons and literacy rate of 74.88 per cent. The proportion of Scheduled Castes (SCs) population was only 0.54 per cent and that of Scheduled Tribes (STs) was nil. Most of the farmers are small and medium land holders. Paddy and pearl millet are major kharif crops while wheat is the major rabi (winter) crop followed by amaranth and tomatoes. During summer, depending on the availability of water, crops like pearl millet, green gram and long beans/snake beans are grown. Ground water is the major source of irrigation. Out of the 40 bore wells in the village, 39 run on diesel and only one is electrified. This is because electricity connections are not easily forthcoming, leaving the farmers with no choice but to operate diesel pumps. All the cultivated land in Dhundi village is irrigated.

A cooperative institution is not a rarity in Dhundi, which is not far from Anand, the cradle of the cooperative dairy revolution in the world. Also,

[1] For details, please see Bhatt and Kalamkar, 2017.

internationally renowned NGOs like the International Water Management Institute (IWMI), Anand and Foundation for Ecological Security (FES), Anand, etc. are located in the vicinity. The DSUUSM was started in Dhundi due to the active role of IWMI, Anand, who were the promoters for DSUUSM and saw it right through its conception to actual formation.

3.3 Sampling Framework

Data from Census of India (Government of India, 2011) regarding population, agricultural land; and caste-wise distribution of land holding in Dhundi etc. were used. Initially, a pilot visit was made to Dhundi. The placement, condition and functionality of solar panels were observed. Informal discussions were held with the members of DSUUSM, on the basis of which, a detailed questionnaire was prepared, which was administered to the respondents. The field survey was conducted in May, 2016. All the 6 members of DSUUSM were included in the sample. Besides, 6 non-members of DSUUSM (who were part of initial discussions with IWMI, but dropped out subsequently) were randomly selected from the names of non-members provided by the DSUUSM members. Thus, total number of respondents were 12 (Members 06 + Non-members 06). With the help of information collected from the respondents, simple tabular analysis was done in order to understand the economic viability and sustainability of the DSUUSM. A SWOC (Strength, Weaknesses, Opportunity and Challenges) analysis of the DSUUSM was also attempted, which has been presented in this paper.

3.4 Nature of Respondents

The average education of DSUUSM members was just 7.5 years (Table 1). In spite of not being highly educated, they exhibited the will to become part of a novel experiment like DSUUSM. Farming was the major occupation of all the respondents followed by animal husbandry and dairying. As shown in Table 2, a majority of members of DSUUSM belonged to BPL (Below Poverty Line) category, while most non-members were of the APL (Above Poverty Line) category. The average family size was quite large at around 8 persons per household. All of the land in Dhundi is irrigated; therefore, rental value of land was reported to be quite high between Rs.77,500 –Rs.85,000 per bigha per year. All the respondents were so far happy with the fertility of their land. The ground water table was also favorable at 35-65 feet. Irrigation was completely dependent on ground water. Each respondent owned a diesel-operated pump to withdraw water.

Table 3.1: Social Characteristics of Selected Respondents

(Per cent)

Characteristics		*Members of DSUUSM*	*Non-Members*
Gender: Male		100.0	100.0
Average years of education		7.5	6.16
Religion : Hindu		100.0	100.0
Caste	SC	50.0	-
	OBC	50.0	100.0
Major occupation: Farming		100.0	100.0
Minor occupation: Animal husbandry and dairying		100.0	100.0

Source: Primary census survey conducted by the researcher in Dhundi, May, 2016.

Table 3.2: Economic Characteristics of Selected Respondents

Sr. No.	*Socio-Economic Characteristic*		*Members of DSUUSM*	*Non Members*
1	Income Group (%)			
	APL		33.33	66.66
	BPL		66.66	33.33
2	Quality of Residence (%)			
	Pucca		50	83.34
	Kutcha		-	16.66
	Semi-pucca		50	-
3	Mean Family Size (No.)		08	8.5
4	Mean Land Ownership (Bigha)		2.375	3.95
5	Irrigated Land (% to total land)		100.00	100.00
6	Rainfed Land (% to total land)		Nil	Nil
7	Main Source of Irrigation	Tube well	100.0	50.00
		Open well	0.00	50.00
8	Average Leased-in Land (bigha)		1.50	1.16
9	Rental Value of Leased-in Land (Rs./bigha/year)		77,500.00	84,375.00
10	Leased-out Land (% to total land)		Nil	Nil
11	Perception about Soil Fertility Status (good)		100.00	100.00
12	Depth of Ground Water Table (feet)- range		35-65	35-70
13	Method of Irrigation -Flood Irrigation		100.00	100.00
14	Distance from canal (meters)		500-1500	500-1500
15	Ownership of diesel-operated pump set (self)		100.00	100.00
16	Capacity of motor in the pump-set (hp)			
	10 hp		80.00	0.0
	12 hp		0.0	80.00
	7 hp		20.00	0.0
	5 hp		0.0	20.00

Notes: 1ha= 4.17 bigha (approximate); hp- horse power; BPL:An economic benchmark of poverty threshold used by the government of India using various parameters with inter-state and intra-state variations; APL: All those households which are not classified as BPL

Source: Data from primary survey

3.5Inception of Dhundi Solar Irrigation Cooperative (DSUUSM):

The DSUUSM was registered on February 16, 2016; while solar energy generation and its use for irrigation started much earlier on November 23, 2015. IWMI did considerable ground work in Dhundi for about a year prior to its formation. The first meeting with the village farmers was held on March 5, 2015; followed by many more meetings to propagate solar power generation and its economic benefits. Long term obligations and legal implications of the formation of DSUUSM were also discussed in detail. Initially about 15 odd farmers had shown their readiness, but finally a group of six farmers remained to become actual members. It is noteworthy that one of the farmers of Dhundi, namely Pravinbhai, was formerly associated with the FES, Anand and was therefore, well-known also at IWMI. Besides, the village folk also trusted him as one of their own. Therefore, through his involvement, the initial ice-breaking and trust development between the Dhundi farmers and IWMI became much easier. Pravinbhai became the first member of the DSUUSM and encouraged others to join as well. He currently acts as its *de facto* secretary cum public relations officer.

The factors that motivated its six members to join the DSUUSM presented in Table 3 indicate that the highest ranked reason was the prospect of avoiding high costs of operating a diesel pump; followed by non-availability of an electricity connection for irrigation needs; and hassles in procuring diesel for running the pumps on a regular basis. Risk-taking instinct of the respondent, peer-pressure and trust in IWMI were the other important motivating factors; ranked at fourth, fifth and sixth position respectively by about a third of the respondents. Clearly therefore, economic factors were most important motivators for joining DSUUSM.

Table 3.3: Motivating Factors to join DSUUSM

Sr. No.	*Motivation to join DSUUSM*	*Rank*	*Per cent (highest single score)*
1	Diesel pump costly to operate	I	83.4
2	Do not have electricity connection	II	50
3	Inconvenience in procuring diesel	III	66.66
4	Progressive farmer (risk-taker)	IV	33.33
5	Personal relations/peer pressure from other members of DSUUSM	V	33.33
6	Trust the NGO and want to support them	VI	33.33

Source: Data from primary survey.

Table 3.4 shows the ranking of reasons expressed by non-members for not joining DSUUSM. They hesitated to join mainly because of the requirement to make initial financial contribution when they were not sure about its success. The other two reasons mentioned were the lack of funds for making a contribution and doubts about the credibility of IWMI.

Table 3.4: Non-Members' Reasons for Not Joining DSUUSM

Sr. No.	*Motivation to not join DSUUSM*	*Rank*	*Per cent (highest single score)*
1	Hesitation to invest funds	I	66.66
2	Lack of investible funds	II	16.66
3	Did not have confidence in NGO	II	16.66

Source: Data from primary survey

3.6 Financial arrangements of DSUUSM

The total capital expenditure on setting up PV panels and connecting them to the grid was close to Rs. 6,000,000. The cost of connecting the solar panels on the farms with the grid is estimated to be Rs. 100,000 for a 1 KV panel, which would go up in proportion to the distance from the grid. The members of DSUUSM were convinced by IWMI to initially contribute a sum of Rs. 54,666 per head (Table 5), which comes to only about 5 per cent of the total project cost. The rest was borne by the donor agency CCAFS (Consortium of International Agricultural Research Centres-Research Programme on Climate Change, Agriculture and Food Security)as reported by Shah *et al.* (2016). Expenditure was done on beneficiary-survey, technical survey, capital equipment like solar panels, pipelines, meters etc., installation and operationalization of the solar pumps etc. Electricity generation and input in the grid was overseen by IWMI. The funds collected initially from the members were deposited as a corpus in its bank account. Thus, the only real contribution of the farmers to this venture was of the land for erecting the solar panels and connecting them with their already existing bore well on the farm.

Even as the farmers did not have to share any burden of this cost or its repayment, their initial contribution to DSUUSM could be considered substantial in view of the fact that they agreed to contribute at a point of time when not only IWMI but the idea of a solar power cooperative itself was novel for them. They seem to have backed this experiment in the hope of saving their costs on irrigation and getting better returns on agriculture. Subsequent to the formation of DSUUSM, they have begun to get substantial direct and indirect benefits. In spite of this, only 33.33 per cent members expressed a willingness to contribute more to DSUUSM if the need for additional funds arose for its expansion or up-gradation. They said that they would still expect the donor agencies and IWMI to arrange for additional funds.

Table 3.5: Members' Contribution to DSUUSM

Particulars	Amount (Rs./Share)
Mean financial contribution to DSUUSM (one time)	54,666.00
Members willing to contribute additional amount to DSUUSM (per cent)	33.33
Additional amount that members are willing to contribute to DSUUSM (per member)	40,000.00

Source: Data from primary survey

3.7 Functioning of DSUUSM

Solar power generation started since November 23, 2015. However, the evacuation of power to the grid started only in only in mid-May 2016. There were no automatic trackers attached to the PV panels, hence, farmers had to change their direction manually throughout the day in order to capture maximum sunlight. The land under the solar panels was being used for cultivation as the shade under the panels keeps shifting throughout the day.

Table 3.6 shows the details regarding number of solar panels on the farm of each member, its size, power generation capacity, units of power generated per day in different seasons viz. winter and summer [from November, 2015 (winter) to May, 2016 (summer)]. It also shows the distance of panels on each farm to the power evacuation point to the grid. This represents requirement to lay wires, pipes etc. and the cost entailed therein.

Post the generation of solar power, the pump connected to the bore well which earlier worked on diesel, started running on solar power. The farmer irrigated his own land during the convenient daylight hours. He could then sell his surplus power for which, he had two options. One, he could empty it into the grid of *Madhya Gujarat Vij Company Limited* (MGVCL, a government of Gujarat owned company for electricity production and transmission). He earned an income at the rate of Rs. 4.63 per unit for selling power as per the 25-year power purchase agreement (PPA) between the DSUUSM and the MGVCL. A consolidated (master) meter was installed by DSUUSM for recording the total power emptied by DSUUSM to the grid. Individual meters were also installed on individual farms, in order to record their individual contribution of solar power. The MGVCL would use the records of the consolidated meter for the purpose of billing and payment for power to the DSUUSM, which in turn, would distribute it to its members according to their respective contributions. Since the readings of the individual meters collectively tally with that in the DSUUSM, the whole process becomes transparent, reliable and easy to understand for the members.

Table 3.6: Installation of Solar Panel and Generation of Power

Farmer No.	No. of solar panels	Size of each panel (ft×ft)	Power generation capacity (units/ day)	Power generated with solar units/day (November 2015 to May 2016)		Area covered by panel (ft × ft)	Panel Distance from Grid (Meters)
				Winter	Summer		
1	4	3×5	40	30	40	60	400
2	6	3×5	70	35	65	90	200
3	6	3×5	55	40	55	90	-
4	6	3×5	62.5	40	62.5	90	-
5	6	3×5	55	40	55	90	1000
6	6	3×5	60	35	55	90	900

Source: Data from primary survey

Second option with the member was to use his surplus solar power in order to withdraw more ground water from his bore well and sell it to his neighboring farmers. The rate of buying water for irrigation is Rs. 100 per hour, using a 5 hp pump. It takes approximately four hours to irrigate 1 bigha of land. Hence, the prevalent price of irrigating 1 bigha of land is around Rs. 400. Approximately 20 units of power are consumed to irrigate 1 bigha of land. If the member were to sell 20 units to MGVCL, he would get (20×4.63) a total income of Rs. 92.60 only. However, if he were to sell ground water to a water buyer, he stood to get Rs. 400 at the prevalent market rates. Hence, contributing surplus power to the grid is not as profitable for him as is the sale of ground water using solar power. Prior to power evacuation from the DSUUSM to the MGVCL having started, i.e. from November 2015 to mid-May 2016, the farmer could use the power either for his own needs or for selling ground water. If he did neither, it would be simply wasted.

In other words, the opportunity cost of using power for ground water sale was zero during that time. It is but natural that he would use most of his surplus power for selling ground water, as noted in Table 7.

Table 3.7: Distribution of Use of Solar Power

Sr. No.	Power Generation/Use	Units	Percentage share	Value (Rs.)
1	Power sold to MGVCL (units)	4,910	17.40	@4.63/unit=`22,733.3
2	Units used for irrigation of own field	4,838	17.14	a) If the farmer were using electricity supplied by MGVCL @ Rs. 0.70/unit: Rs. 3,386.6** b) If the farmer were using diesel pump: 1 liter of diesel approx. @ Rs. 50/*l* is required to generate approx. 20 units of power: 4838/20 units= 241.9 1 *l* of diesel use 241.9 × 50=Rs. 12,095
3	Power used to withdraw water to sell	18,477	65.46	@Rs. 250 per 20 units(required to irrigate one bigha): Rs. 2,30,962.5. @400 it could be Rs. 369,540 (maximum)
4	Total power generated till date of survey	28,225	100.00	

*Notes: **Rate at which electricity is supplied to farmers by MGVCL, as quoted in Shah et al., 2016.*
Source: Data from primary survey

The perusal of Table 3.7 shows the distribution of solar power generated by members of DSUUSM. While they empty only about 17 per cent of power to the MGVCL grid and use almost the same amount for their own irrigation needs; the bulk of the power is used for withdrawing ground water and selling it to their fellow farmers. Hence, value of solar power used for selling ground water is more than seventeen times that of the solar power emptied into the MGVCL grid. The implicit monetary value of the farmer's own consumption of power also stands at a paltry Rs. 3,386 in the scenario of him using grid power. It would be only slightly more than twelve thousand, even if he were using diesel.

During the survey, it was found that the DSUUSM members had resolved to charge Rs. 250 per bigha for solar-pumped groundwater instead of Rs. 400 per bigha by diesel pumps. They said that they reduced the rate out of goodwill for their fellow farmers and mainly because solar power was free of cost for them.

Hence, ground water purchase had become *de facto* cheaper in Dhundi. This effectively means that the supposed benefit of free solar power is mainly accrued by water buyers in Dhundi. It does not significantly benefit either the MGVCL or the farmers themselves.

Another significant fact is that the emptying of power from the farmers towards the grid is one-way only. There is no provision to store the power at the DSUUSM or revert back the power that has been already emptied in the grid. The farmers opined that if solar power could be stored at the farm level through mobile solar cells, they could use it for their household needs also; or rent them out for public functions, processions etc. which could be an additional source of income. The farmers did not initiate the purchase of solar cells from their own funds. Instead, they were hoping that the donor agency would provide it for them. The donors however, revealed no such possibility, since that would considerably increase their costs. It is noteworthy that in Rajasthan, where the entire solar power generating apparatus is mobile and can be locked up, it is transported to and from the farms and used by the farmers for their irrigation as well as household needs (Tewari, 2012).

