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Solarisation of Agricultural Water Pumps in Gujarat

Sonal Bhatt, S. S. Kalamkar and M. Makwana

Study Coordinated by
Agro-Economic Research Centre,
Sardar Patel University, Vallabh Vidyanagar, Gujarat (India)

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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 Gujarat

Sonal Bhatt, S. S. Kalamkar and M. Makwana[1]

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.

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

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 and prospects of solarisation of agricultural pumps in selected districts of Gujarat. The data were collected from three distinct groups of farmers, viz. farmers who had adopted SIPs with the help of subsidy by the government, farmers who had adopted SIPs without any support in the form of subsidy by the government, and the farmers who had not adopted SIPs. The first group was of 100 sample farmers (25 from each of the four districts under study, i.e. 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 (Table 1). 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 studied earlier is presented in this report.

Table 1: Sampling Framework Area in Gujarat state

Sr. No	*Selected Region and District*	*Selected Tehsil/ Taluka*	*Selected Villages*	*Selected provider/agency and users*				
				GUVNL	*GGRC*	*Private Solar*	*Non-Ben.*	*Total*
1.	South-Narmada	Dediapada	Kokam, Piplod, Moti Singloti, Morjadi, Rakhas Kundi, Chikada	24	1	1	5	31
2.	East-Dahod	Devgadh Bariya, Fatepura, Dahod	Zapatiya, Jagola, Nava Talav, Hingla, Rampura	24	1	0	5	30
3.	North-Sabarkantha	Himmatnagar, Talod, Idar, Khed brahma	Illol, Rupal, Kankrol, Sankrodia, Hadiyol, Hathrol, Bhimpura, Modhuka, Panapur, Fojivada, Rozad, Bakkarpura, Ratanpur	*24*	*1*	*2*	*5*	*32*
4.	West-Bhavnagar	Talaja	Vejodari, Dakana, Mangela, Kerala, Pithalpur, Ralgaon	*24*	*1*	*1*	*5*	*31*
			Gujarat State	96	4	4	20	124

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.

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.

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

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.

Solar Pump Irrigators' Cooperative Enterprise:

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 Data

- 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.

Policy Implications:

- 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.

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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

[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:

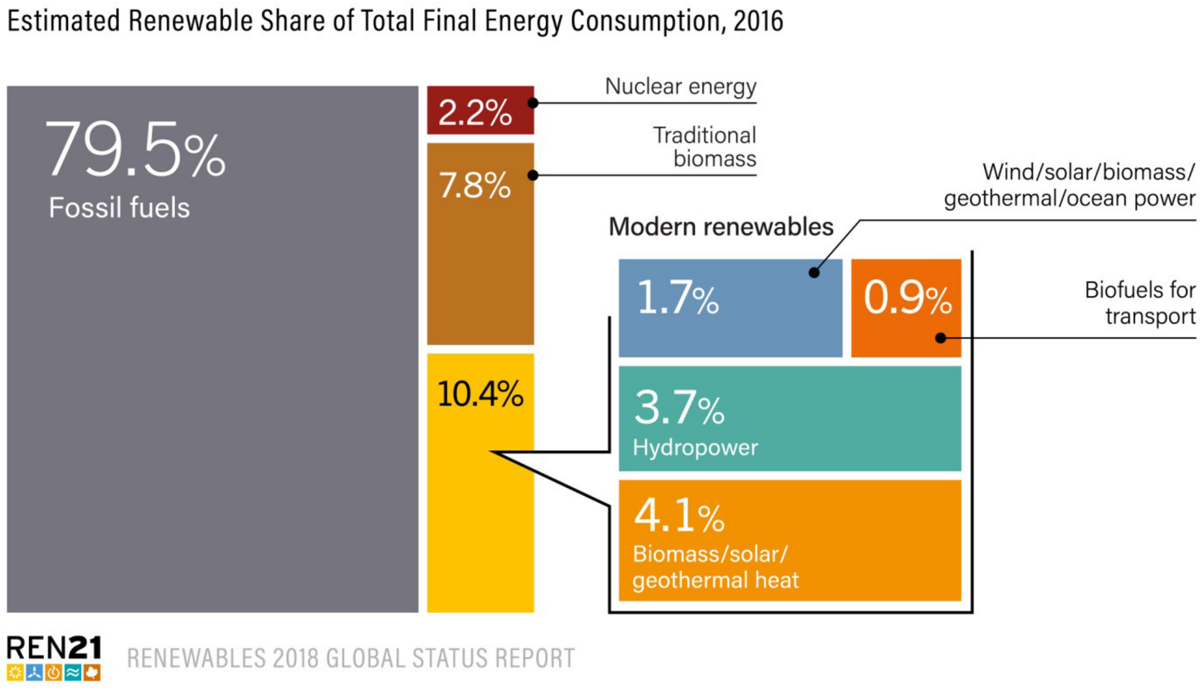
Rising international fuel prices, growing demand for energy and concerns about global warming are the key factors driving the increasing interest in renewable[2] energy sources (Rosegrant et al., 2006). Renewable technologies for power generation, heating and cooling, as well as transportation are considered 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).

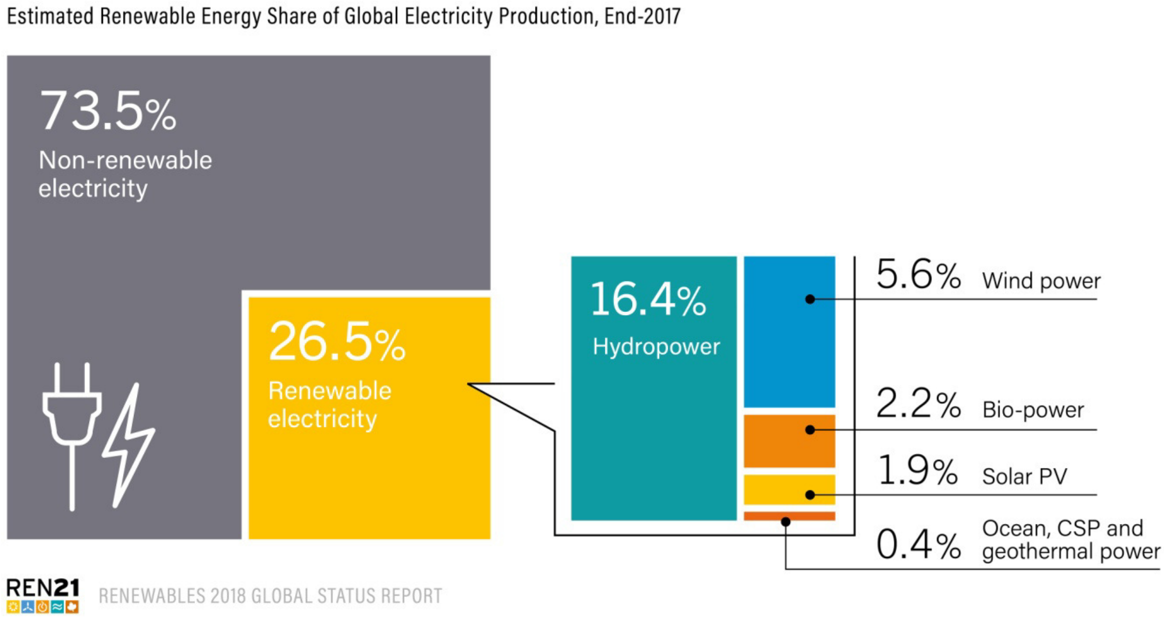
Fig 1.1: Energy Resources of the World (2016)