3.8 Potential Benefits from DSUUSM

The DSUUSM promises to bring a win-win situation for all, as its potential benefits are discussed as follows:

To the Members

As per the PPA, the six solar pumps are presumed to have an aggregate annual capacity of 56.4 KW which can generate annually nearly 85,000 units of solar energy, assuming 5 units per KW on an average daily basis over 300 sunny days per year. About 40,000 units could be used by farmers for their own irrigation needs. Hence, they could save on roughly 3,600 litres of diesel required to produce 40,000 units of power for their own irrigation needs. Assuming the price of diesel @Rs. 50 per liter, it comes to a saving of Rs. 1,80,000. The surplus of about 45,000 units could be injected into the grid, bringing an income of more than two lakhs for them (Shah *et al*., 2016; Nair, 2015 and 2016). There is also a scope for DSUUSM to include 11-12 more members; in order to complete its obligation of 54 KW of power per year under the PPA.

To MGVCL

Due to the formation of DSUUSM, the MGVCL is saved from the prohibitory transaction costs and well as a variety of hassles of getting individual farmers on board for purchasing solar power from them; paying them on an individual basis and collecting their small marketable surpluses through individual meters. Shah *et al.* (2016) show that power purchase from DSUUSM could also be cheaper for MGVCL because on an average, it buys power from solar power companies at the rate of Rs.13 per unit, whereas the PPA with DSUUSM freezes the price at only Rs.4.63 per unit for 25 years. Additionally, the DSUUSM would also enable the MGVCL to earn money from the sale of renewable energy certificates (RECs) against the 85,000 units of solar power that it would generate. Assuming a value of Rs.3,500/megawatt hours for the RECs being traded on electricity exchanges; it comes to an income of almost Rs.3 lakhs. This translates into a gain of about Rs.18.2 per unit for MGVCL (Shah *et al*., 2016).

To the exchequer

The subsidy outgo on provision of agricultural power could be reduced considerably; as under the PPA, the six DSUUSM members have surrendered their right to apply for grid power connections for a period of 25 years. If they did not do so, the MGVCL would have been obliged to supply power to them at Rs.0.70/unit, while purchasing the same at an average of Rs.5 per unit. Moreover, the grid power consumption of Dhundi farmers would have been 162,000 units, assuming an 8-hour supply for 360 days @ Rs.0.70 per unit. Besides, the cost of delivery of power borne by MGVCL would have been much more, at Rs. 4.50 per unit. In this way, even if only two-thirds of the power supplied was used, the annual subsidy burden of MGVCL would have worked out to be well over Rs.4.00 lakh per farmer. Besides, it would have had to invest Rs.2.00 lakhs for connecting every new connection with the grid through poles and cables. The annual interest and depreciation of this investment even at conservative estimates would be 20,000 per year. All these expenditures stand to be wiped out with the inception of DSUUSM.

3.9 Impact of DSUUSM

DSUUSM is a novel experiment in solar power generation and usage in agriculture. Even though not much time has elapsed since its inception, it could be worthwhile to explore its immediate and potential impact.

(a) On Water Markets

The prevailing rate of buying water for irrigation through a 5 hp solar pump is Rs. 400 per bigha. If the water seller were to withdraw water with the help of a diesel pump, he would be spending on diesel as well as occasional maintenance costs of the pump-set. It was estimated that approximately 5 liters of diesel were consumed in irrigating 1 bigha of land. If the price of diesel were Rs.50 per litre, he would be spending around Rs.250 to sell water worth Rs.400. Hence, the net profit per bigha would be around Rs.150. On the other hand, if he sold water withdrawn through the solar pump, operating costs were near-zero, while the price that he could charge could be anywhere between Rs.400 (the going rate) and Rs.250. If he were to charge Rs.400, his net profit would be more than doubled. Alternately, if he were to charge a reduced rate of Rs.250 per bigha (as resolved by DSUUSM members), net profit would still be Rs.250; which is more than that accrued by using a diesel pump. Hence, it is but natural that DSUUSM members were encouraged to extract more ground water and sell it, albeit at a lower price than before. This would result in expanded demand for ground water in Dhundi. This happens because ground water is ‘free’ and extraction of the same is not regulated by the state. Hence, it would be economically very profitable for DSUUSM members, given the fact that they are ground water rich and are able to find enough buyers for their water. In fact, geographical distance between the water buyer and water seller is the only factor that could put a tab on the unabated extraction of ground water in Dhundi. However, if the government were to bring in stringent laws and regulations for groundwater extraction, unabated expansion of groundwater demand could be controlled.

In another scenario, if the farmers were using more diesel to extract and sell more ground water, the precarious situation of ground water extraction would be more or less similar. However, it could be said that due to the onset of solar pumps, ground water extraction is perceived to have become much cheaper and easier, encouraging the farmers to gear up their water sales.

Table 3.8: Water Sale to Fellow Farmers through Solar Power

Total hours of water sale	Before DSUUSM (water sale through diesel pump)	After DSUUSM (water sale through solar pump)	Percentage change
Total hours of sale in Rabi season	732	990	+135.24
Total hours of sale in Summer season	900	2188	+243.11
Total number of irrigations in major Rabi crop	54	82	-
Total number of irrigations in major summer crop	67	107	-
Total number of pumping hours per day in Rabi	46.5**	40**	-
Total number of pumping hours per day in summer	49**	42.5**	-
Total number of farmers to whom water sale was done	34	78	+229
Aggregate net income generated from selling water (Rs.)	37,150	1,48,750	+400

*Note: **Size of withdrawal pipe remained constant at either 3 inches or 4 inches for different farmers.*
Source: Data from primary survey and authors' calculations

Table 3.8 represents the change in sale of ground water in Dhundi after the formation of DSUUSM. It can be seen that the total hours of water extraction for sale has increased by more than 135 per cent. However, the number of pumping hours per day was reported to have reduced. The reason for this as explained was that solar pumps extracted more water per unit of time. Also, instances of break down, heating up of the motor etc. were found to be rare to nil. The number of water buyers has more than doubled after the solarization of irrigation pumps, increasing the income of water sellers in DSUUSM by more than 400 per cent.

(b) On Saving in Costs of Irrigation

Earlier, farmers incurred high direct costs on buying diesel, repairs and maintenance of pump-sets; as well as indirect costs in terms of time and effort to procure diesel on a regular basis. These costs have disappeared after they moved from diesel-powered to solar-powered pump-sets. These savings are presented in Table 3.9.

Table 3.9: Direct and Indirect Expenditure and Savings through Use of Solar-powered Irrigation Pumps

Sr. No.	**Particulars**	**Before DSUUSM**	**After DSUUSM**
(A) 1	*Direct Costs on Irrigation* Mean Expenditure on irrigation through diesel per year (Rs.)13,375/month)×8**	1,07,000.00	00
2	Mean Expenditure on repairs of irrigation pump (Rs. per year),	8,250	Nil
3	Direct Savings due to Solar Pumps (Rs.)	NA	1,15,250
(B) 1	*Indirect Costs of Irrigation* Respondents feeling shortage of availability of diesel (per cent)	100.00	NA
2	Mean distance from sale point of diesel (m)	700	NA
3	Mean requirement of man-hours to procure diesel (hours per week)	1.60	NA
4	Indirect Savings on Irrigation	-	Time and effort for all of the above

*Notes: **Since irrigation is required only in Rabi and summer, diesel has to be purchased only for 8 months in a year; NA - Not Applicable.*
Source: Data from primary survey and Authors' calculations

The annual savings on cost of diesel after shifting to solar powered irrigation was reported to be around Rs. 13,375 per month. Apart from this, one could also save the bother and expenditure on repairs and maintenance of diesel engines, which were reported to be around Rs. 8,250 per year. Thus, direct monetary savings come to Rs. 115,250 per annum. This is a substantial sum which also bears upon the farmers' returns from agriculture. Apart from this, one also saves on all the indirect costs in terms of time and effort of having to procure diesel from the point of sale on a regular basis.

(c) On the ground water level

Environmental implications of groundwater markets expanded by DSUUSM are not to be ignored. Near-zero operating costs of solar pumps were reported to have resulted in over-extraction of ground water. At present the farmers of DSUUSM did not find it worth getting alarmed, because the water table in their bore wells was quite comfortable. However, in the long term, this situation is bound to get more serious. This issue was discussed with the respondents in greater depth. It emerged that only 33.33 per cent respondents recognized the negative impact of over-extraction of ground water. They explained the reason for this by saying that since the irrigation canal was quite close by; ground water would be continually recharged naturally. None of the members had made any attempt or expenditure on artificial recharge of their bore wells.

(d) On Use of Diesel

Use of solar power reduced the dependence on diesel and resultant air and noise pollution. Table 3.10 shows the decrease in the usage of diesel post solarization of irrigation pumps.

Table 3.10: Impact of DSUUSM on Use of Diesel

Usage of Diesel on Irrigation	*Before DSUUSM*	*After DSUUSM*
Mean Usage of diesel in Rabi (liters per day)	10.83	Nil
Mean Usage of diesel in summer (liters per day)	13.33	Nil

Source: Data from primary survey

3.10 Price Intervention by IWMI

The upsurge of ground water extraction and sale in Dhundi during the period between May 2015 and November 2015 which has been reported in this paper; was perhaps also due the fact that during this period, the evacuation of power to the MGVCL grid had not begun. Hence, if the farmers did not use it, it would simply be wasted, as there was no provision of storage at the farm level. In other words, the opportunity cost of using power for ground water sale was zero. Hence, their obvious choice was to increase ground water extraction and sale through solar power. However, the question is, that if there would be an opportunity cost associated with using power for ground water sale, i.e., if the option of selling power to MGVCL was available, would the farmers continue with the same approach towards power sale?

The purchase price at which the MGVCL would buy solar power from the DSUUSM members has been fixed vide the PPA at Rs. 4.63 per unit for a period of 25 years. The PPA does not provide for any revision or even inflation indexation during this period. Further, the price reflects only commercial value of the power, not its economic value as a renewable form of energy or the value of its favourable impact on ground water sale. If these factors were taken into account, the entire calculation is likely to change. On the face of it, ground water sale looks more profitable, because the returns from selling power to MGVCL at the offered price would be much lower. Unless, the MGVCL were to revisit its offer price (which it does not have to, under the PPA), ground water sale would continue unabated.

Nevertheless, on closer study, it turns out that there are several transaction costs involved in selling ground water to neighbouring farmers, like for instance that of labour, supervision and measurement of amount of water. The amount of water actually withdrawn is difficult to ascertain for the seller. Besides, the payments from neighbouring farmers are mostly received after a great delay, and often not fully or not at all. Harsh methods cannot be adopted for recovery, as personal relations are at stake.

On the other hand, transaction costs of selling power to MGVCL are almost nil for the farmers. The evacuated power is reliably and transparently recorded through the DSUUSM meter, price is fixed and assured; and the payment is upfront. Hence, the farmers have many reasons to choose to sell power to MGVCL instead of using it to sell ground water. It is fair to assume that if the price of power purchase were to improve, this could actually happen.

In the light of the above, IWMI decided to top-up the price offered on power evacuation to the grid to DSUUSM members from the CCAFS funds itself, on experimental basis for some period of time. The final price per unit paid to the farmer works out as follows:

MGVCL pays	4.63
Green Energy cess	+ 1.25 (paid from CCAFS funds)
Ground Water Cess	+ 1.25 (paid by CCAFS funds)
Total received by farmer	**= 7.13 per unit**

This was done in the hope of making power sale to the MGVCL, slightly more attractive. The purpose of IWMI behind this experiment was to understand whether farmers would change their ground water pumping behaviour (for own use + sale) if the opportunity cost of selling power for ground water extraction went up. Whether this change actually happens, is a matter of further study.

3.11 Sustainability of DSUUSM

The longevity of any institution depends upon wholehearted participation of its members; as well as their satisfaction in its activities. Since its inception, about 13 meetings in all were held in DSUUSM (Table 3.11). It was reported that all the meetings were attended by all 6 members. Each of them felt that at this stage, the decisions of the DSUUSM were taken by consensus. Elite capture was not apparent during the field survey. This may not be surprising, with the present total membership at a single digit. Members reported that they were involved in the functioning of DSUUSM only to the extent of cleaning and maintaining the solar panels on their own farms and rotating them regularly. They did not do any other work of technical nature like arranging meetings, preparing agenda and minutes of the meetings, maintenance of accounts, solution of problems faced by fellow members, handling and maintaining of various records and registers etc. All the above functions were currently handled by only one particular member only. Capacity-building of members for running and expansion on their own after the withdrawal of IWMI, was yet to be done. The DSUUSM had not yet decided its secretary, membership fee, yearly operation and maintenance charges etc. In case of a dispute in future, the DSUUSM may fumble to keep itself afloat due to a lack of competence of most of the members in crucial areas of operation.

Table 3.11: Participation of Members in DSUUSM

Indicator of Participation	Extent of Participation
Number of Meetings held in DSUUSM since inception	13
Members who attended all the meetings (Per cent)	100.00
Members who think that decisions in DSUUSM are taken after consulting everyone (Per cent)	100.00
Functions undertaken by members of DSUUSM	Cleaning solar panels on their own farms, rotating them regularly

Source: Data from primary survey

The perusal of Table 3.12 shows transparency in the functioning of DSUUSM and satisfaction of members with the income from solar power. Members were satisfied by the maintenance of meters which recorded the emptying of power to the MGVCL. However, a majority (66.67 per cent) of them were not satisfied with the price for power offered by MGVCL. This was because they were getting higher income by selling ground water to their fellow farmers instead of emptying it into the grid. Instead of the price of Rs. 4.63 per unit offered to them currently, they expected an increase up to Rs. 6-10 per unit (25-50 per cent).

Table 3. 12: Transparency and Satisfaction of Members in the Functioning of DSUUSM

(Per cent)

Sr. No.	*Indicator*	*Yes*	*No*
1	Satisfaction with the maintenance of power meters by DSUUSM	100.00	Nil
2	The meters record the units of solar power contributed by me correctly	100.00	Nil
3	Satisfied by the payment offered for the sale of solar power	33.33	66.67
4	Willingness to contribute more to DSUUSM corpus	33.33	66.67

Source: Data from primary survey

3.12 SWOC Analysis of DSUUSM

Even as the DSUUSM is in its infancy, it has been attempted to make a SWOC analysis of its various aspects like formation, functioning, financing and sustainability as follows:

Strengths

- The cooperative model of DSUUSM made decentralized solar power generation less complicated because the MGVCL was saved from having to engage with individual farmers. This brings speed and efficiency in solar power generation and its evacuation in the grid.
- It enabled the MGVCL to save on transaction and vigilance costs which could have been prohibitive if the farmers were not organized through DSUUSM.

- With the formation of DSUUSM, the MGVCL could evacuate power through a single point, which cuts down on transmission losses to an extent.
- Payment could be done to at a single point, i.e. DSUUSM, which saves on metering and monitoring costs and hassles of individual payments.
- It was able to create a substantial corpus from members' initial contribution.
- The process of emptying power to the grid was reported to be transparent and fair, which inspired confidence amongst members.
- Transparency ensures reliability; and hence lesser possibility of conflicts between the DSUUSM, its members and the MGVCL.
- Shifting to solar power brought substantial gains for the farmers in terms of savings on costs of diesel. This improved their returns from agriculture.
- Saving of diesel, a non-renewable resource, also contributes in reducing the carbon footprint of irrigation.

Weaknesses

- DSUUSM was formed and survives completely on IWMI's support. Capacity building of the members or financial planning for self-sufficiency post-withdrawal of IWMI was not done.
- Membership fee was not yet decided. No provision made for meeting routine administrative expenditure.
- With use of solar power, irrigation would be possible only during day time. This may bring more evaporation and greater water use, in turn impacting water use efficiency.
- There was no provision to store the generated power at the farm level; making it unavailable for household use or sale for non-agricultural purposes at the local level.

Opportunities

- The DSUUSM promises to bring a win-win situation for both the farmers and the MGVCL. The farmers get free power for their irrigation needs and the MGVCL could buy power at a cheaper rate than that obtained from thermal plants.
- Removal of need to use diesel pumps for irrigation could go a long way in liberating the MGVCL and Gujarat state government from the heavy burden of agricultural power subsidies.
- The assured power buyback guarantee from MGVCL opens up another avenue of income generation for small-holder farmers and insures them against a failed agricultural season.
- In future, power sale by DSUUSM could be opened up for private electricity companies as well.
- If the farmer were to get a competitive price for power sale to the grid, he could be discouraged from over-extracting ground water.

Challenges

- If the upsurge in sale of ground water were not dealt with urgently, it could have a very negative impact on ground water levels in the long run.
- Smooth functioning of DSUUSM would be challenging after the withdrawal of support by IWMI.

3.13 Chapter Summary

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.

Next chapter presents the results from the field level data from Gujarat.

Chapter IV

Findings from Field Survey in Gujarat

4.1 Introduction

In order to understand the possible reasons for the adoption of solar technology, information were collected from selected households on various parameters such as their socio-economic profile, operational holdings, sources of irrigation, land holding including leased in and leased out land, source of income and items of expenditure as well as their cropping pattern and returns from cultivation. Further, their reasons for adopting solar technology or otherwise, either with or without subsidy from the government, were also probed. The respondents' experiences with solarized irrigation and their suggestions in order to expand the area under solarized irrigation in Gujarat were also sought. The collected information is presented in a tabular form and analysed in order to draw meaningful conclusions and bring out policy implications as discussed in the present chapter.

4.2 Social Profile of the Selected Households

As mentioned in introductory chapter, three groups of respondents were studied by the researches viz. i) farmers who had adopted SIPs with the help of subsidy by the government, ii) 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 data were collected from three distinct groups of farmers. The first group was of 100 sample farmers (25 from each of the four districts under study, i.e. Sabarkantha, Bhavnagar, Narmada and Dahod) who had installed Solar Irrigation Pumps (SIP) with the support of subsidy from the government (beneficiary farmer households). The second group consisted of 4 sample farmers (1 from each of the four districts) who had installed SIPs on their own without any support in the form of subsidy (non-beneficiary farmers). The third group included 20 sample farmers (5 each from the four districts under study) who had not yet adopted solarized irrigation (non-adopters). They were still using other conventional fuels for powering their irrigation pumps when they were visited by the researchers. Thus, the total sample consisted of 124 selected farmers. The details of social profile of selected farmers are presented in Table 4.1.

Table 4.1: Personal Profile of Selected Respondents in Gujarat

Sr. No.	Particulars	Beneficiary Adopters (n=100) BEN	Non-Beneficiary Adopters (n=4) NONBEN	Non-Adopters (n=20) NSUSER	Av (n=124)
1	Gender of Respondent (%)				
	Male	91.00	100.00	100.00	92.74
	Female	9.00	0.00	0.00	7.26
2	Average Size of household (Nos.)	9.37	4.00	7.95	7.11
3	Average No. of members working in Agriculture	4.34	3.17	4.1	3.87
4	Mean Age of respondent (years)	51.0	33.0	43.9	43.9
5	Mean years of Education of respondent (years)	6.7	16.8	9.3	10.9

Source: Field survey data.

It can be seen from the Table that expect 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.

Table 4.2: Social Characteristics of Selected Respondents

Sr. No.	Characteristic	Beneficiary Adopters	Non-Beneficiary Adopters	Non-Adopters	Av.
A	*Religion (% to total)*				
1	Hindu	94.00	75.00	95.0	93.5
2	Muslim	5.00	25.00	5.0	5.6
3	Christian	0.00	0.00	0.0	0.0
4	Others	1.00	0.00	0.0	0.8
B	*Social group (% to total)*				
1	Scheduled Tribe	50.00	25.00	50.0	49.2
2	Scheduled Caste	2.00	0.00	10.0	3.2
3	Other Backward Castes	25.00	50.00	20.0	25.0
4	General/Open	23.00	25.00	20.0	22.6

Source: Field survey data.

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.

4.3 Economic Profile of the Selected Respondents

The details on economic characteristics of the selected households are presented in Table 4.3. It can be seen that 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.

Table 4.3: Economic Characteristics of Selected Respondents

Sr. No	Particulars	Beneficiary Adopters	Non-Beneficiary Adopters	Non-Adopters	Av.
A	*Principal Occupation (%)*				
1	Cultivator	91.0	25.0	90.0	88.7
2	Animal Husbandry and Dairying	0.0	0.0	0.0	0.0
3	Agricultural Labour	0.0	0.0	0.0	0.0
4	Non-farm Labour	0.0	0.0	0.0	0.0
5	Own Non-Farm Establishment	0.0	0.0	0.0	0.0
6	Trade	8.0	75.0	0.0	8.9
7	Employee in Service	1.0	0.0	10.0	2.4
8	Other	0.0	0.0	0.0	0.0
B	*Subsidiary Occupation (%)*				
1	Cultivator	9.0	75.0	10.0	11.3
2	Animal Husbandry and Dairying	69.0	25.0	50.0	64.5
3	Agricultural Labour	15.0	0.0	35.0	17.7
4	Non-farm Labour	1.0	0.0	0.0	0.8
5	Own Non-Farm Establishment	3.0	0.0	0.0	2.4
6	Trade	1.0	0.0	5.0	1.6
7	Employee in Service	1.0	0.0	0.0	0.8
8	Other	1.0	0.0	0.0	0.8
C	*Mean years of experience in farming*	*29.6*	*13.5*	*21.0*	*21.4*
D	*Income Group (%)*				
1	BPL	44.0	0.0	55.0	44.4
2	APL	54.0	100.0	45.0	54.0
3	AAY	2.0	0.0	0.0	1.6
E	*House Structure (%)*				
1	Pucca	25.0	100.0	45.0	30.6
2	Semi-Pucca	12.0	0.0	5.0	10.5
3	Kuccha	63.0	0.0	50.0	58.9

Source: Field survey data.

From the field data, it was found that on average, selected households had around 21 years of experience in farming (Table 4.3). 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.

4.4 Size of Land Holdings with Selected Households

The details on operational landholding of the selected sample households are presented in table 4.4. It can be seen that the average land holding size of selected beneficiary households was 3.25 ha and non-adopters was 2.95 ha, 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.

Table 4.4: Operational Landholding of the Selected Sample Households

Sr. No	Particulars	Beneficiary Adopters	Non-Beneficiary Adopters	Non-Adopters	Av.
A	Total owned land (ha/hh)				
	Rainfed	0.65	0.20	1.01	0.69
	Irrigated	2.54	9.44	1.60	2.61
	Total	3.19	9.64	2.61	3.30
B	Un-cultivated land				
	Rainfed	0.00	0.00	0.00	0.00
	Irrigated	0.00	0.00	0.00	0.00
	Total	0.00	0.00	0.00	0.00
C	Cultivated land				
	Rainfed	0.65	0.20	1.01	0.69
	Irrigated	2.54	9.44	1.60	2.61
	Total	3.19	9.64	2.61	3.30
D	Leased-in land				
	Rainfed	0.02	0.00	0.16	0.04
	Irrigated	0.05	0.70	0.18	0.09
	Total	0.00	0.70	0.34	0.08
E	Leased –out land				
	Rainfed	0.00	0.00	0.00	0.00
	Irrigated	0.00	0.00	0.00	0.00
	Total	0.00	0.00	0.00	0.00
G	Total operational land (ha/hh)				
	Rainfed	0.67 (20.6)	0.20 (1.9)	1.17 (39.7)	0.73 (21.3)
	Irrigated	2.59 (79.7)	10.14 (98.1)	1.78 (60.3)	2.70 (78.7)
	Total	3.25 (100.0)	10.34 (100.0)	2.95 (100.0)	3.43 (100.0)

Note: Figures in parenthesis are percentage to total.
Source: Field survey data.

4.5 Changes in Cropped Area and Cropping Intensity:

Changes in cropped area of selected beneficiary households after solarization is presented in table 4.5. It can be seen from the table 4.5 that after solarization, gross cropped was increased by about 37 per cent 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.

Table 4.5: Changes in Net Sown Area, Gross Cropped Area and Cropping Intensity of Sample Beneficiary Households

Sr. No.	Seasons	Particulars	Beneficiary Households	
			Before Solarization (2015-16)	After Solarization (2016-17)
A	Gross Cropped Area (ha)		3.89	5.33
B	Gross Irrigated Area (ha)		2.93	4.59
C	Kharif	Rainfed (% to season total area)	35.59	25.02
		Irrigated (% to season total area)	64.41	74.99
		Total as percentage of GCA	69.16	55.31
D	Rabi	Rainfed (% to season total area)	0.00	0.00
		Irrigated (% to season total area)	100.00	100.00
		Total as percentage of GCA	25.13	34.23
E	Summer	Rainfed (% to season total area)	0.00	0.00
		Irrigated (% to season total area)	100.0	100.0
		Total as percentage of GCA	5.71	10.46
F	Total	Rainfed (% to GCA)	24.62	13.84
		Irrigated (% to GCA)	75.39	86.16
G	Net Area Sown (% to GCA)		95.69	73.73
H	Cropping Intensity (%)		144.59	180.79

Source: Field survey data.

The changes in the cropped area in case of selected non-beneficiary households after solarization are presented in Table 4.6. 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. The cropping intensity, GCA and net sown area of non-adopters shown in Table 4.7 indicate relatively better cropping intensity compared to non adopter households.

Table 4.6: Changes in Net Sown Area, Gross Cropped Area and Cropping Intensity of Sample Non-beneficiary Households

Sr. No	Seasons		Non-beneficiary Households Changes in area (% to GCA)	
			Before	After
A	Gross Cropped Area (ha)		6.81	11.98
B	Gross Irrigated Area (ha)		6.33	8.47
C	Kharif	Rainfed (% to season total area)	7.05	29.22
		Irrigated (% to season total area)	63.86	44.50
		Total as percentage of GCA	70.91	73.72
D	Rabi	Rainfed (% to season total area)	0.00	0.00
		Irrigated (% to season total area)	29.09	26.28
		Total as percentage of GCA	29.09	26.28
E	Summer	Rainfed (% to season total area)	0.00	0.00
		Irrigated (% to season total area)	0.00	0.00
		Total as percentage of GCA	0.00	0.00
F	Total	Rainfed (% to GCA)	7.05	29.23
		Irrigated (% to GCA)	92.95	70.77
G	Net Area Sown (NAS)		70.91	73.72
H	Cropping Intensity (%)		141.0	135.6

Source: Field data survey.

Table 4.7: Net Sown Area, Gross Cropped Area and Cropping Intensity of Sample Non-adopter households

Sr. No.	Season		Non-adopter households Area (% to GCA)
A	Gross Cropped Area (ha)		4.27
B	Kharif	Rainfed (% to season total area)	29.3
		Irrigated (% to season total area)	70.7
		Total as percentage of GCA	63.7
C	Rabi	Rainfed (% to season total area)	0.0
		Irrigated (% to season total area)	100.0
		Total as percentage of GCA	27.4
D	Summer	Rainfed (% to season total area)	0.0
		Irrigated (% to season total area)	100.0
		Total as percentage of GCA	8.9
E	Total	Rainfed (% to GCA)	18.7
		Irrigated (% to GCA)	81.3
F	Net Area Sown (% to GCA)		63.7
G	Cropping Intensity (%)		157.0

Source: Field data survey.

It is evident from the above Tables (4.5 to 4.7) that 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.

4.6 Changes in Cropping Pattern

Changes in cropping pattern of sample beneficiary households are presented in table 4.8. It can be seen from the table that 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 (Table 4.9). 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 (Table 4.10). 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.

Table 4.8: Changes in Cropping Pattern of Sample Beneficiary Households

Sr. No.	Season	Irrigated/ Unirrigated	Crops	Area in % to GCA	
				Before	After
A	Kharif	(a) Rainfed	Cotton	2.95	1.92
			Groundnut	5.00	3.63
			Pearl Millet (jowar)	1.93	0.09
			Maize	6.19	2.51
			Vegetables	0.21	1.49
			Paddy	5.72	2.64
			Pigeon Pea (tur)	2.34	1.10
			Urad	0.21	0.24
			Millet (bajra)	0.08	0.21
			Total Rainfed	24.62	13.84
		(b) Irrigated			
			Cotton	10.50	11.86
			Fodder	1.55	1.30
			Groundnut	8.03	5.11
			Maize	3.92	5.63
			Paddy	3.21	4.88
			Soya bean	7.72	9.95
			Tur	1.68	1.11
			Bajra	0.21	0.06
			Urad	1.81	1.49
			Dragon fruit	0.37	-
			Castor seeds	0.12	0.09
			Fruit crops	5.43	-
			Total irrigated	44.55	41.48
B	Rabi	(a) Irrigated	Fennel	1.42	0.95
			Fodder	1.74	1.41
			Gram	3.02	5.76
			Maize	0.92	3.65
			Potato	0.80	1.13
			Vegetables	1.47	1.45
			Wheat	15.14	19.50
			R & Mustard	0.62	0.27
			Watermelon	-	0.11
C	Summer	Irrigated	Bajra	0.98	1.12
			Fodder crop	0.56	0.84
			Maize	0.31	0.60
			Moong	0.15	1.58
			Groundnut	0.62	0.44
			Lemon	1.54	1.88
			Vegetables	-	0.65
			Fodder	-	1.36
			Paddy	-	0.11
			Fruit crops	1.54	1.88

Source: Field Survey data.

Table 4.9: Changes in Cropping Pattern of Sample Non-beneficiary Households

Sr. No.	Season	Type	Crops	Non-beneficiary Households % to GCA	
				Before Solarization	After Solarization
A	Kharif	Rainfed	Groundnut	7.05	29.22
		Irrigated	Cotton	37.44	25.04
			Groundnut	11.01	8.01
			Urad	15.42	10.44
			Fodder	-	1.00
		Total		70.92	73.71
B	Rabi	Irrigated	Onion	7.05	5.01
			Wheat	22.02	21.28
		Total		29.08	26.29

Source: Field Survey

Table 4.10: Cropping Pattern Sample Non-adopter Households

Sr. No.	Seasons	Crops	Non-adopter Households % to GCA -(2016-17)
A	Kharif	Cotton	3.20
		Groundnut	0.00
		Maize	6.33
		Jowar	2.09
		Paddy	3.20
		Tur	2.50
		Urad	2.09
		Fodder	1.25
		Total Rainfed	*20.65*
		Cotton	4.17
		Paddy	3.76
		Castor	13.33
		Soyabean	2.09
		Maize	2.09
		Total Irrigated	25.43
		Total Kharif	46.09
B	Rabi	Gram	4.38
		Wheat	30.48
		Fodder	5.84
		Total Rabi (Irrigated)	40.68
C	Summer	Fodder	9.21
		Bajra	1.11
		Onion	0.42
		Urad	2.50
		Total Summer (Irrigated	13.23

Source: Field Survey

4.7 Possession of Irrigation Pumps:

The details about the possession of irrigation pumps by selected sample households are presented in Table 4.11. It indicates that 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.