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

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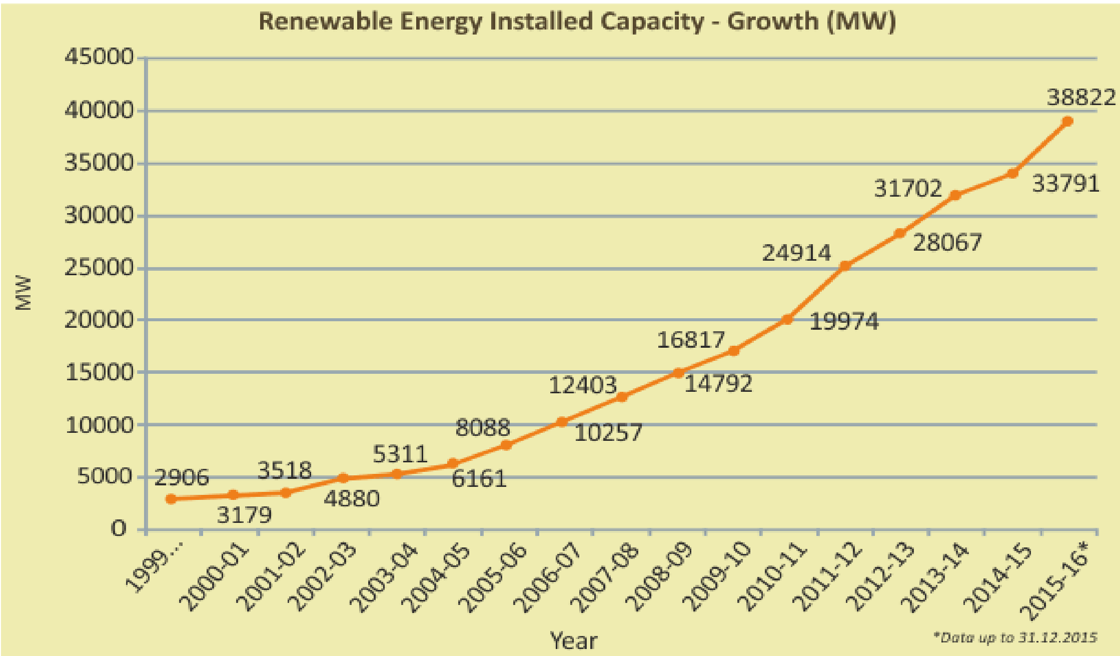
[4] https://niti.gov.in/writereaddata/files/writereaddata/files/document_publication/report-175-GW-RE.pdf
[5] See Annexure III (https://powermin.nic.in/en/content/power-sector-glance-all-india).

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: India- Solar Power Capacity Achieved (MW), 2008-09 to 2015-16



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.

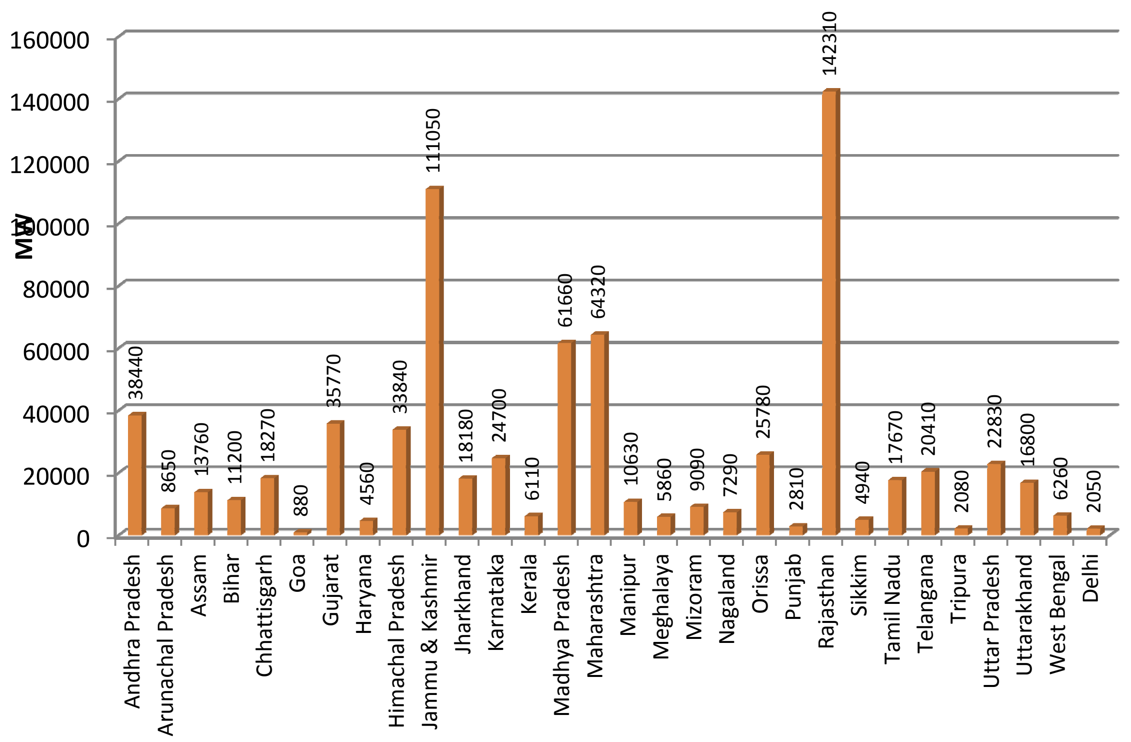
Source: NITI (2015).

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) 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.