Table 4.11: Details on Possession of irrigation Pumps by Selected Respondents

Sr. No.	Particulars	Beneficiary Adopters	Non-Beneficiary Adopters	Non-Adopters	Av.
1	Surface AC	0.0	0.0	60.0	9.7
2	Submersible AC	75.0	50.0	40.0	68.5
3	Surface DC	0.0	0.0	0.0	0.0
4	Submersible DC	25.0	50.0	0.0	21.8

Source: Field survey data.

4.8 Status of Irrigation before Solarization

It can be seen from the Table 4.12 that 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.

Table 4.12: Sources and Methods of Irrigation Before Solarization (per cent)

Sr. No	Particulars	Beneficiary Adopters	Non-Beneficiary Adopters	Av.
1	% of HHs having grid supply/ connection on farm	25.0	25.00	25.0
2	Average Rate			
	Metered (Per Unit)	0.80	Flat rate	0.80
	Average payment Rs./Year	5096.3	6266.7	5681.48
3	Average Grid power availability (hrs)			
	Rainy	8.00	8.00	8.00
	Winter	8.00	8.00	8.00
	Summer	8.00	8.00	8.00
4	Sources of Irrigation			
	Open well (%)	57.0	75.0	57.7
	Tube well (%)	54.0	50.0	53.8
	Tank (%)	2.0	0.0	1.9
	Canal (%)	5.0	0.0	4.8
	Others (%)	6.0	0.0	5.8
5	Average Water depth (ft.)	111.0	508.3	309.68
6	Nature of irrigation pumps before solar pumps			
	Diesel (%)	64.0	50.0	63.5
	Electric (%)	20.0	25.0	20.2
	Rented diesel (%)	15.0	75.0	17.3
	Rented electric (%)	6.0	0.0	5.8
7	Average Capacity in HP			
	Diesel	5.5	5.3	5.40
	Electric	5.5	2.5	3.98
8	Method of Irrigation			
	Drip (No.s/ %)	20.0	75.0	22.1
	Sprinkler (No.s/ %)	5.0	0.0	4.8
	Flood No.s (%)	94.0	100.0	94.2
9	Average Distance of Canal/River water (Meter)	916.8	1200.0	1058.38
10	% of HHS having water storage availability	21.0	25.0	21.2
11	% of HHS having ground water recharging facility	31.0	50.0	31.7

Source: Field survey data.

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.

4.9 Installation of Solar Panels and Availability of Power

The details about the installation of solar panels and availability of power with selected beneficiary and non-beneficiary households are presented in Table 4.13.

Table 4.13: Installation of Solar Panels and Availability of Power

Sr. No.	Particulars	Beneficiary Adopters	Non-Beneficiary Adopters
1	Mean land area on which solar PV panels and pump are installed (ha)	1.57	3.00
2	HHs having solar PV panels (% to total)		
	on Field	98.0	100.0
	at home (on field)	2.0	0.0
3	HHs having device rotated (% to total)		
	Manual	100.0	100.0
	Automatic	0	0
4	Mean No. of solar stand poles	4	7
5	Mean No. of rectangular panels in stand poles	20	25
6	Mean Size of each panel (ft*ft)	3x5	2.5x5
7	Mean power generation capacity (units/day)	NA	NA
8	Average Actual power generated with solar units/day	NA	NA
9	Mean area covered by each stand pole(ft x ft)	5x5	12x24
10	Connection of solar power plant to the grid (No.s/%)	0.0	0.0
11	Mean sale of power to the grid (units/ per month)	0	0
12	Selling rate (Rs./unit)	0	0
13	HHs that installed solar power storage cells (No.s/%)	79.0	100.0
14	Approximate cost per unit (range)	NA	NA
15	Type of use of storage cells		
	On own field	100.0	100.0
	On others' field	0	0
	Renting out for social function	NA	NA
16	Approximate hours of power used per irrigation	NA	NA
17	Prevalent water rates in the district (Rs./bigha/hour of irrigation)		
	i) Through canal flow (Rs. Per Hectare)	700	650
	ii) Through canal lift	100	-
	iii) Through govt. tube well (Rs. Per Hrs)	50	-
	iv) Purchased (Rs. Per Hrs)	100	-
18	No. of HHs using solar power		
	(a) for household use	0.00	0.00
	(b) for agriculture	57.0	100.0
	(c) for both (those who stay on farm)	43.00	0.00

Source: Field survey data.

It can be seen from the Table 4.13 that 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 which was built on farm, 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 (Table 4.13).

4.10 Reasons for Adopting Solar Pumps

The selected farmers were asked about the reasons for adoption of solar power generation unit on their farm. They cited multiple reasons for choosing SIPs on their farm as shown in Table 4.14.

Table 4.14: Reasons for Adopting SIPs

Sr. No	Reason	Reasons (responses % to total)-multiple responses		
		Beneficiary Adopters	Non-Beneficiary Adopters	Av.
1	Non-availability of electricity connection	96.0	75.0	79.8
2	Costly diesel	91.0	25.0	74.2
3	Costly to run electric pump	86.0	25.0	70.2
4	Unreliability of electricity supply	81.0	25.0	66.1
5	Inconvenient hours of electricity supply	82.0	25.0	66.9
6	Wanted to take advantage of subsidy being offered	96.0	0.0	77.4
7	Wanted to try a new technology	83.0	100.0	70.2
8	Wanted to try renewable technology as it is environment-friendly	86.0	50.0	71.0
9	Personal relations with the person who marketed solar technology	84.0	25.0	68.5
10	Recommendation of fellow farmers, friends or relatives	83.0	75.0	69.4
11	Savings on the cost of fertilizers and weeding	82.0	25.0	66.9
12	Saving on the electricity bill	78.0	50.0	64.5
13	To avoid hassles of irrigating crop irrigation during night hours	77.0	75.0	64.5

Source: Field survey data.

The data indicates that 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.

4.11 Sources of Finance to Purchase Solar 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 had contributed own investment to the tune of 15 to 27 thousand and the rest was paid through subsidy by the government agencies. However, the non-beneficiary households had spent 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.

Table 4.15: Sources of Finance for purchasing solar pump

Sr. No.	Break up of Finance for Installation of SIP by Source	Beneficiary Adopters	Non-Beneficiary Adopters
1	Average Cost of solar pump (Rs.)		
	GUVNL	330980.5	-
	GGRC	399779.5	-
	Private	-	558750.0
2	Average Own investment (Rs.)		
	GUVNL	15471.0	
	GGRC	27154.8	
	Private		558750.0
3	Subsidy amount (Rs.)		
	GUVNL	315509.0	
	GGRC	372624.7	
	Private	--	---
4	Bank loan availed by - amount (Rs.)	NA	440000.0
5	Households financed/supported by NGO (Nos)	1	0
6	Cost of documentation & installation (Rs.)	387.80	212.5
67	Cost of installation (Rs.)	0.0	0

Source: Field survey data

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 (Table 4.15). 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.

4.12 Installation of Solar Pumps and Post-installation Service

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 (Table 4.16). 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.

Table 4.16: Process of Installation and Pre and Post-installation Support

Sr. No	Particulars	BEN	Non-BEN
1	No. of times that the representative of the agency visited the respondent (Avg. Days)	2.80	2.5
2	No. of working days taken to complete installation (Range)	18.69	5
3	Percentage share in company from the agency that made installation? (Percent)		
	AVI	2.00	-
	Bright	1.00	25.00
	Duke	1.00	-
	Green Tech	1.00	-
	Harmison	2.00	-
	Kosol	8.00	-
	Lotu	3.00	-
	LUBI	29.00	50.00
	Mitra Shakti	3.00	-
	Niti	3.00	-
	Rotosol	11.00	-
	Sahaj	2.00	-
	Shakti	1.00	-
	Shaswat Clintech Pvt. Ltd.	3.00	-
	Top Sun	5.00	25.00
	Yuratom Pvt. Ltd.	2.00	-
	SOYO SOLAR	4.00	-
	Power Tek	5.00	-
	Goldi Green Technologies Pvt Ltd	7.00	-
	Sonali Solar	3.00	-
	Falcon Solar	4.00	-
4	Respondent who received instructions/ training/demonstration about operating solar pump	95.00	100.00
5	Satisfaction with support services provided by agency	73.00	75.00
6	No. of insured solar pumps	17.00	25.00
7	Satisfaction of respondents with quality of solar panels	71.00	100.00

Source: Field Survey

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, such a facility was not actually available. Hence, 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.

4.13 Conditions of Eligibility for Subsidy

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 (Table 4.17).

Table 4.17: Conditions of eligibility of receiving subsidy

Sr. No	Eligibility conditions	% to total responses
1	Caste/Category	91.0
2	Gender (Female)	42.0
3	No Grid connection	89.0
4	Income group (BPL)	57.0
5	Land ownership (Marginal >1 ha; Small >2 ha)	86.0
6	Backwardness of region/area	44.0
7	Availability of Diggi=1/Tank=2	40.0
8	Availability of micro irrigations instruments (drip/sprinklers)	00.0
9	Ready to take Solar with micro irrigation	00.0

Source: Field Survey

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).

Table 4.18: Characteristics of Respondents using SIPs

Sr. No	Characteristics	Beneficiary Adopters (N=100)	Non-beneficiary Adopters (n=4)	Av. (N=104)
1	Solar pump with MIS	14.0	25.0	14.4
2	Solar pump without MIS	86.0	100.0	86.5
3	Adopted micro-irrigation along with solar pump	14.0	75.0	50.0
4	Solar pump without subsidy	00.0	100.0	29.8
5	Adopted solar irrigation only because bank loan was available	41.0	100.0	43.3
6	Would advise others to adopt solarization of irrigation pumps	27.0	100.0	29.8

Source: Field Survey

4.14 Water Use and Sale 'Before' and 'After' the Installation of SIPs

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.

Table 4.19: Water Use and Sale 'Before' and 'After' solar pump

Sr. No	Particulars	Water use			
		Before		After	
		BEN	NonBEN	BEN	NonBEN
1	Mean depth of groundwater (ft)	110.7	450.0	116.4	450.0
2	Mean consumption of electricity for irrigation (hrs/bigha)				
	Rabi	6.5	6.0	-	-
	Summer	8	9	-	-
3	Mean amount of diesel (litres/ watering/bigha)				
	Rabi	15	18	-	-
	Summer	20	22	-	-
4	Approximate mean expenditure on repair of diesel pump (Rs/year)	6533.0	10375.0	0	0
5	Approximate mean expenditure on repair of electric pump (Rs/year)	3987.9	6250.0	0	0
6	Approximate mean distance from sale point of petrol/ diesel (km)	12.5	7.5	NA	NA
7	Approximate mean time spent on procuring diesel/petrol per week	2.2	1	NA	NA
8	Respondents having issues with electricity supply	77	4	40	
9	Mean expenditure on irrigation (Rs/bigha/season)				
	Diesel pump	7027	3750	-	-
	Electric pump	4287	2500	1228	0
	Solar pump	0	0	0	0
10	Respondents purchasing water	8	0.0	0	0
11	Average hours of purchased irrigation/season	1.64	0.0	0	0
12	Selling water to others (diesel/electric/solar)	-	-	-	-
13	Mean hours of water sale per total/season	-	-	-	-
14	Price of water sale (diesel/electric/ solar)	-	-	-	-
15	Average income from water sale (per year)	-	-	-	-
16	Average amount of water sale per season	-	-	-	-
17	Average No. of farmers to whom water sold	-	-	-	-
18	Average no. of irrigations under water sale	-	-	-	-
19	Average no. of hours of pumping for water sale	-	-	-	-
20	Average diameter of withdrawal water pipe	-	-	-	-
21	No. of farmers who believe that excessive water withdrawal for sale is harmful in long run	71	4	71	4
22	No. of farmers who had taken steps to curtail water withdrawal for sale	-	-	-	-
23	No. of farmers who had taken steps for artificial recharge of ground water	12	4	12	4
24	Average Expenditure on water recharging efforts	-	-	-	-

Besides, on an average, an expenditure of Rs. 6,533 and Rs. 10,375 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 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 travelled 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 (Table 4.20).

Table 4.20: Crop Diversification & Changes in Productivity

Sr. No.	Particulars	Crop Diversification & Changes in Productivity-After Solarization	
		BEN	NonBEN
1	Respondents who adopted crop diversification		
	Kharif	42	0
	Rabi	51	0
	Summer	40	0
2	Respondents who reporting increase in crop productivity		
	Kharif	69	3
	Rabi	78	2
	Summer	48	2
3	No. of farmers reporting changes in crop productivity with solar pump		
	Has increased	74	4
	Has decreased	0	0
	Remained constant	26	0

4.15 Maintenance of Solar PV Panels

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.

Table 4.21: Frequency of Cleaning of Solar Panels

Sr. No	Time period/Frequency	Beneficiary	Non-Beneficiary	Average
1	Every day	1.0	0.0	1.0
2	Alternative day	23.0	25.0	23.1
3	Twice in week	66.0	25.0	64.4
4	one in a week	10.0	50.0	11.5
5	fortnightly	0.0	0.0	0.0
6	Approximate time taken for cleaning (minutes)	19.8	22.5	21.2

Source: Field Survey

It was observed that households adopted different time schedules as per their convenience for cleaning the surface of solar PV panels (Table 4.21). 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.

4.16 Experiences with Solarized Irrigation

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 (Table 4.22).

Table 4.22: Experiences with Solarized Irrigation

Sr. No	Particulars	Before Solarization (%)			After Solarization (%)		
		BEN	NonBEN	Av.	BEN	NonBEN	Av.
1	Ease of Operation	17.0	25.0	17.3	84.0	100.0	84.6
2	Ease of maintenance	20.0	0.0	19.2	88.0	100.0	88.5
3	Frequency of break-down and repair	76.0	75.0	76.0	22.0	0.0	21.2
4	Labour and supervision required	85.0	75.0	84.6	16.0	25.0	16.3
5	Instances of interruptions due to outages/ shortage of diesel	86.0	100.0	86.5	24.0	50.0	25.0
6	Convenience in timings for irrigation	10.0	25.0	10.6	91.0	100.0	91.3
7	Output of water	25.0	50.0	26.0	97.0	100.0	97.1
8	Use of fertilizers per bigha	25.0	25.0	25.0	70.0	75.0	70.2
9	Use of micro-irrigation methods	10.0	25.0	10.6	13.0	50.0	14.4
10	Total sample size	100.0	4.0	104.0	100.0	4.0	104.0

Source: Field Survey data.

4.17 Experiences of Advantages and Disadvantages of Solar pumps

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 to fetch diesel or petrol time and again (Table 4.23).

Table 4.23: Experiences of Advantages of Solar Pumps

Sr. No	Advantages	Advantages of Solar Pumps (% to total)		
		Beneficiary	Non-Beneficiary	Av.
1	No maintenance cost	80.0	100.0	80.8
2	No cost of fuel	83.0	75.0	82.7
3	No harassment of fetching diesel	85.0	75.0	84.6
4	Almost nil monthly cost of operation	88.0	100.0	88.5
5	Quality supply of power	62.0	100.0	63.5
6	Generate income through sale of water	0.0	0.0	0.0
7	Generate income through renting out of power cells	0.0	0.0	0.0
8	Saving labour cost	75.0	100.0	76.0
9	No harassment of irrigating crop in night	85.0	100.0	85.6

Source: Field Survey

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 (Table 4.24).

Table 4.24: Experiences of Disadvantages of Solar Pumps

Sr. No	Disadvantages	Disadvantages of Solar Pumps (% to total)		
		Beneficiary	Non-Beneficiary	Av.
1	Only can be used during sunny days	74.0	100.0	75.0
2	High initial cost of installation	33.0	75.0	34.6
3	Heavy depletion of groundwater	13.0	0.0	12.5
4	High cost of batteries/power cell	5.0	0.0	4.8
5	Height of panel is lower thus cannot use space below panel	71.0	100.0	72.1

Source: Field Survey

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.

4.18 Factors for Non-Adoption and Perceptions of Non-Adopters

The non-adopter households were asked the reasons for non-adoption of SIPs. The Table 4.25 reveals that the 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.

Table 4.25: Factors for Non-Adoption of SIPs

Sr. No.	Description	Garrent Ranking Score	
		%	Rank
1	Lack of funds	72.85	1
2	Opposition from family members	62.45	2
3	Hesitation to invest/ Risk aversion	62.25	3
4	Less land, unviable for investment on solar pump	57.80	4
5	Do not have confidence in the NGO/donor agency/Government/external agents	56.20	5
6	Personal differences with other members	54.85	6
7	Have flat rate electricity connection	49.35	7
8	Land plot is situated at a distance; not found economical to connect to the grid	48.65	8
9	Came to know about it much later	34.60	9
10	Ground water is at great depth, unsuitable for solar	33.60	10
11	Subsidy is insufficient. I want .....% subsidy	33.45	11
12	No one contacted me persuasively	32.95	12

Source: Field Survey

Although the non-adopters could not adopt SIPs due to a variety of reasons as mentioned in Table 4.25, 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 advantages of SIPs pointed out by the non-adopters are presented in Table 4.26.

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 (Table 4.27).

Table 4.26: Advantages of SIPs as Perceived by Non-Adopters

Sr. No.	Advantage	% to total responses
1	No maintenance cost	90.0
2	No cost of fuel	55.0
3	No harassment of fetching diesel	45.0
4	Almost nil monthly cost of operation	10.0
5	Quality supply of power	15.0
6	Generate income through sale of water	5.0
7	Generate income through renting out of power cells	0.0
8	Saving labour cost	25.0
9	No harassment of irrigating crop in night	65.0
10	No operational cost	70.0
11	Govt. offer of subsidy	70.0

Source: Field Survey

Table 4.27: Disadvantages of SIPs as Perceived by Non-Adopters

Sr. No.	Particulars	% to total responses
1	Only can be used during sunny days	80.0
2	High initial cost of installation	65.0
3	Heavy depletion of groundwater	15.0
4	High cost of batteries/power cell	0.0
5	Height of panel is lower thus cannot use space below panel	0.0

Source: Field Survey data.

4.19 Suggestions for Expansion of Solarized Irrigation

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 (Table 4.28).

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 (Table 4.29).

Table 4.28: Suggestions of Beneficiary and Non-Beneficiary Adopters of SIPS for the Expansion of Solarization of Irrigation in Gujarat

Sr. No	Suggestions	Suggestions (% to total)-multiple		
		Beneficiary	Non-Beneficiary	Av.
1	Height of the solar panel should be little bit more so that space below can be used	49.0	100.0	51.0
2	Service Centre should be provided at local level	40.0	75.0	41.3
3	Technical manpower is required for the company who taking the responsibilities of installation of SIPs	34.0	0.0	32.7
4	Manual rotation system is very difficult , automatic rotated system should be incorporated	34.0	0.0	32.7
5	Proper Space/Land management will be required for solar pump installation	29.0	0.0	27.9
6	For Protection of System Financing Facilities need to provided with solar pumps	35.0	0.0	33.7
7	Prompt service is required for maintenance	36.0	100.0	38.5

Source: Field Survey

Table 4.29: Suggestions of Non-Adopters for Expansion of Solarization of irrigation in Gujarat

Sr. No.	Suggestions	Percent of Respondents
1	Awareness about SIP schemes	55.0
2	Portability of grid connectivity to SIPs	40.0
3	Criteria of subsidy should be relaxed	55.0
4	Increase the subsidy rate	45.0

Source: Field Survey data.

4.20 Chapter Summary

This chapter presents the findings from the data collected from the survey of farmers in the selected study areas, i.e. the districts of Narmada, Dahod, Sabarkantha and Bhavnagar in Gujarat. In conclusion, it could be said that while the socio-economic profile of beneficiaries of SIP subsidy and the non-adopters of SIP is poor, the non-beneficiary adopters of SIPs enjoy a higher socio-economic status. Solarized irrigation has benefitted its adopters, but mainly the beneficiaries. The cropping pattern, crop diversity and productivity have been positively impacted due to solarization of irrigation. However, 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.

The next chapter present survey results conducted in Rajasthan.

Chapter V

Findings from Field Survey in Rajasthan

5.1 Introduction

In order to understand the possible reasons for the adoption of solar technology, information were collected from selected households on various parameters such as their socio-economic profile, operational holdings, sources of irrigation, land holding including leased in and leased out land, source of income and items of expenditure as well as their cropping pattern and returns from cultivation. Further, their reasons for adopting solar technology or otherwise, either with or without subsidy from the government, were also probed. The respondents' experiences with solarized irrigation and their suggestions in order to expand the area under solarized irrigation in Rajasthan were also sought. The collected information is presented in a tabular form and analysed in order to draw meaningful conclusions and bring out policy implications as discussed in the present chapter.

5.2 Social Profile of the Selected Households

As mentioned earlier, 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 or support-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). The details of social profile of selected households are presented in Table 5.1. It can be seen from the table 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.

Table 5.1: Personal Profile of Selected Respondents in Rajasthan

Sr. No.	Particulars	Beneficiary Adopters (n=100) BEN	Non-Beneficiary Adopters (n=5) NONBEN	Non-Adopters (n=20) NSUSER	Av. (n=125) ALL
1	Gender of Respondent (%)				
	Male	95.00	100.00	100.00	96.00
	Female	5.00	0.00	0.00	4.00
2	Average Size of household (Nos.)	6.91	5.30	5.40	5.87
3	Average No. of members working in Agriculture	3.67	3.30	3.15	3.37
4	Mean Age of respondent (years)	51.3	50.10	48.3	49.90
5	Mean years of Education of respondent (years)	6.70	11.80	6.60	8.37

Source: Field survey data.

The religion-wise distribution of selected respondents presented in Table 5.2 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.

Table 5.2: Social Characteristics of Selected Respondents

Sr. No.	Characteristic	Beneficiary Adopters	Non-Beneficiary Adopters	Non-Adopters	Av.
A	Religion (% to total)				
1	Hindu	94.00	80.00	95.00	93.60
2	Muslim	1.00	0.00	0.00	0.80
3	Christian	0.00	0.00	0.00	0.00
4	Others	5.00	20.00	5.00	5.60
B	Social group (% to total)				
1	Scheduled Tribe	1.00	0.00	0.00	0.80
2	Scheduled Caste	1.00	0.00	35.00	6.40
3	Other Backward Castes	81.00	40.00	55.00	75.20
4	General/Open	17.00	60.00	10.00	17.60

Source: Field survey data.

5.3 Economic Profile of the Selected Respondents

The details on economic characteristics of the selected households are presented in Table 5.3. It can be seen from the table 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 indicate that more than 98 percent of beneficiary and non beneficiary households were better off term sof income as compared to non-adopters group in which half of the selected respondents were from below poverty line income group. Thus low income status may have kept non adopters away from adoption of this new power generation technology. In case of dwelling structure, it was observed that 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.

Table 5.3: Economic Characteristics of Selected Respondents

Sr. No.	Particulars	Beneficiary (N=100)	Non-Beneficiary (n=5)	Non-Adopters (n=20)	Av. (N=125)
A	**Principal Occupation (%)**				
1	Cultivator	92.00	60.00	90.00	90.40
2	AH & Dairying	0.00	0.00	0.00	0.00
3	Agri. Labour	0.00	0.00	0.00	0.00
4	Nonfarm Labour	0.00	0.00	0.00	0.00
5	Own Non-Farm Establishment	2.00	0.00	0.00	1.60
6	Trade	1.00	0.00	0.00	0.80
7	Employee in Service	5.00	40.00	10.00	7.20
8	Other	0.00	0.00	0.00	0.00
B	**Subsidiary Occupation (%)**				
1	Cultivator	8.00	60.00	50.00	16.80
2	AH & Dairying	72.00	40.00	25.00	63.20
3	Agri. Labour	0.00	0.00	0.00	0.00
4	Nonfarm Labour	0.00	0.00	0.00	0.00
5	Own Non-Farm Establishment	10.00	0.00	0.00	8.00
6	Trade	9.00	0.00	0.00	7.20
7	Employee in Service	1.00	0.00	25.00	4.80
8	Other	0.00	0.00	0.00	0.00
C	Av. years of experience in farming	29.60	28.00	30.00	29.20
D	**Income Group (%)**				
1	BPL	2.00	0.00	50.00	9.60
2	APL	98.00	100.00	50.00	89.60
3	AAY	0.00	0.00	0.00	0.00
E	**House Structure Nos. (%)**				
1	Pucca	98.00	60.00	45.00	88.00
2	Semi-Pucca	2.00	20.00	35.00	8.00
3	Kuccha	0.00	20.00	20.00	4.00

Source: Field survey data.

5.4 Size of Land Holdings with Selected Households

Land is the most important and limited factor in agriculture. The details on operational landholding of the selected sample households are presented in Table 5.4. It can be seen from the table that 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 holding of 0.91 ha as marginal land holders, while corresponding figure for non-beneficiary households was 6.10 ha, indicating 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.

Table 5.4: Operational Landholding of the Selected Sample Households

Sr. No	Particulars	Beneficiary	Non-Beneficiary	Non-Adopters	Total
A	Total owned land				
	Rainfed (% to total)	6.12	0.00	25.35	3.65
	Irrigated (% to total)	93.88	100.00	74.65	96.35
	Total (ha)	**2.45**	**5.86**	**0.71**	**3.01**
B	Un-cultivated land				
	Rainfed (% to total)	0	0	0	0
	Irrigated (% to total)	0	0	0	0
	Total (ha)	**0**	**0**	**0**	**0**
C	Cultivated land				
	Rainfed (% to total)	12.50	0.00	19.78	4.42
	Irrigated (% to total)	87.50	100.00	80.22	95.58
	Total (ha)	**1.2**	**5.35**	**0.91**	**2.49**
D	Leased-in land				
	Rainfed (% to total)	0.0	0.0	-	0.0
	Irrigated (% to total)	100.0	100.0	-	100.0
	Total (ha)	**0.01**	**0.75**	**0**	**0.25**
E	Leased –out land				
	Rainfed (% to total)	-	-	-	-
	Irrigated (% to total)	-	-	-	-
	Total (ha)	**0**	**0**	**0**	**0**
G	Total operational land/HHs				
	Rainfed (% to total)	12.40	0.00	19.78	4.01
	Irrigated (% to total)	87.60	100.00	80.22	95.99
	Total (ha)	**1.21**	**6.1**	**0.91**	**2.74**

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 had 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 build confidence in farmers to invest in installation of solar pumps on their farm with their own expenditure, i.e. without any subsidy.

5.5 Changes in Cropped Area, Cropping Intensity and Irrigation Method:

Changes in cropped area and changes in use of irrigation methods of selected beneficiary households after solarisation are presented in Tables 5.5 and 5.6. It can be seen from these tables that after solarisation, area under cropped as well as irrigated area was increased by around 17 percent while cropping intensity was almost constant. The share of area sown to gross cropped area during kharif and summer season has shown meager increase. It can be seen from table 3.6 that distribution of 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.

Table 5.5: Changes in Net Sown Area, Gross Cropped Area and Cropping Intensity of Sample Beneficiary Households

Sr. No	Seasons	Particulars	Before Solarisation (2015-16)	After Solarisation (2016-17)
A	Kharif	Rainfed (% to season total area)	0.83	0.32
		Irrigated (% to season total area)	99.17	99.68
		Total as percentage of GCA	63.07	64.13
B	Rabi	Rainfed (% to season total area)	0.43	1.00
		Irrigated (% to season total area)	99.57	99.00
		Total as percentage of GCA	35.41	33.86
C	Summer	Rainfed (% to season total area)	0.00	0.00
		Irrigated (% to season total area)	100.00	100.00
		Total as percentage of GCA	1.51	2.01
D	Total	Rainfed (% to GCA)	0.67	0.54
		Irrigated (% to GCA)	99.33	99.46
E	Net Area Sown (% to GCA)		63.07	64.13
F	Cropping Intensity (%)		158.55	155.94

Source: Field Survey data.

Table 5.6: Changes in use of Irrigation Methods of Beneficiary Households

Sr. No.	Method of irrigation	Area in ha		Percentage change
		Before solarisation	After Solarisation	
A	**Gross Irrigated Area**	**281.97**	**329.53**	**16.90**
1	Flood	154.96 (54.67)	109.25 (33.09)	-29.50
2	Sprinkler	116.76 (41.19)	200.70 (60.78)	71.89
3	Drip	10.25 (3.62)	19.58 (5.93)	91.02
B	Rainfed	1.48 (0.52)	0.67 (0.20)	-54.73
C	**GCA**	**283.45 (100.00)**	**330.20 (100.00)**	**16.49**

Note: Figures in parenthesis are percentage total.
Source: Field Survey data.

The changes in net sown area, gross cropped area and cropping intensity of and changes in use of irrigation methods of non-beneficiary households after solarisation are presented in Tables 5.7 and 5.8. It can be seen from these tables that 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.

Table 5.7: Changes in Net Sown Area, Gross Cropped Area and Cropping Intensity of Sample Non-beneficiary Households

Sr. No	Seasons		Changes in area (% to GCA) n=5	
			Before	After
A	Kharif	Rainfed (% to season total area)	11.62	5.76
		Irrigated (% to season total area)	88.38	94.24
		Total as percentage of GCA	63.07	64.13
B	Rabi	Rainfed (% to season total area)	0.00	0.00
		Irrigated (% to season total area)	100.00	100.00
		Total as percentage of GCA	35.41	33.86
C	Summer	Rainfed (% to season total area)	0.00	0.00
		Irrigated (% to season total area)	100.00	100.00
		Total as percentage of GCA	1.51	2.01
D	Total	Rainfed (% to GCA)	7.49	3.42
		Irrigated (% to GCA)	92.51	96.58
E	Net Area Sown (NAS) % to GCA		64.5	59.3
F	Cropping Intensity (%)		155.12	168.49

Source: Field data survey.

It can be seen in the table that the 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.

Table 5.8: Changes in use of Irrigation Methods of Non-beneficiary Households

Sr. No.	Irrigation Methods	Area in ha.		Percentage change
		Before solarisation	After Solarisation	
A	Gross Irrigated Area	36.3	47.77	31.60
1	Flood	26 (66.24)	18.85 (38.11)	-27.50
2	Sprinkler	9.18 (23.39)	26.73 (54.04)	191.18
3	Drip	1.13 (2.88)	2.19 (4.43)	93.81
B	Rainfed	2.94 (7.49)	1.69 (3.42)	-42.52
C	GCA	39.24 (100.00)	49.46 (100.00)	26.04

Note: Figures in parenthesis are percentage total.
Source: Field Survey

In case of non-adopters, cropping intensify was 166 per cent (Table 3.9) mainly because of more than four fifth of total cropped area having irrigation coverage.