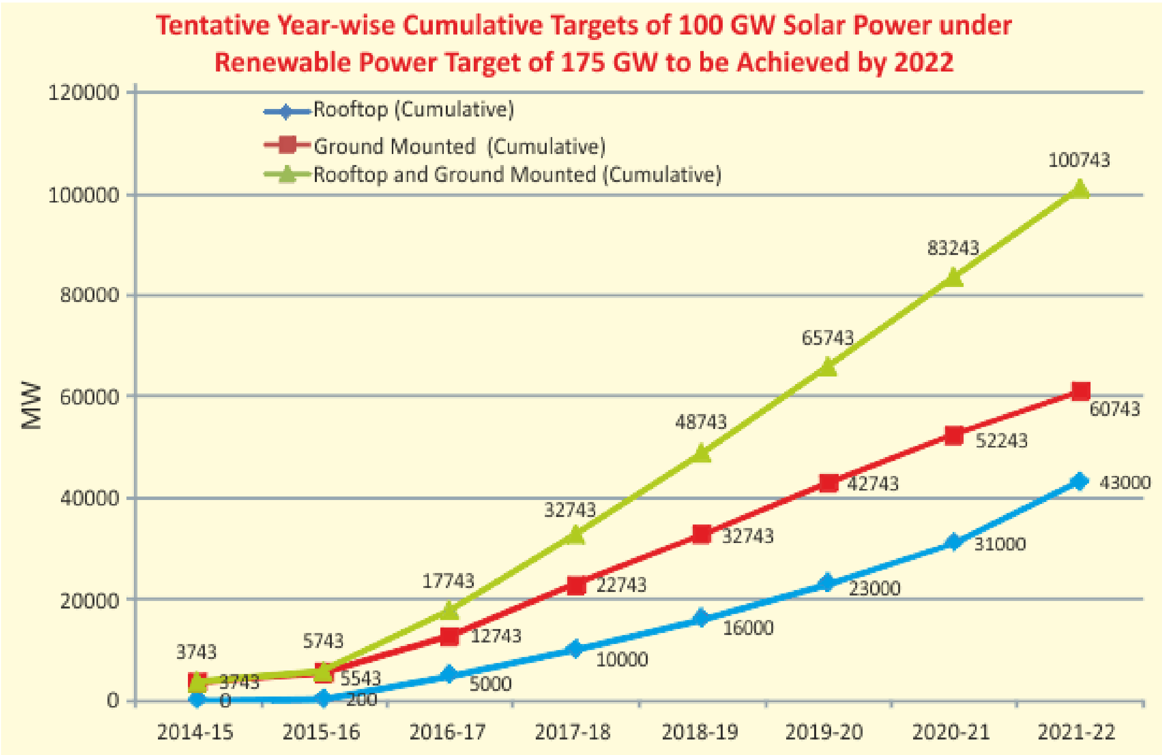
Table 1.2: State-wise estimated Solar Energy Potential vs. installed solar capacity in the Country as on 31.12.2016

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 producer 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 baseload 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.

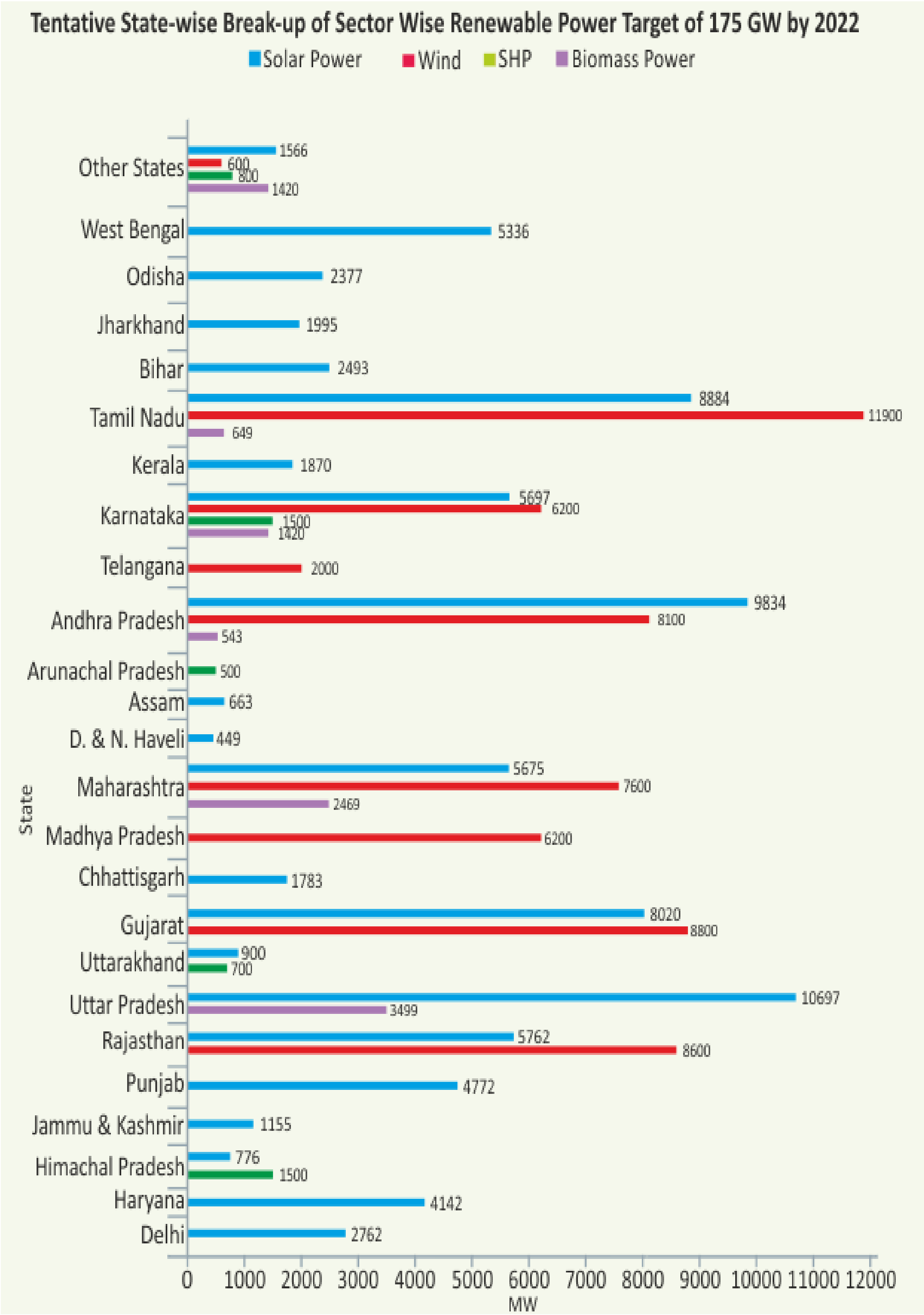
Fig. 1.5: Targeted 100 GW Solar Power under RE 175 GW by 2022



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).