Table 5.9: Net Sown Area, Gross Cropped Area and Cropping Intensity of Sample Non-adopter households

Sr. No.	Season		Area (% to GCA)
A	Kharif	Rainfed (% to season total area)	12.71
		Irrigated (% to season total area)	87.29
		Total as percentage of GCA	60.16
B	Rabi	Rainfed (% to season total area)	0.00
		Irrigated (% to season total area)	100.00
		Total as percentage of GCA	
C	Summer	Rainfed (% to season total area)	0.00
		Irrigated (% to season total area)	0.00
		Total as percentage of GCA	0.00
D	Total	Rainfed (% to GCA)	7.65
		Irrigated (% to GCA)	92.35
E	Net Area Sown (NAS)		15.73
F	Cropping Intensity (%)		166.21

Source: Field data survey.

5.6 Status of Irrigation before Solarisation

It can be seen from the Table 3.10 that before solarisation of irrigation pumps, out of selected solar water pumps users, only 37 percent of beneficiary households had grid connection facility available on their farm while all the non-beneficiary farmers had grid connectivity to their irrigation pumps. In case of rate charged towards use of electricity, almost two third pumps of beneficiary households were metered and remaining were charge on flat rate basis. While in case of non-beneficiary households, all irrigation pumps 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 had used multiple method of irrigations such drip and sprinkler irrigation. The average water depth was estimated to be 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 mostly 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.

Table 5.10: Details about Grid Connectivity and Irrigation Pumps before Solarisation

Sr. No.	Particulars	Beneficiary (n=100)	Non Beneficiary (n=5)
1	% of HHs having grid supply/ connection on farm	37.00	100.0
	Average Rate		
	Metered (%)	59.46	100.0
	Flat rate (%)	40.54	0.00
2	Average payment Rs./Year	3500.0	3225.0
3	Average Grid power availability (hrs)		
	Rainy	6.00	6.00
	Winter	6.00	6.00
	Summer	6.00	6.00
4	Major source of Irrigation		
	Open well (%)	19.00	0.00
	Tube well (%)	40.00	60.00
	Tank (%)	25.00	40.00
	Canal (%)	36.00	60.00
5	Average Water depth (ft.)	198.31	205.83
6	Nature of irrigation pumps before solar pumps		
	Diesel (%)	50.00	60.00
	Electric (%)	37.00	40.00
	Rented diesel (%)	13.00	0.00
	Rented electric (%)	0.00	0.00
	Floods (%)	100.00	100.00
7	Average Capacity in HP		
	Diesel	3.00	3.00
	Electric	5.00	5.00
8	Method of Irrigation		
	Drip (No.s/ %)	68.00	40.00
	Sprinkler (No.s/ %)	89.00	40.00
	Flood No.s(%)	14.00	60.00
9	Average Distance of Canal/River water (mtrs)	909.47	762.50
10	% of HHS having water storage availability	66.00	60.00
11	% of HHS having ground water recharging facility	0.00	0.00

Source: Field Survey

5.7 Changes in Cropping Pattern

Changes in cropping pattern of sample beneficiary households are presented in Table 5.11. It can be seen from the table that due to about 17 per cent increase in gross cropped as well as irrigated area after solarisation, area under fruits and vegetables, wheat and maize crop was 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 subsistence crops like bajra, maize, soybean in kharif and wheat, gram and mustard in rabi, and feed crops as well to earn income and benefit. After solarisation, not only numbers of crops grown have increased but also 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, cropping pattern indicate that kharif season was the major season (Table 5.12) for them. However, 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 the use of diesel and electricity pump. As expected after solarisation, the share in area of traditional crops such as jowar, moong, moth, guar and bajra has declined 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 about 26 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 also 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.

Table 5.11: Changes in Cropping Pattern of Sample Beneficiary Households

Sr. No.	Crop Name		Before solarisation % GCA	After Solarisation % GCA	% age change Area
1	Kharif				
a	Rainfed	Maize	0.06	0.07	43.75
		Jowar	0.25	0.10	-54.17
		Moth	0.12	0.00	-100
		Guar	0.10	0.03	-59.26
b	Irrigated	Bajra	18.00	16.10	4.21
		Maize	7.51	7.10	10.09
		Jowar	7.18	7.73	25.52
		Moong	4.71	4.37	8.1
		Moth	0.32	0.37	35.16
		Urad	0.03	0.05	100
		Groundnut	5.36	7.73	68.03
		Sesamum	0.03	0.02	0
		Soybean	3.94	4.18	23.55
		Cotton	6.60	5.69	0.53
		Guar	5.22	4.54	1.22
		Tomato	0.02	0.06	233.33
		Ladyfinger	0.02	0.02	0
		Kinnow	3.62	4.43	42.73
		Lemon		0.47	100
		Pomegranate		0.41	100
		Guava		0.50	100
		Chilly		0.06	100
		Brinjal		0.02	100
		Cabbage/Cauliflower		0.04	100
		Rose		0.03	100
2	Rabi				
a	Rain fed	Gram	0.12	0.25	138.24
		Mustard	0.03	0.09	244.44
b	Irrigated	Barley	0.24	0.07	-66.67
		Wheat	18.49	16.75	5.55
		Gram	7.77	7.23	8.4
		Rapeseed & Mustard	8.47	8.60	18.28
		Linseed	0.06	0.08	47.06
		Razka	0.02	0.03	50
		Onion	0.02	0.06	216.67
		Chilly	0.05	0.14	200
		Isabgul	0.06	0.07	37.5
		Tomato	0.08	0.25	281.82
		Cucumber		0.14	100
		Ginger		0.04	100
		Palak & Methi		0.04	100
		Marigold		0.04	100
3	Summer	Jowar Fodder	1.50	1.89	47.06
		Vegetable	0.01	0.01	33.33
		Watermelon	0.00	0.02	600
		Muskmelon		0.02	100
		Tomato		0.02	100
		Aowla		0.04	100
		GCA			16.49

Table 5.12: Cropping Pattern of the Non-Beneficiary Sample Household

Sr. No.	Crop Name	Before solarisation % GCA	After Solarisation % GCA	% age change In area
a	Rainfed			
	Moth	1.91	1.52	0
	Guar	3.97	1.90	-40
	Bajra	1.60	0.00	-100
b	Irrigated	0.00		
	Bajra	9.04	8.51	18.59
	Maize	1.35	1.60	48.58
	Jowar	1.27		-100
	Moong	1.27	2.02	100
	Moth	3.03	1.52	-36.84
	Soybean	15.36	13.91	14.01
	Groundnut		5.94	
	Cotton	14.98	12.78	7.48
	Guar	2.06	0.63	-61.54
	Tomato	2.88	2.87	26.22
	Ladyfinger	0.15	0.53	320
	Chilly	2.70	2.34	9.41
	Kinnow	2.88	3.29	44.44
2	Rabi			
a	Irrigated			
	Wheat	11.84	12.63	23.36
	Gram	5.99	10.37	76.89
	R & Mustard	14.01	11.81	34.22
	Linseed	0.79	0.00	45.45
	Onion	0.64	0.71	87.5
	Cucumber	0.32	0.51	88.5
3	Summer			
	Jowar Fodder	0.97	0.89	16.67
	Vegetable	0.97	2.61	243.33
	Pomegranate		1.13	----
	GCA			24.59

Source: Field Survey

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 (Table 5.13). 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.

Table 5.13: Changes in Cropping Pattern Sample Non-adopters Households

Sr. No.	Crop name	% GCA
1	Kharif	
a	Rainfed	
	Moth	4.78
	Guar	2.87
b	Irrigated	0.00
	Bajra	12.20
	Maize	4.21
	Jowar	5.74
	Moong	5.74
	Moth	4.55
	Groundnut	5.12
	Soybean	3.94
	Cotton	6.46
	Guar	4.05
	Tomato	0.50
2	Rabi	
a	Irrigated	
	Wheat	21.15
	Gram	4.78
	Rapeseed & Mustard	5.74
	Linseed	1.19
	Onion	0.96
	Cucumber	0.48
	Fodder	5.54

Source: Field Survey

5.8 Possession of Irrigation Pumps:

The details on possession of irrigation pumps of selected households presented in table 5.14 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.

Table 5.14: Details on Possession of irrigation Pumps of selected Respondents

Sr. No.	Particulars	Responses (% to total)			
		Beneficiary (N=100)	Non-Beneficiary (n=4)	Non-Adopters (n=20)	Total (N=124)
1	Surface AC	2.00	0.00	0.00	1.60
2	Submersible AC	33.00	0.00	0.00	26.40
3	Surface DC	11.00	0.00	0.00	8.80
4	Submersible DC	54.00	100.00	0.00	47.20

Source: Field Survey

5.9 Installation of Solar Panels and Availability of Power

The details about the installation of solar panels and availability of power with selected beneficiary and non-beneficiary households are presented in Table 5.15. It can be seen from the table 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.

Table 5.15: Installation of Solar Panels and Availability of Power

Sr. no.	Particulars	Beneficiary (n=100)	Non Beneficiary (n=5)
1	Mean land area on which solar PV panels and pump are installed (ha)	4.8	4.43
2	HHs having solar PV panels (%)		
	on Field	100.0	100
	at home	0	0
3	HHs having device rotated (%)		
	Manual	30.0	40.0
	Automatic	70.0	60.0
4	Mean No. of solar stand poles	4	6
5	Mean No. of rectangular panels in stand poles	12	13
6	Mean Size of each panel (ft*ft)	3x5	3x5
7	Mean power generation capacity (units/day)	NA	NA
8	Average Actual power generated with solar units/day	NA	NA
9	Mean area covered by each stand pole		
	(FT x FT)	5x5	5x5
10	Connection of solar power plant to the grid (No.s/%)	37.00	5.00
11	Mean sale of power to the grid (units/ per month)	NA	NA
12	Selling rate (Rs./unit)	NA	NA
13	HHs that installed solar power storage cells (No.s/%)	NA	NA
14	Approximate cost per unit (range)	NA	NA
15	Type of use of storage cells		
	On own field	NA	NA
	On others' field	NA	NA
16	Renting out for social function	NA	NA
16	Approximate hours of power used per irrigation	NA	NA
17	Prevalent water rates in the district (Rs./bigha/hour of irrigation) (range)		
	i) Through canal flow	NA	NA
	ii) Through canal lift	NA	NA
	iii) Through govt. tube well	NA	NA
	iv) Purchased	NA	NA
18	No. of HHs using solar power		
	(a) for household use		
	(b) for agriculture	98.0	100
	(c) for both	2.0	0

5.10 Reasons for Adopting Solar Pumps

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 field and it is 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 (Table 5.16).

Table 5.16: Reasons for Adopting Solarised Irrigation Pumps

Sr. No	Particulars	Responses (%)	
		Beneficiary (n=100)	Non Beneficiary (n=5)
1	Non-availability of electricity connection	50.00	**60.00**
2	Costly diesel	51.00	60.00
3	Costly to run electric pump	24.00	70.00
4	Unreliability of electricity supply/ Inconvenient grid supply timings	46.00	40.00
5	Inconvenient hours of electricity supply	41.00	60.00
6	Wanted to take advantage of subsidy being offered	36.00	0.00
7	Wanted to try a new technology	3.00	0.00
8	Wanted to try renewable technology as it is environment-friendly	34.00	20.00
9	Personal relations with the person who marketed solar technology	4.00	0.00
10	Recommendation of fellow farmers, friends or relatives	14.00	0.00
11	Savings on the cost of fertilizers and weeding	16.00	20.00
12	Saving electric bill	56.00	80.00
13	To avoid hassle of irrigating crop irrigation during night hours	66.00	30.00

Source: Field survey data.

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 through solar.

5.11 Sources of Finance to Purchase Solar Pumps

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 sources of finance for purchasing solar pump are given in the table 3.17. It can be seen in the table that 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/- (Table 5.17). The expenditure of Rs. 1584/- was incurred towards installation by the beneficiary while corresponding figure for non-beneficiary household was Rs. 1848/-.

Table 5.17: Sources of Finance for Purchasing Solar Pump

Sr. No.	Particulars	Beneficiary (n=100)	Non Beneficiary (n=5)
1	Av. Cost of solar pump (Rs.)		
	3 HP	480449.0	449281.0
	5 HP	646870.0	606167.0
2	Av. Subsidy on Solar (Rs.)		
	3 HP	323966.8 (67.43)	0.00
	5 HP	456370.0 (70.55)	0.00
3	Own investment (Rs.) Range		
	3 HP	156482.2 (32.57)	449281 (100.00)
	5 HP	190500.0 (29.45)	606167 (100.00)
4	Amount of bank loan (Rs.)		
	3 HP	100750 (55.82)	250000 (55.64)
	5 HP	150500 (79.00)	280333 (46.25)
5	Number of HH taken bank loan (%)	48.00	100.00
6	Bank Interest rate (%)	4.00	4.00
7	Number of Bank Provided Loan	4.75	3.00
8	HHs financed/supported by NGO	-	-
9	Av. Cost of documentation and installation (Range) in Rs.	1111.00	1847.75
10	Av. Cost of installation Rs.	1584.00	3514.00

Source: Field survey data.

5.12 Installation of Solar Pumps & Post installation Service

The process of installation of solar pump took almost 6-7 days (Table 5.18) 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.

Table 5.18: Process of Installation and Pre and Post-installation Support

Sr. No.	Particulars	Beneficiary (n=100)	Non Beneficiary (n=5)	Total (n=105)
1	No. of times that the representative of the agency visited the respondent (Avg .Days)	2.23	4.5	3.36
2	No. of working days taken to complete installation (Range)	6.32	5.4	6.02
3	Percentage share in funds from the agency that made installation?			
	Jain Irrigation	62.00	60.00	61.90
	LUBI	6.00	0.00	5.71
	Modern Solar	1.00	0.00	0.95
	Shakti	3.00	20.00	3.81
	Tata Solar	4.00	20.00	4.76
	Topsun	5.00	0.00	4.76
	Waaree	10.00	0.00	9.52
	Reel Solar	6.00	0.00	5.71
	SunEdison	2.00	0.00	1.90
	Lanco	1.00	0.00	0.95
4	Respondent who received instructions/ training/demonstration about operating solar pump (%)	98.00	60.00	96.19
5	Satisfaction with support services provided by agency (%)	95.00	100.00	95.24
6	No. of insured solar pumps (%)	92.00	100.00	92.38
7	Satisfaction of respondents with quality of solar panels (%)	98.00	100.00	98.10

Source: Field survey data.

5.13 Conditions of Eligibility for Subsidy

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.

Table 5.19: Conditions of Eligibility of Receiving Subsidy

Sr.	Eligibility conditions	% to total
a	Caste/Category	0.0
b	Gender (Female)	0.0
c	Income group (BPL)	0.0
d	Land ownership (Marginal >1 ha; Small >2 ha)	80.0
e	Backwardness of region/area	0.0
f	No Grid connection	14.0
g	Availability of Diggi=1/Tank=2	80.0
h	Availability of micro irrigations instruments (drip/sprinklers)	83.0
i	Ready to take Solar with micro irrigation	52.0

Source: Field survey data.

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 (Table 3.20). Characteristics of respondents using solarised irrigation pumps are given table 5.20. 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.