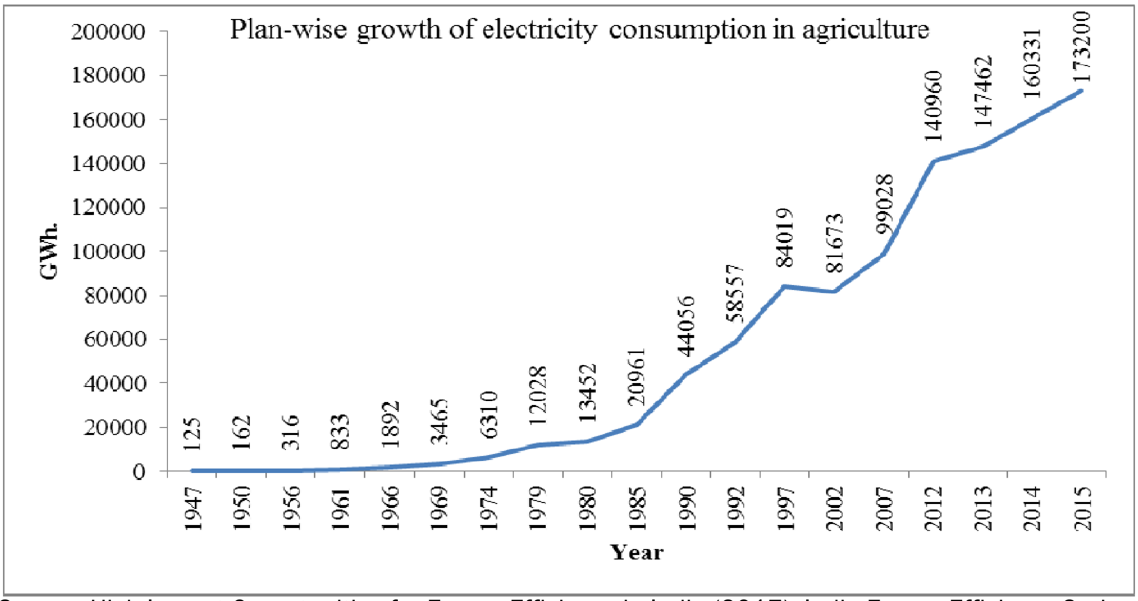
Indian farmers and the national and sub-national government both face several challenges with regard to irrigation. Electricity in India is provided at highly subsidized low tariffs, mostly at flat rates, and this has led to widespread adoption of inefficient pumps (Desai, 2012). Farmers have little 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

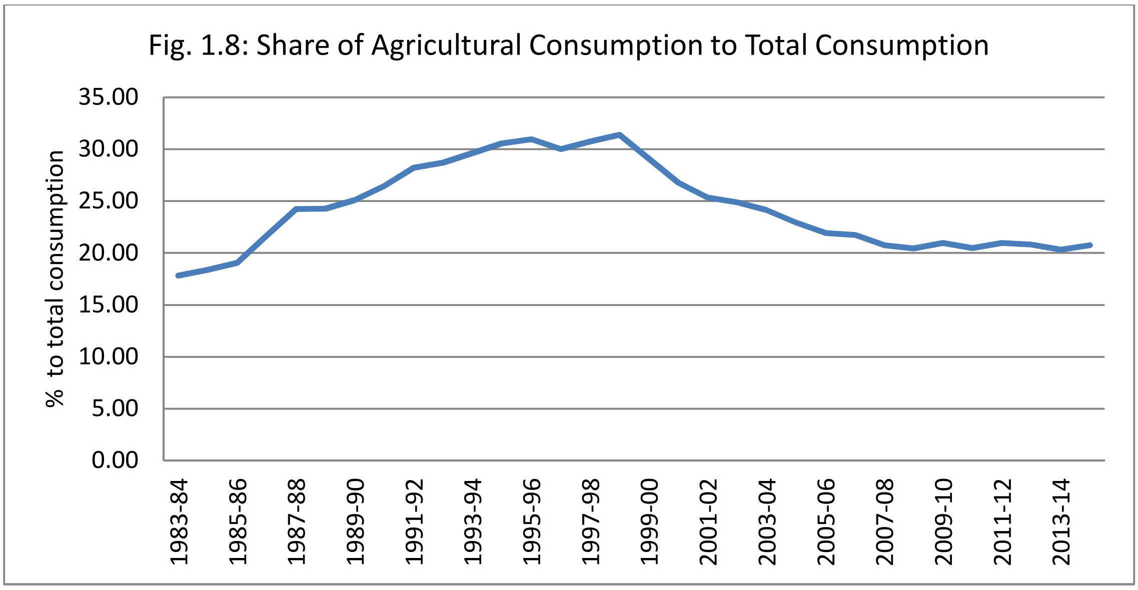
India is usually intermittent, fraught with voltage fluctuations, and the waiting time for an initial connection can be quite long (Banerjee *et.al*. 2015). Solar pumps provide freedom to farmers from these constraints, by giving a reliable access to irrigation on most occasions. However, some of the 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 ~~absent~~. The role of canal irrigation becomes very crucial in this scenario. However, in the absence of sufficient and reliable canal water supply, the only other option that remains with the farmers is that they irrigate their fields with the help of ground water withdrawn through either electricity or diesel-driven pumps. Provision of power for irrigation and other farm operations therefore, is a high priority area for the States. 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



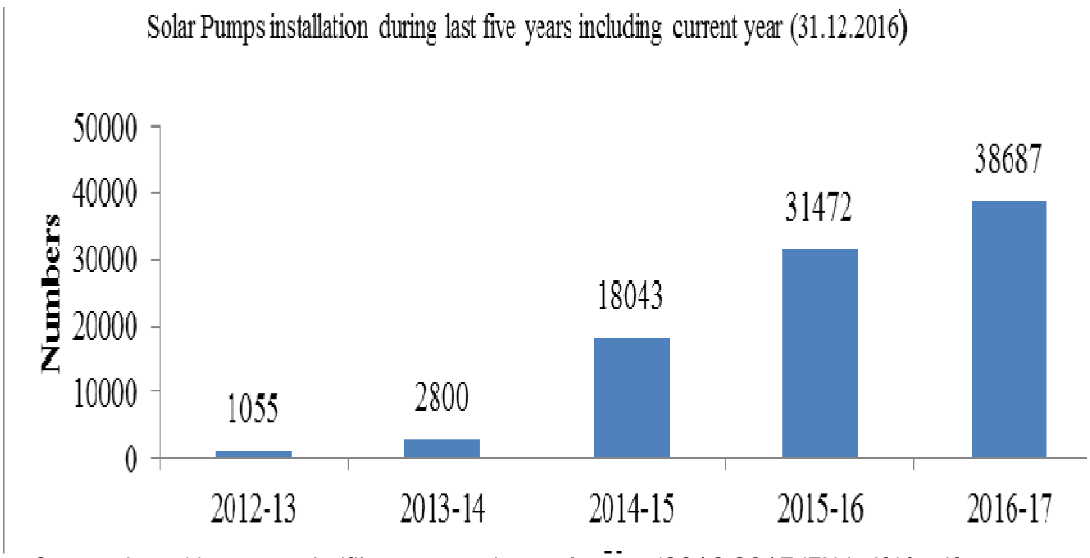
Source: GOI (2018).

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 2016-17



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.

In light of the above, this study attempts to study the status and prospects of solarisation of agricultural pumps in selected districts of Gujarat.

1.6 Objectives of the study:

- To study the coverage of solar irrigation pump in selected districts of Gujarat
- 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 pertains to the 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. These 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 four agro-ecological regions of Gujarat 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 Area of Study

The area of study was the State of Gujarat. The entire state was divided into four broad regions on the basis of their agro-ecological as well as socio-economic characteristics (Shah et al, 2009) into North Gujarat, South Gujarat, Saurashtra and Eastern-Gujarat (Map 1.1 and Annexure VIII). The four districts have been chosen from four regions of the state as they represent the characteristics of that region and are also relevant to research problem under study, i.e. solarisation of irrigation pumps. Therefore, including these four distinct districts in Gujarat 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 in Gujarat be done and what could be the constraints for the same. The selected districts were: i) Sabarkantha in north-Gujarat, ii) Dahod in the eastern tribal belt of Gujarat, iii) Narmada in the southern region of Gujarat, and iv) Bhavnagar in Saurashtra region of Gujarat

Map 1.1: Four Agrarian Socio-Ecologies of Gujarat & Location Map of Study Districts

.

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. 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, lift or flood irrigation. In terms of 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 socio-ecological zones of Gujarat. Similarly, there is a wide variety amongst adopters of solarised irrigation in Gujarat 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 IX). With respect to financial costs of SIPs, many farmers have adopted subsidized solar pumps while there are also those who have purchased them at market rates without availing of government subsidy.

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).

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. Thus, to cover the SIPs installed by both agencies as per the area in which each agency had a dominant presence, four villages were selected from GUVNL and one village for GGRC sample households. 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.

Sampling Framework

As mentioned earlier, primary data were collected from the selected sample households from selected regions and districts on the basis of the sampling design described below as presented in Table 1.3.

- 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.
- 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.
- From each district, 24 sample beneficiary households of GUVNL and 1 household from GGRC were selected, thus making total of 25 beneficiary households from each district, i.e. 100 beneficiary households in the State.
- From each selected district, 1 non-beneficiary households (who had not availed subsidy and installed pump at own cost) was selected, thus making total of four non-beneficiary sample household in the State of Gujarat.
- From each selected district, 5 sample non-adopter households who had not at all installed pump were selected, making total sample of 20 households.

Table 1.3: Details on Number of Selected respondents in Gujarat

Sr. No	Selected Region and District	Selected Tehsil/ Taluka	Selected Villages	Selected provider/agency and users				
				GUVNL	GGRC	Private Solar	Non-Ben.	Total
1.	South-Narmada	Dediapada	Kokam, Piplod, Moti Singloti, Morjadi, Rakhas Kundi, Chikada	24	1	1	5	31
2.	East-Dahod	Devgadh Bariya, Fatepura, Dahod	Zapatiya, Jagola, Nava Talav, Hingla, Rampura	24	1	0	5	30
3.	North-Sabarkantha	Himmatnagar, Talod, Idar, Khed brahma	Illol, Rupal, Kankrol, Sankrodia, Hadiyol, Hathrol, Bhimpura, Modhuka, Panapur, Fojivada, Rozad, Bakkarpura, Ratanpur	*24*	*1*	*2*	*5*	*32*
4.	West-Bhavnagar	Talaja	Vejodari, Dakana, Mangela, Kerala, Pithalpur, Ralgaon	*24*	*1*	*1*	*5*	*31*
			Gujarat State	96	4	4	20	124

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

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 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 Gujarat and enhancing its efficiency in terms of energy use, water use, agricultural production and productivity as well as and farmer welfare in Gujarat; 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.

1.10 Structure of the report

The present study report is divided into five chapters including this introductory chapter. Chapter I discuss about brief the renewable energy resources at global level, renewable and solar energy scenario in India, energy-irrigation nexus and 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 highlighting the policies adopted by the government of Gujarat 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 and the last chapter presents summary and conclusions of the study.

The next chapter presents status of solarisation in Gujarat state.

Chapter II

Status of Solarisation of Agricultural Pumps in Gujarat

2.1 Introduction:

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.

2.2 Energy Overview of Gujarat

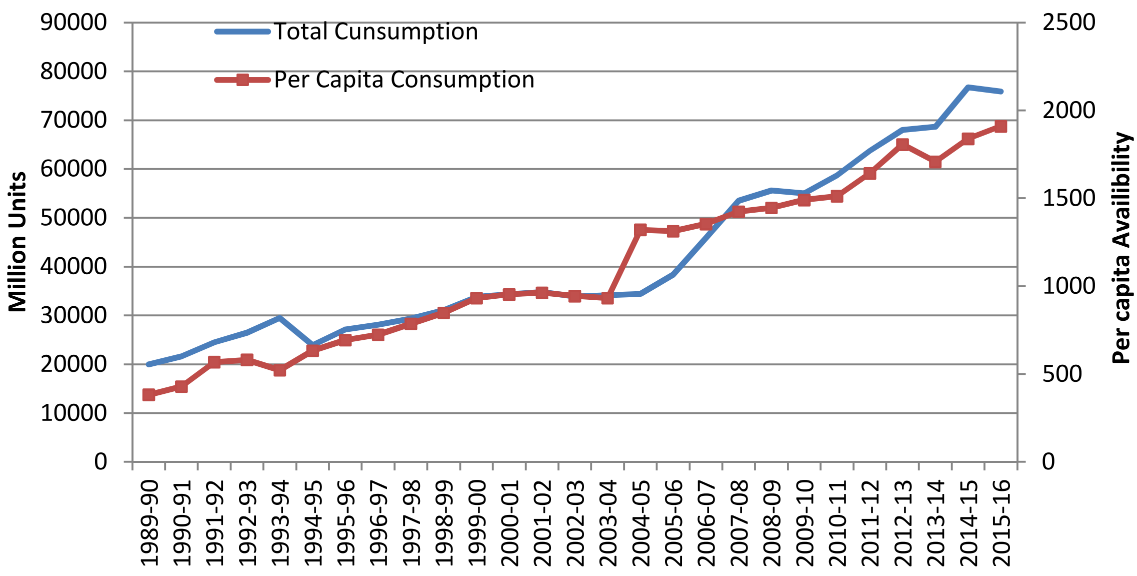
Gujarat has recorded significant economic growth over the past decade. Gujarat leads the country in the per capita consumption of electricity[1].Power is a key factor for the overall growth of the economy and the state of Gujarat has attracted a large number of private players in the sector in recent past. Installed capacity of the State has increased from 315 MW in 1960-61 to 27200 MW up to October 31, 2018[2]. 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

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

agricultural consumers which was done under the Jyotigram scheme[3], 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. 2.1: Growth in Total Electricity Consumption and Per Capita Availibility in Gujarat