Table 5.20: Characteristics of Respondents Using Solarised Irrigation Pumps

Sr. No.	Characteristic	Responses (%)		
		Beneficiary (n=100)	Non Beneficiary (n=5)	Av. (n=105)
1	Solar pump with MIS	93.0	100.0	93.33
2	Solar pump without MIS	6.0	0.0	5.71
3	Adopted micro-irrigation along with solar pump	93.0	100.0	93.33
4	Solar pump without subsidy	0.0	100.0	4.76
5	Adopted solar irrigation only because bank loan was available	0.0	40.0	1.90
6	Would advise others to adopt solarization of irrigation pumps	100.0	100.0	100.00

Source: Field Survey data.

5.14 Water Use and Sale 'Before' and 'After' Solar Pump

The water use and sale 'before' and 'after' solar pump installed comparative analysis between beneficiary and non beneficiary are given in table 5.21. 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.

Table 5.21: Water Use and Sale 'Before' and 'After' Solar Pump

Sr. No	District	Before Solarisation		After Solarisation	
		BN	NBN	BN	NBN
1	Mean depth of groundwater (ft)	210.14	225.80	210.14	235.8
2	Mean amount of diesel (litres/ watering/bigha) Rabi Summer	3.45	3.93	-	-
3	Approximate mean expenditure on repair of diesel pump (Rs/year)	8520.0	10016.0	-	-
4	Approximate mean expenditure on repair of electric pump (Rs/year)	4581.0	6847.0	-	-
5	Approximate mean distance from sale point of petrol/ diesel (km)	10.09	12.61	-	-
6	Approximate mean time spent on procuring diesel/petrol per week (minutes)	120.0	150.0	-	-
7	(%) Respondents having issues with electricity supply	70.00	80.00	-	-
8	Mean expenditure on irrigation (Rs/bigha/year)				
	Diesel pump	3872	4548	-	-
	Electric pump	13584	15841	-	-
	Solar pump	-	-	-	-
9	Respondents purchasing water/ Selling	N	N	N	N
10	No. of farmers who believe that excessive water withdrawal for sale is harmful in the long run	N	N	N	N
11	No. of farmers who had taken steps to curtail water withdrawal for sale	N	N	N	N
12	No. of farmers who had taken steps for artificial recharge of ground water	N	N	N	N
13	Mean expenditure on water recharging efforts	N	N	N	N

Source: Field Survey data.

About 20 to 25 per cent respondent have realized that the crop productivity increased and about 40 to 45 per cent respondent have adopted the crop diversity after solar and increase the numbers of crops in a season. They were grown 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 (Table 3.22).

Table 5.22: Crop Diversification and Changes in Productivity

Sr. No.	Particulars	Changes			
		Before Solarisation		After Solarisation	
		BEN	NonBEN	BEN	NonBEN
1	Respondents who adopted crop diversification (%)				
	Kharif	18	5	40.00	80.00
	Rabi	20	5	45.00	100.0
	Summer			40.00	100.0
2	Respondents who reporting increase in crop productivity (%)				
	Kharif	-	-	25.00	80.00
	Rabi	-	-	22.00	80.00
	Summer	-	-	18.00	80.00
3	No. of farmers reporting changes in crop productivity with solar pump (%)				
	Has increased	-	-	40	4
	Has decreased	-	-	-	-
	Remained constant	-	-	60	1

Source: Field Survey data.

5.15 Maintenance of Solar Panel

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 (Table 5.23). 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.

Table 5.23: Frequency of Cleaning of solar panels

Sr. No	Time period	Responses (%)		
		Beneficiary	Non-Beneficiary	Av.
1	Every day	25.00	0.00	23.81
2	Alternative day	3.00	0.00	2.86
3	Twice in week	26.00	20.00	25.71
4	one in a week	43.00	80.00	44.76
5	fortnightly	3.00	0.00	2.86
6	Approximate time taken for cleaning (minutes)	28.70	32.10	30.40

Source: Field Survey

5.16 Experiences with Solarized Irrigation

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 (Table 5.23). 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.

Table 5.24: Experiences with Solarized Irrigation

Sr. No.	Particulars	Before Solarisation (%)			After Solarisation (%)		
		Beneficiary (n=100)	Non Beneficiary (n=5)	Av (n=105)	Beneficiary (n=100)	Non Beneficiary (n=5)	Total (n=105)
1	Ease of Operation	36.00	40.00	36.19	100.00	100.00	100.00
2	Ease of maintenance	16.00	80.00	19.05	80.00	100.00	81.00
3	Frequency of break-down and repair	94.00	80.00	93.33	40.00	20.00	39.05
4	Labour and supervision required	99.00	100.00	99.05	40.00	40.00	40.00
5	Instances of interruptions due to outages/ shortage of diesel	53.00	80.00	54.29	0.00	0.00	0.00
6	Convenience in timing for irrigation	9.00	20.00	9.52	100.00	100.00	100.00
7	Output of water	68.00	20.00	65.71	90.00	80.00	89.52
8	Use of fertilizers per Bigha	82.00	40.00	80.00	90.00	100.00	90.48
9	Use of micro-irrigation methods	74.00	80.00	74.29	100.00	100.00	100.00

Source: Field Survey

5.17 Experiences of Advantages and Disadvantages of Solar pumps

The advantages of solar pumps realizations by beneficiary and non beneficiary household are presented in table 5.25. 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.

Table 5.25: Experiences of Advantages of Solar Pumps

Sr. No.	Advantages	Responses (% to total)		
		Beneficiary	Non Beneficiary	All
1	No maintenance cost	99.00	80.00	98.10
2	No cost of fuel	100.00	100.00	100.00
3	No harassment of fetching diesel	29.00	40.00	29.52
4	Almost nil monthly cost of operation	70.00	80.00	70.48
5	Quality supply of power	90.00	100.00	90.48
6	Generate income through sale of water	0.00	0.00	0.00
7	Generate income through renting out of power cells	0.00	0.00	0.00
8	Saving labour cost	86.00	60.00	84.76
9	No harassment of irrigating crop in night	75.00	100.00	76.19

Source: Field survey data.

The disadvantages of solar panel were asked to selected households. 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 (Table 5.26). 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.

Table 5.26: Experiences of Disadvantages of Solar Pumps

Sr. No	Disadvantages	Responses (% to total)		
		Beneficiary (n=100)	Non Beneficiary (n=5)	Av (n=105)
1	Only can be used during sunny days	24.00	60.00	25.71
2	High initial cost of installation	84.00	100.00	84.76
3	Heavy depletion of groundwater	0.00	0.00	0.00
4	High cost of batteries/power cell	0.00	0.00	0.00
5	Height of panel is lower thus cannot use space below panel	0.00	0.00	0.00

Source: Field survey data.

5.18 Factors for non-adoption and Perceptions

The few reasons were given by the selected households for non- adopting the solar water pump is given in Table. 5.27. It can be seen in the table that the 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.

Table 5.27: Ranking of Factors for not Adopting Solar Water Pump

Sr. No.	Description	Responses	
		%	Rank
1	Lack of funds-RANK	79.00	1
2	Hesitation to invest/lack of confidence/risk averse-	66.05	2
4	Less land, unviable for investment on solar pump-	57.40	3
3	Opposition from family members	56.55	4
8	Have flat rate electricity connection	55.95	5
5	Do not have confidence in the NGO/donor agency /Government/external agents-	51.15	6
6	Personal differences with other members of DSIC	48.40	7
7	Land plot is situated at a distance; not found economical to connect to the grid	46.85	8
9	Ground water is at great depth, unsuitable for solar	43.90	9
10	Subsidy is insufficient. I want .....% subsidy	38.15	10
12	No one contacted me persuasively	28.75	11
11	Came to know about it much later.	26.85	12

Source: Field survey data.

5.19 Suggestions

The few suggestions given by the selected non-adopter households to expand solarisation of irrigation and its benefits are presented in Table 5.28. It can be seen from the table that 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.

Table 5.28: Suggestions by Non-adopter to Expand Solarisation of Irrigation Pumps in Rajasthan

Sr. No.	Suggestions	% to total
1	Awareness about solar irrigation pump schemes	30.0
2	Portability of grid connectivity to solar irrigation pumps	40.0
3	Criteria of subsidy should be relaxed	75.0
4	Increase the subsidy rate	60.0

5.20 Chapter Summary

This chapter presented the results of field survey conducted in Rajasthan state. The results indicate that after solarisation, gross as well as irrigated has been increased. The changes in cropping pattern were noticed towards high value crops and more area was irrigated through use of micro-irrigation methods. Besides, cop diversification and increase in crop productivity was also reported. The main reason for adoption of solar was because of high cost of diesel and significant time require to fetch it and assured quality solar power supply, while high cost of solar panel was major concern. Lack of finance and awareness about solar irrigation system were the major reasons cited by the non adopters. The major suggestions of respondent households were need to increase in subsidy rate, portability of solar pump with grid, criteria need to be relaxed and awareness campaigns of solar need to be organized.

The next chapter presents summary and conclusions of the study.

Chapter VI

Summary and Conclusions

6.1 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. 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 6.1).

Table 6.1: 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.

6.2 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. 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 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 6.2: 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, as 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 6.2). 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.

6.4 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 6.3). 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 6.4). The top five districts having highest coverage of solar pumps are Bikaner, Jaipur, Sri Ganganagar, Hanumangarh and Sikar.

Table 6.3: 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.

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.

Table 6.4: 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.

6.5 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.

6.6 Findings from Field Survey in Gujarat

- Except 9 percent households in beneficiary group, all other respondents were males, which indicate 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, 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 non-adopters owned surface AC pumps while remaining households had submersible AC pumps. In total, two-thirds of selected households owned submersible AC pumps; 40 per cent of households had submersible DC pumps while 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 *GUVNL*. 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.

6.7 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 others.
- 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.

6.8 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.

6.9 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.

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Annexure I: Power Supply Position in the Country (2009-10 to 2018-19)

Year	Energy				Peak			
	Requirement	Availability	Surplus(+)/Deficits(-)		Peak Demand	Peak Met	Surplus(+) / Deficits(-)	
	(MU)	(MU)	(MU)	(%)	(MW)	(MW)	(MW)	(%)
2009-10	8,30,594	7,46,644	-83,950	-10.1	1,19,166	1,04,009	-15,157	-12.7
2010-11	8,61,591	7,88,355	-73,236	-8.5	1,22,287	1,10,256	-12,031	-9.8
2011-12	9,37,199	8,57,886	-79,313	-8.5	1,30,006	1,16,191	-13,815	-10.6
2012-13	9,95,557	9,08,652	-86,905	-8.7	1,35,453	1,23,294	-12,159	-9
2013-14	10,02,257	9,59,829	-42,428	-4.2	1,35,918	1,29,815	-6,103	-4.5
2014-15	10,68,923	10,30,785	-38,138	-3.6	1,48,166	1,41,160	-7,006	-4.7
2015-16	11,14,408	10,90,850	-23,558	-2.1	1,53,366	1,48,463	-4,903	-3.2
2016-17	11,42,929	11,35,334	-7,595	-0.7	1,59,542	1,56,934	-2,608	-1.6
2017-18	12,12,134	12,03,567	-8,567	-0.7	1,64,066	1,60,752	-3,314	-2
2018-19*	7,69,399	7,64,627	-4,773	-0.6	1,77,022	1,75,528	-1,494	-0.8

Source: * Upto October 2018 (Provisional),
Source: CEA- Central Electricity Authority https://powermin.nic.in/en/content/power-sector-glance-all-india.

Annexure II: State-wise Power Generation from Various Renewable Energy Sources in India (2016-2017)

(In Mega Watts)

Sl. No.	States/ UTs	Wind Power	Small Hydro Power	Bio-Energy			Solar	Total
				Biomass Power	Bagasse Cogeneration	Waste to Energy		
1	Andhra Pradesh	14497	978	578	300	123	38440	54916
2	Arunachal Pradesh	236	1341	8			8650	10236
3	Assam	112	239	212		8	13760	14330
4	Bihar	144	223	619	300	73	11200	12559
5	Chhattisgarh	314	1107	236		24	18270	19951
6	Goa		7	26			880	912
7	Gujarat	35071	202	1221	350	112	35770	72726
8	Haryana	93	110	1333	350	24	4560	6470
9	Himachal Pradesh	64	2398	142		2	33840	36446
10	Jammu & Kashmir	5685	1431	43			111050	118208
11	Jharkhand	91	209	90		10	18180	18580
12	Karnataka	13593	4141	1131	450		24700	44015
13	Kerala	837	704	1044		36	6110	8732
14	Madhya Pradesh	2931	820	1364		78	61660	66853
15	Maharashtra	5961	794	1887	1250	287	64320	74500
16	Manipur	56	109	13		2	10630	10811
17	Meghalaya	82	230	11		2	5860	6185
18	Mizoram		169	1		2	9090	9261
19	Nagaland	16	197	10			7290	7513
20	Orissa	1384	295	246		22	25780	27728
21	Punjab		441	3172	300	45	2810	6768
22	Rajasthan	5050	57	1039		62	142310	148518
23	Sikkim	98	267	2			4940	5307
24	Tamil Nadu	14152	660	1070	450	151	17670	34152
25	Telangana						20410	20410
26	Tripura		47	3		2	2080	2131
27	Uttar Pradesh	1260	461	1617	1250	176	22830	27593
28	Uttarakhand	534	1708	24		5	16800	19071
29	West Bengal	22	396	396		148	6260	7222
30	Andaman & Nicobar	365	8				0	373
31	Chandigarh					6	0	6
32	Dadra & Nagar Haveli						0	0
33	Daman & Diu	4					0	4
34	Delhi					131	2050	2181
35	Lakshadweep						0	0
36	Puducherry	120				3	0	123
37	Others					1022	790	1812
	Total	102772	19749	17536	5000	2554	748990	896602

Source: https://mnre.gov.in/file-manager/annual-report/2016-2017/EN/pdf/1.pdf

Annexure III: Total Installed Capacity (as on 31.10.2018)

Sr. No.	Fuel	MW	% of Total
A	Total Thermal	2,21,768	64.10%
	Coal	1,95,993	56.60%
	Gas	24,937	7.20%
	Oil	838	0.20%
B	Hydro (Renewable)	45,487	13.10%
C	Nuclear	6,780	2.00%
D	RES* (MNRE)	72,013	20.80%
	Total	346,048	

Notes: * Installed capacity in respect of RES (MNRE) as on 30.06.2018; RES (Renewable Energy Sources) include Small Hydro Project, Biomass Gasifier, Biomass Power, Urban & Industrial Waste Power, Solar and Wind Energy.
Source: https://powermin.nic.in/en/content/power-sector-glance-all-india

Annexure IV: Grid Connected Targets for Solar Power Installations

MW	Grid Connected Targets for Solar Power Installations							
	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Total
Rooftop Solar	200	4800	5000	6000	7000	8000	9000	40000
Ground Mounted Solar	1800	7200	10000	10000	10000	9500	8500	57000
Total	2000	12000	15000	16000	17000	17500	17500	97000

Source: http://mnre.gov.in/file-manager/grid-solar/100000MW-Grid-Connected-Solar-Power-Projects-by-2021-22.pdf