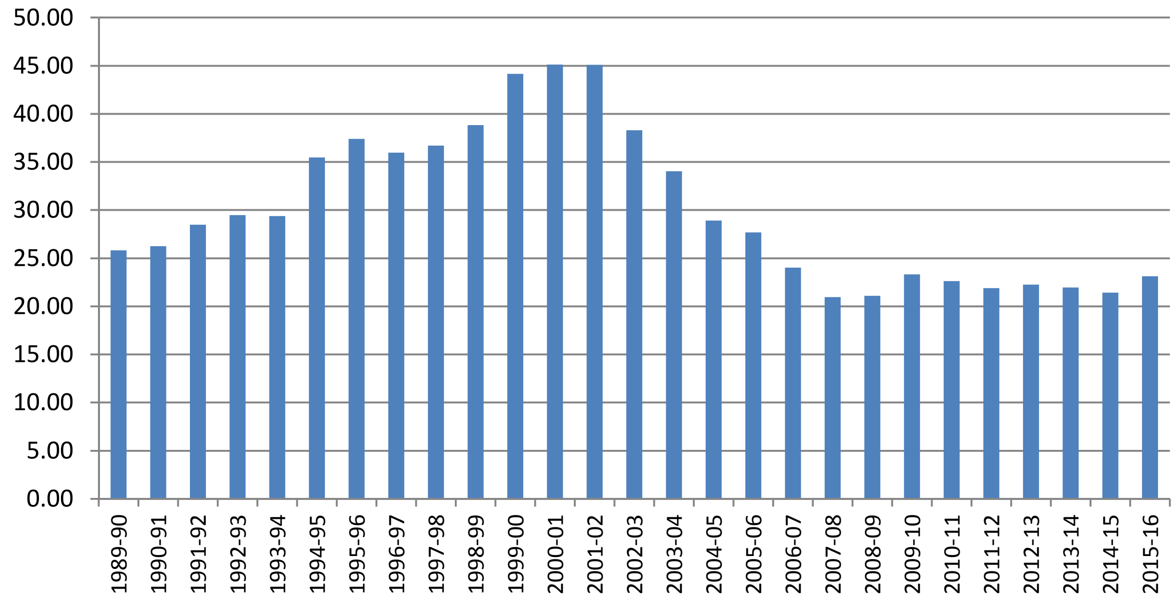
2.3 Solar Power Policy of Gujarat State

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

[3] 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. 2.2: Share of Electricity Use in Agriculture to total consumption in Gujarat



2.3.1 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[4]. 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.

2.3.2 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[5]' 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.

[4]TERI (2012).
[5]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

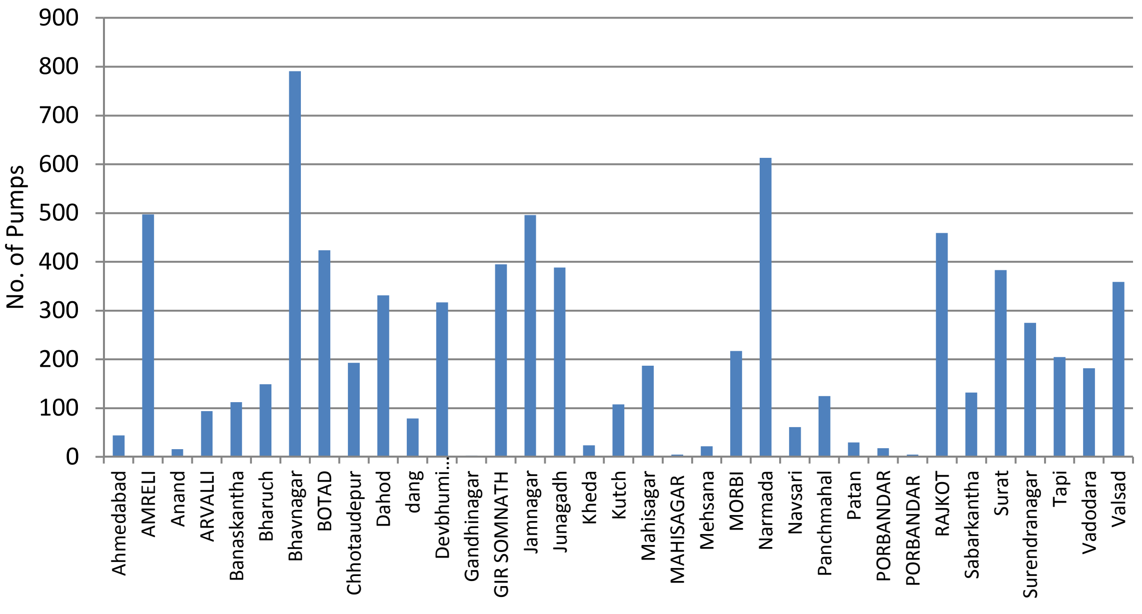
Government has successfully implemented pilot projects of solar power generation which is gaining traction at several grassroots-level interventions. Grassroot Trading Network for Women (GTNfW), an initiative by Self-Employed Women’s Association (SEWA), is in the process of implementing one such project 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. 2.3: 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 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)

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 ~~damaged~~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 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 (See Annexure XI).

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

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

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 Chapter Summary:

This chapter presented the policies and programme adopted by the State Government of Gujarat in expanding the coverage of solar pumps along with success stories of adoption of solar with MIS.

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

Dhundi Solar Irrigation Cooperative: Case Study[1]

3.1 Introduction

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. 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,

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[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 `6,000,000. The cost of connecting the solar panels on the farms with the grid is estimated to be `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 `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 (`/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 `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 `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 `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 (`)
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 @ `0.70/unit: `3,386.6** b) If the farmer were using diesel pump: 1 liter of diesel approx. @ `50/*l* is required to generate approx. 20 units of power: 4838/20 units= 241.9 1 *l* of diesel use 241.9 × 50=`12,095
3	Power used to withdraw water to sell	18,477	65.46	@`250 per 20 units(required to irrigate one bigha): `2,30,962.5. @400 it could be `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 `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 @` 50 per liter, it comes to a saving of ` 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 `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 (`)	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 (`)13,375/month)×8**	 1,07,000.00	 00
2	Mean Expenditure on repairs of irrigation pump (` per year),	8,250	Nil
3	Direct Savings due to Solar Pumps (`)	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 `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 `8,250 per year. Thus, direct monetary savings come to `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 `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 `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.

Chapter IV

Findings from Field Survey Data

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

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 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.

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	14846.1	
	GGRC	27154.8	
	Private		448125.0
3	Subsidy amount (Rs.)		
	GUVNL	316134.4	
	GGRC	372624.7	
	Private		110625.0
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 after Solarization

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, western part of India. 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 presents a summary of the study report and policy implications emerging from the findings of the study.

Chapter V

Summary and Policy Implications

5.1 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 and prospects of solarisation of agricultural pumps in selected districts of Gujarat. The data were collected from three distinct groups of farmers, viz. farmers who had adopted SIPs with the help of subsidy by the government, farmers who had adopted SIPs without any support in the form of subsidy by the government, and the farmers who had not adopted SIPs. The first group was of 100 sample farmers (25 from each of the four districts under study, i.e. 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.

Table 5.1: Sampling Framework Area in Gujarat state

Sr. No	*Selected Region and District*	*Selected Tehsil/ Taluka*	*Selected Villages*	*Selected provider/agency and users*				
				GUVNL	*GGRC*	*Private Solar*	*Non-Ben.*	*Total*
1.	South-Narmada	Dediapada	Kokam, Piplod, Moti Singloti, Morjadi, Rakhas Kundi, Chikada	24	1	1	5	31
2.	East-Dahod	Devgadh Bariya, Fatepura, Dahod	Zapatiya, Jagola, Nava Talav, Hingla, Rampura	24	1	0	5	30
3.	North-Sabarkantha	Himmatnagar, Talod, Idar, Khed brahma	Illol, Rupal, Kankrol, Sankrodia, Hadiyol, Hathrol, Bhimpura, Modhuka, Panapur, Fojivada, Rozad, Bakkarpura, Ratanpur	*24*	*1*	*2*	*5*	*32*
4.	West-Bhavnagar	Talaja	Vejodari, Dakana, Mangela, Kerala, Pithalpur, Ralgaon	*24*	*1*	*1*	*5*	*31*
			Gujarat State	96	4	4	20	124

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 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 5.2: Subsidy Norms with Cost and Types of Solar Water Pumps

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 2.1). 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.

Solar Pump Irrigators' Cooperative Enterprise: Case Study:

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 Data

- 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.

Policy Implications:

- 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.

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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**

Annexure XI

GUJARAT URJA VIKAS NIGAM LTD.

(An ISO 9001:2008 Company)
Registered and Corporate Office:
Sardar Patel Vidyut Bhavan Racecourse, Vadodara-390007
CINU40109GJ2004SGC045195
Tele: (Dir) 2340205 PBX: 2310582 to 86
FAX: 2337918, 2338164
Email: cetech.guvnl@gebmail.com

No. GUVNL/Tech./AKF/Solar/2033 Date: 09/12/2014

To,
The Managing Director,
DGVCL/ MGVCL/PGVCL/UGVCL
Corporate Office,
Surat/Vadodara/Rajkot/ Mehsana

Sub: Solar Irrigation Pump Set for Agriculture Purpose

Respected Sir,

Please find enclosed herewith a copy of GR No.Budget-2014-1447-k1dated 25.09.2014 and Revised GR No.Budget-2014-1447-k1 dated 26.11.2014 approving implementation of scheme of 1500 solar pump sets for agriculture purpose at an estimated expenditure of RS.60 crores. In line with the GR and as approved by the Competent Authority, following procedures are to be initiated at DISCOM level.

A. The DISCOMs have to invite applications for selecting beneficiaries by publishing an advertisement in the newspapers and displaying the terms and their indicative target on their website as under.

DISCOM	No. of Solar Pumps as per Target
DGVCL	150
MGVCL	150
PGVCL	1050
UGVCL	150
TOTAL	1500

B. DISCOMs may accept applications for the period from 0.12.2014 to 09.01.2015.

C. In case of excess number of applications if any, the deposit amount may be refunded at the earliest.

D. The eligibility criteria as per GR dated.25.09.2014 & GR dated.26.11.2014 are to be followed to select beneficiaries from the pending list as on 31.03.2014.

E. The Committee meeting was held on 01.12.2014 to finalize technical specifications, terms and conditions of Solar Pump Sets for agriculture purpose. Based on discussion during the meeting, the guidelines for publishing advertisement in newspapers is attached herewith.

This is for your kind information and further necessary action, please.

Thanking you, Yours Faithfully,

(Y.D. Brahmbhatt)

I/c. Chief Engineer (Tech)

Encl. As Above

Copy fwcs to:

- The M.D.GUVNL Vadodara
- The Director (A), GUVNL, Vadodara

Translated version

A Scheme to provide solar energy powered irrigation pump sets to the farmers in the state.

Government of Gujarat
Energy & Petrochemicals Department
GR No.BJT-2014-1447-K1
Sachivalaya, Gandhinagar
Date: 25/09/2014

Preamble:

Due to the large number of applications received from farmers for agricultural electrical connection in the state, the customers have to wait for years to get an electricity connection even after they have registered for the same. Besides, more agricultural consumers account for more than 20% of the total power consumption which results in a huge amount of expenditure incurred on giving subsidy by the State government; which keeps on increasing year after year. The additional infrastructure for the new agricultural power connections such as light/heavy pressure, high power lines, thermal installations, transformers, feeders, meters etc. is also very costly. Therefore, efforts have been undertaken by the State government to encourage the option of using solar energy-powered pump sets for agriculture instead of conventional energy powered pump sets in order to save on power consumed in agriculture; to create awareness of solar energy in agriculture and to reduce the burden of subsidy on the state government. For this purpose Rs. 50.00 crores have been allocated in the budget of the State government and it has been decided to implement the scheme from the current financial year 2014-15.

Resolution:

After intense consideration by the state government, the scheme for solar energy operated Irrigation pump sets is decided to be implemented in the state from the financial year 2014-15. However, in the current financial year, the scheme has been implemented for the purpose of distributing 1000 Pump sets on experimental basis in the State. Under this scheme, every beneficiary farmer will be provided with 3 to 5 horsepower power solar photovoltaic submersible pump sets (only AC power stream based) as per the requirement. For the year 2014-15, power distribution company's (DISCOMs) targets and the expected expenditure for that would be as follows.

DISCOMs	No. of Solar Pumps	Price per unit (Rs. in lakhs)	Total Cost (Rs. in lakhs)
DGVCL	100	6.0	600.00
MGVCL	100	6.0	600.00
PGVCL	700	6.0	4200.00
UGVCL	100	6.0	600.00
TOTAL	1000		6000.00

This is an indicative target, which will be changed on the basis of the feedback received from the farmers. After the evaluation of the success of the scheme, the expansion and continuation of the scheme shall be considered in the coming year. The standards/criteria/conditions for applicants seeking benefit of this scheme shall be as follows:

1. At least one acre of agricultural land along with a bore well should be available in the name of the applicant in order to get the benefit from this scheme.
2. As on 31/03/2014, the application should have been submitted as well as registered. Applicants who have paid the registration fees shall get the benefit of this scheme. Those who have not applied for agricultural electricity connection till 31/03/2014 shall not get the benefit of this scheme.
3. The applicants who have paid up the charges for a conventional power connection shall be compensated against that amount while making payment for this scheme.
4. Switched-over/transferred applications will not be considered for this scheme in connection with this plan-.2013
5. The bore/well which is to be connected to the solar pump should be at a distance of one kilometer from the grid (agricultural feeder line). However, in cases where there are obstructions such as reserved forest areas, railway crossings or river-courses, the norm of one km distance (parameter????? Or is it perimeter?) will not be applicable. However, it will be necessary to get the approval of the power company's competent authority.
6. Applicants from the Dark zone area must implement micro-irrigation system according to existing standards of government.
7. The applicants who fulfill the above-mentioned criteria can only apply and not others. Applicants must submit a photocopy of the old registration receipt with the application dated 31/03/2014 or earlier. The priority of the applicant will be decided as per the date of the original application.
8. All applicants applying for this scheme will be required to deposit Rs. 1000 at the time of applying. The deposit amount of the eligible applicants will be adjusted against the final amount paid for the pump sets. Deposits of other non-eligible applicants shall be

refunded to them.