Annexure V: Growth of Electricity Consumption in India

Growth of Electricity Consumption in India								
Year	Consumption (GWh)	% of Total						Per-Capita /year (in kWh)
		Domestic	Commercial	Industrial	Traction	**Agriculture**	Misc	
31-Dec-1947	4,182	10.11	4.26	70.78	6.62	2.99	5.24	16.3
31-Dec-1950	5,610	9.36	5.51	72.32	5.49	2.89	4.44	18.2
31-Mar-1956	10,150	9.20	5.38	74.03	3.99	3.11	4.29	30.9
31-Mar-1961	16,804	8.88	5.05	74.67	2.70	4.96	3.75	45.9
31-Mar-1966	30,455	7.73	5.42	74.19	3.47	6.21	2.97	73.9
31-Mar-1974	55,557	8.36	5.38	68.02	2.76	11.36	4.13	126.2
31-Mar-1979	84,005	9.02	5.15	64.81	2.60	14.32	4.10	171.6
31-Mar-1985	124,569	12.45	5.57	59.02	2.31	16.83	3.83	228.7
31-Mar-1990	195,098	15.16	4.89	51.45	2.09	22.58	3.83	329.2
31-Mar-1997	315,294	17.53	5.56	44.17	2.09	26.65	4.01	464.6
31-Mar-2002	374,670	21.27	6.44	42.57	2.16	21.80	5.75	671.9
31-Mar-2007	525,672	21.12	7.65	45.89	2.05	18.84	4.45	559.2
31-March-2012	785,194	22.00	8.00	45.00	2.00	18.00	5.00	883.6
31-March-2013	824,301	22.29	8.83	44.40	1.71	17.89	4.88	914.4
31-March-2014	881,562	22.95	8.80	43.17	1.75	18.19	5.14	957
31-March-2015	938,823	23.53	8.77	42.10	1.79	18.45	5.37	1010.0
31-March-2016	1,001,191	23.86	8.59	42.30	1.66	17.30	6.29	1075
31-March-2017	1,066,268	24.32	9.22	40.01	1.61	18.33	6.50	1122
31-March-2018	1,130,244	24.20	8.51	41.48	1.27	18.08	6.47	1149

Source:

Annexure VI: Consumption of Electricity for Agricultural Purposes

Year	Consumption for Agricultural Purposes (GWh)	Total Consumption (GWh)	% Share of Agricultural Consumption to total Consumption
1983-84	18234	102344	17.82
1984-85	20960	114068	18.38
1985-86	23422	122999	19.04
1986-87	29444	135952	21.66
1987-88	35267	145613	24.22
1988-89	38878	160196	24.27
1989-90	44056	195419	25.11
1990-91	50321	190357	26.44
1991-92	58557	207645	28.2
1992-93	63328	220674	28.7
1993-94	70699	238569	29.63
1994-95	79301	259630	30.54
1995-96	85732	277029	30.95
1996-97	84019	280206	29.98
1997-98	91242	296749	30.75
1998-99	97195	309734	31.38
1999-00	90934	312841	29.07
2000-01	84729	316600	26.76
2001-02	81673	322459	25.33
2002-03	84486	339598	24.88
2003-04	87089	360937	24.13
2004-05	88555	386134	22.93
2005-06	90292	411887	21.92
2006-07	99023	455748	21.73
2007-08	104182	501977	20.75
2008-09	107776	527564	20.43
2009-10	119492	569618	20.98
2010-11	126377	616969	20.48
2011-12	140960	672933	20.95
2012-13	147462	708843	20.8
2013-14	152744	751908	20.31
2014-15	168913	814250	20.74

Source: GOI (2017).

Annexure VII: State-wise Consumption of Electricity for Agriculture purpose in 2013-14

Region	State/UT	Consumption for Agriculture Purpose (GWh)	Total Energy sold (GWh)	% Share of Consumption for Agriculture
Northern	Haryana	8535.22	29082.52	29.35
	Himachal Pradesh	47.64	7649.49	0.62
	Jammu & Kashmir	280.73	5754.36	4.88
	Punjab	10223.57	37556.79	27.22
	Rajasthan	17262.84	43151	40.01
	Uttar Pradesh	10210.93	59176.69	17.25
	Uttarakhand	343.99	9596.89	3.58
	Chandigarh	1.46	1419.27	0.1
	Delhi	29.23	23980.79	0.12
	Sub-Total	46935.61	217367.8	21.59
Western	Gujarat	14729.72	66877.5	22.02
	Madhya Pradesh	11858.49	36770.45	32.25
	Chhattisgarh	2492.2	14791.14	16.85
	Maharashtra	22257.94	100842.25	22.07
	Goa	21	3085.2	0.68
	Daman & Diu	3.15	1818.54	0.17
	D. & N. Haveli	3.82	5189.51	0.07
	Sub-Total	51366.32	229374.59	22.39
Southern	Andhra Pradesh	21857.35	72919.24	29.97
	Karnataka	18077.62	53716.25	33.65
	Kerala	317.81	18024.6	1.76
	Tamil Nadu	12295	71772.37	17.13
	Puducherry	57	2531.92	2.25
	Lakshdweep	0	41.03	0
	Sub-Total	52604.78	219005.41	24.02
Eastern	Bihar	321.79	7979.71	4.03
	Jharkhand	92.4	18174.64	0.51
	Odisha	171.82	14411.46	1.19
	West Bengal	1183.15	36591.59	3.23
	A. & N. Islands	0.88	215.77	0.41
	Sikkim	0	404.71	0
	Sub-Total	1770.04	77777.88	2.28
North Eastern	Assam	36	4763	0.76
	Manipur	1.66	397.96	0.42
	Nagaland	0.05	394.5	0.01
	Tripura	29.56	722.28	4.09
	Arunachal Pradesh	0.06	480.52	0.01
	Mizoram	0.06	302.79	0.02
	Sub-Total(NER)	67.59	8382.56	0.81
	Total (All India)	**152744.34**	**751908.24**	**20.31**

Note: GWh: Giga Watt-hour,
Source: Central Electricity Authority, New Delhi; Source: GOI (2017).

Annexure VIII: Four Agrarian Socio-ecologies of Gujarat

Regions	Districts	Features
Tribal areas	Dahod, Panchmahal and Dangs	First or second generation crop and dairy farmers; low level of economic enterprise; rainfed farming; semi-arid to humid climate.
North Gujarat	Ahmedabad, Gandhinagar, Patan, Mehsana, Banaskantha, Sabarkantha	Enterprising farmers; Groundwater is the main source of irrigation; deep, alluvial aquifer system that is overexploited; highly developed dairying and dairy cooperatives.
Canal districts (South and Central Gujarat)	Anand, Kheda, Vadodara, Bharuch, Surat, Narmada, Navsari, Valsad	Humid and water-abundant part of Gujarat; large areas under canal irrigation systems such as Mahi, Ukai-Kakarapar, Karjan, Damanganga, Sardar Sarovar; conjunctive use of groundwater and canal water through farmer initiative; alluvial aquifers that are amply recharged by surface irrigation; enterprising farmers; strong dairy cooperatives.
Saurashtra and Kachchh	Amreli, Bhavnagar, Junagadh, Jamnagar, Porbandar, Rajkot, Surendranagar, Kachchh	Arid to semi-arid climate; groundwater the main source of irrigation; hard rock aquifers have poor storativity; open dugwells are the main source of irrigation; feudal culture; poor dairy cooperatives. Agriculture dependent mostly on monsoon; early withdrawal of monsoon the bane of kharif crop.

Source: Shah, et al, 2009.

Annexure IX: Types and Configuration of Solar Pumps

(a) Types of Pump

Surface Pump: Placed besides the water source (lake, well, etc.).

Submersible Pump: Placed in the water source.

Floating pump: Placed on top of the water.

(b) There are three main solar water pumping configurations used in India:

- **Brushless Direct Current (DC) pump:** Highest efficiency, low maintenance, but higher cost compared to other pumping technologies.
- **DC positive displacement pump:** Less efficient than brushless motors but performs well under low power conditions, and can achieve high lift.
- **3 AC centrifugal pump:** Not as efficient as DC pumps, yet, reasonably priced, easily available/ serviced and deep reaching, making it currently the most preferred choice among users and system integrators.

(c) Components of a solar PV water pumping system:

- **Solar PV array:** The Solar PV array is a set of photovoltaic modules connected in series and possibly strings of modules connected in parallel.
- **Controller:** The Controller is an electronic device which matches the PV power to the motor and regulates the operation of the pump according to the input from the solar PV array.
- **Pump Set:** Pump sets generally comprise of the motor, which drives the operation and the actual pump which moves the water under pressure.

(d) Water pumping motors are "alternating current' (AC) or 'direct current' (DC):

- **AC Motors:** AC Motors require inverters to convert DC to AC. Solar pumping systems use special electronically controlled variable-frequency inverters, which optimises matching between the panel and the pump.
- **DC Motor:** The DC Motors with permanent magnet are generally more efficient. DC Motors may be with or without carbon brushes. DC motors with carbon brushes need to be replaced after approximately every 2 years. Brushless designs require electronic commutation. Brushless DC Motors are becoming popular in the solar water pumps.

(e) Main solar water pump technologies:

- **Centrifugal Pump:** Centrifugal pump uses high-speed rotation to suck in water through the middle of the pump. Most AC pumps use such a centrifugal impeller.
- **Positive Displacement Pump:** The positive displacement pump is currently being used in many solar water pumps. The pump transfers water into a chamber and then forces it out using a piston or helical screw.

Annexure X: District-wise Coverage of Solar Pumps in Gujarat

DISTRICT	AC					DC					Grand Total
	DGVCL	MGVCL	PGVCL	UGVCL	AC Total	DGVCL	MGVCL	PGVCL	UGVCL	DC Total	
Ahmedabad				41	41				3	3	44
AMRELI			407		407			90		90	497
Anand		15			15		1			1	16
ARVALLI				89	89				5	5	94
Banaskantha				65	65				47	47	112
Bharuch	21				21	128				128	149
Bhavnagar			**587**		**587**			**204**		**204**	**791**
BOTAD			248	1	249			175		175	424
Chhotaudepur		80			80		113			113	193
Dahod		**310**			**310**		**21**			**21**	**331**
Dang	79				79						79
Devbhumi Dwarka			263		263			54		54	317
Gandhinagar				3	3						3
GIR SOMNATH			314		314			81		81	395
Jamnagar			371		371			125		125	496
Junagadh			272		272			116		116	388
Kheda		13			13		11			11	24
Kutch			48		48			60		60	108
Mahisagar		64		17	81		106			106	187
MAHISAGAR		2			2		3			3	5
Mehsana				18	18				4	4	22
MORBI			174		174			43		43	217
Narmada	**434**				**434**	**179**				**179**	**613**
Navsari	51				51	10				10	61
Panchmahal		88			88		37			37	125
Patan				30	30						30
PORBANDAR			13		13			5		5	18
PORBANDAR			3		3			2		2	5
RAJKOT			302		302			157		157	459
Sabarkantha				**132**	**132**						**132**
Surat	319				319	64				64	383
Surendranagar			135	3	138			136	1	137	275
Tapi	205				205						205
Vadodara		164			164		18			18	182
Valsad	315				315	44				44	359
Grand Total	**1424**	**736**	**3137**	**399**	**5696**	**425**	**310**	**1248**	**60**	**2043**	**7739**

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Comments on draft report

1.	Title of report	Solarisation of Agricultural Water Pumps in Gujarat, AERC Report No. 172
2.	Date of receipt of the Draft report	January 18, 2019
3.	Date of dispatch of the comments	January 20, 2019
4.	Comments on the Objectives of the study	Objectives of the study have been satisfied.
5.	Comments on the methodology	Study is based on Primary and secondary data.
6.	Comments on analysis, organization, presentation etc.	The study has explained the importance of solarisation of Agricultural Water Pump in a very satisfactory manner. However, the study can be strengthened if further analysis is conducted, if possible. (a) On p 13, Table 1.2, one more column showing installed capacity as percentage of potential can be included. (b) In Table 2.1 the subsidy norms are outlined. However, has the government outlined any criteria for eligibility of subsidy based on socio-economic considerations? If so, the same may be discussed. (c) In chapter 4, perhaps last column in most tables should be “average” and not “total”. In Table 4.15, column 3, the average amount of bank loan (Rs) is indicated as Rs 96 – GUVNL and Rs 4 – GGRC. These figures can be checked. Also the amount of subsidy received by beneficiaries may be included in the Table 4.15.

(d) The study shows that cropping intensity increased from 144.59 per cent to 180.79 per cent after solarisation for beneficiary households. However, it would be interesting if the study could also indicate how this increase in cropping intensity is translated into increase in income for the beneficiary households. Further, in case of non-beneficiary households, what could be the possible reasons for increase in rainfed area as percentage to GCA after solarisation (from 7.05 percent to 29.23 percent) and hence decline in irrigated area. This could be the cause of decline in cropping intensity for non-beneficiaries. As they are only 4 in number, throwing more light on this issue would be useful.

(e) How many years would it take for non- beneficiaries to recover their own investment in SIP?

(f) The saving in electricity for beneficiaries as well as non-beneficiaries after solarisation may also be indicated, if possible.

(g) In the executive summary, p xxxi, the average expenditure on repair of electric pumps and diesel pumps is indicated. But the time period over which this expenditure is incurred is not indicated.

7. References: Major references covered

8. General remarks: The study is a comprehensive study on solar pumps in Gujarat and appropriate policy measures have been suggested.

9. Overall view on acceptability of report: The report is acceptable and suggestions may be incorporated wherever possible and then treated as final.

Annexure XII

Comments on the Draft Report received from

Agro-Economic Research Centre, Gokhale Institute of Politics and Economics (Deemed University), Pune, Maharashtra

Comments on draft report		
1.	Title of report	"Solarisation of Agricultural Water Pumps in Rajasthan, AERC Report No. 173"
2.	Date of receipt of the Draft report	January 21, 2019
3.	Date of dispatch of the comments	January 30, 2019
4.	Comments on the Objectives of the study	Objectives of the study have been satisfied.
5.	Comments on the methodology	Primary and Secondary data have been used and analysed
6.	Comments on analysis, organization, presentation etc.	The study is a very good attempt to understand solarisation of Agricultural Water Pumps in Rajasthan. However the following may be noted: (a) In chapter 3, in last column, in case of Tables 3.1 to 3.4, "Total" may be replaced by "Average". (b) In Table 3.3 Percentage may be written against (A) and (B). (c) In Table 3.4 the average operational landholding size is shown as 2.74 ha. However, a simple average of three groups may not be proper as sample size of non-beneficiaries is 5 and non-adopters is 20 while sample size of beneficiaries is 100. Hence addition of operational holding of 125 sample households and dividing by 125 will give the correct average

size of operational holding.

(d) Table 3.5 shows decline in cropping intensity of sample beneficiaries from 158.55 percent before solarisation to 155.94 percent after solarisation. However on p 71, it is mentioned that there is 17 percent increase in gross cropped area .... Wheat, maize showed increase ..However, it is observed that share of wheat in gross cropped area declined from 18.49 percent before solarisation to 16.75 percent after solarisation. In this context it would be useful to show actual Net Sown Area and Gross Cropped Area of sample households before and after solarisation.

(e) On p 83, the expenditure on diesel and electric pumpsets is indicated. The time period over which this expenditure is incurred must be specified.

(f) The actual increase in income of beneficiaries and non-beneficiaries before and after solarisation must be indicated, if possible as this will strengthen the case for solarisation. This per hectare income can be compared with the per hectare income of non-adopters.

7. References: Major references covered

8. General remarks: The study is a comprehensive study on solar pumps in Rajasthan and appropriate policy measures have been suggested.

9. Overall view on acceptability of report: The report is acceptable and with suitable changes as suggested the report can be strengthened and then treated as final.

Annexure XIII

Actions taken by the authors based on the comments received from the Coordinator of the study.

- All the comments made by the Coordinator of the study have been addressed at the appropriate places in this final report.

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