9. Eligible applicants belonging to the Scheduled Castes and Scheduled Tribes shall have to pay Rs. 1000 per hp and all other beneficiaries will have to pay Rs. 5000 per hp.
10. Beneficiaries of the scheme or their descendants will not be entitled to apply for a conventional agricultural power connection in the same plot number or a part/fraction of the same plot for up to a period of five years from the date of application for getting a solar pump. A notarized affidavit stating the above should be submitted for this purpose.
11. The Solar pump and its allied equipment will be installed by the respective power distribution company.
12. For the maintenance of solar pumps, panels and other structures, beneficiaries need to have fencing facilities at their own expense.
13. The beneficiary will not be able to move the solar pump from where it has been installed to anywhere else, nor permit anyone else to do so.
14. After the installation of solar pump, if the beneficiary sells the land within five years, then the entire amount of subsidy will have to be returned to the respective power distribution company.
15. Each beneficiary will be provided with a lamp and mobile charger point along with solar pump for own needs of lighting.
16. The use of solar pumps should be done only in order to draw water from the bore/well for the purpose of irrigating the land belonging to the respective survey number for which the solar pump has been allotted. If the applicant is found to be using this pump for a purpose other than this, the concerned power distribution company will be entitled to withdraw the pump/panel and no compensation will be paid to the applicant, nor will the deposit amount be refunded.
17. Consumption of units of solar energy will be registered by the power distribution companies, but they will not be billed or charged.
18. The entire responsibility of the solar pump will be of the respective beneficiary.
19. Under the tender for insuring of the solar pumps, the annual cost of insurance coverage will be covered for the next five years.

The project will be implemented by the Gujarat Urja Vikas Nigam Limited (GUVNL) and four power distribution companies (DISCOMs) with the following specifications.

A. A committee of Chief Engineers/Special Engineers of Gujarat Urja Vikas Nigam Limited (GUVNL) and four power distribution companies (DISCOMs) will have to be formed. The committee will have to monitor the tender related criteria, documents, etc. and all related matters to the tender.

B. According to the procedure of Central Purchase Committee, GUVNL will have to work on deciding on tender and Agencies.

C. The bidders participating in the tender should be the partners of the recognized SPVs of the Ministry of New and Renewable Energy (MNRE), Government of India and having adequate experience and good track records.

D. DISCOMs will have to make wide publicity of the project through local newspapers and other publicity media.

E. The documents received from the applicants and the exact fees received will be verified by DISCOMs in two weeks.

F. The applicants will have to pay the deposit amount in the concerned sub-divisional office.

G. The DISCOMs, the beneficiary and the supplier of solar energy pump sets will have to make a tripartite agreement.

H. The suppliers will have to supply pump sets (all equipment) within 60days of receipt of order and after 30days the pump sets will be installed after duly checking the applicant's bore/well.

I. Officers of the respective power distribution company will have to go through the premises and check all the pump sets.

J. The respective power distribution companies will have to pay the respective amount to the supplier according to the conditions of the tender.

K. Gujarat Urja Vikas Nigam Limited and Gujarat Urja Vikas Agency will undertake the joint responsibility of preparing the proposal to be sent by the state government to the Ministry of Renewable Energy for this purpose and for realizing the subsidy receivable from the Central Government.

By the order and in the name of Governor of Gujarat,

(H.F.Gandharv)

Joint Secretary

A Correction in Scheme to provide solar energy powered irrigation Pump sets to the farmers in the state.

Government of Gujarat
Energy & Petrochemicals Department
GR No.BJT-2014-1447-K1
Sachivalaya, Gandhinagar
Date: 26/11/2014

Read: 1. MNRE letter No.42/25/2014-15/PVSE, Dated 31/08/2014
2. Energy & Petrochemicals Department's GR No.BJT-2014-1447-K1, Dated 25/09/2014

Correction of Resolution:

Correction in the state government's resolution regarding the plan to make available solar irrigation pump sets to the state's farmers implemented from the financial year 2014-15, It is proposed to provide 1,000 pump sets through a budgetary provision of 50.00 crore.

In accordance with the aforesaid letter, a new scheme for providing solar irrigation pump sets in all the states of India is fixed in the financial year 2014-15 by the MNRE. Accordingly, an initial amount of Rs. 10 crores has been earmarked for the state of Gujarat as being a part of the 30% of the cost that the state is supposed to bear.

The Central Government's contribution is for the purpose of supplementing the state government's scheme through its own expenditure as well as estimated contribution from the beneficiaries themselves. For the financial year 2014-15, the target of 1500 solar pump sets has been fixed in place of the earlier target of 1000 solar pump sets. Estimated cost and estimated assistance structure will be as follows.

No. of Solar Pumps	Price per unit (Rs. in lakhs)	Total Cost (Rs. in lakhs)	State government's Grants (Rs. in lakhs)	MNRE, subsidy as per 30% share	Share of beneficiary according to 5% (Rs. in lakhs)	Total Cost (Rs. in lakhs)
1500	5.00	7500.00	5000.0	2250.00	375.00	7625.00

In the above figures, the contribution of beneficiaries is estimated at 5% of the cost. The eligible applicants or beneficiaries would have to pay the subscriber's share as per the condition number:9 of original resolution dated 25/09/2014.

In addition, as per the change in the target, the target of the power company will now be as follows:

DISCOMs	No. of Solar Pumps
DGVCL	150
MGVCL	150
PGVCL	1050
UGVCL	150
TOTAL	1500

Other terms and conditions of the resolution and other details will remain unchanged.

In addition to the formation of the Steering Committee on the specific issues mentioned in the MNRE letter, the Deputy Secretary (NCE), Government of India, is required to take all the necessary steps in consultation with the Gujarat Energy Development Agency, for which a proposal for assistance will be sent to the Government of India.

By the order and in the name of Governor of Gujarat,

(H.F.Gandharv)

Joint Secretary

GUJARAT URJA VIKAS NIGAM LTD.

(An ISO 9001:2008 Company)
Registered and Corporate Office:
Sardar Patel Vidyut Bhavan Racecourse, Vadodara-390007
CINU40109GJ2004SGC045195
Tele: (Dir) 2340205 PBX: 2310582 to 86; FAX: 2337918, 2338164
Email: cetech.guvnl@gebmail.com

No. GUVNL/Tech./AKF/Solar/234 Date: 02/02/2015

BY FAX

To,
The Managing Director,
DGVCL/ MGVCL/PGVCL/UGVCL
Corporate Office, Surat/Vadodara/Rajkot/ Mehsana

Sub: Solar Irrigation Pump Set for Agriculture Purpose for the FY 2014-15.
Ref: 1. Our letter No. GUVNL/Tech./AKF/Solar/2033 dated 09.12.2014
2. Our letter No. GUVNL/Tech./AKF/Solar/39 dated 06.01.2015

Respected Sir,

This has reference to this office letter dated 09.12.2014 sending guides line for publishing advertisement in news papers to invite applications from farmers to avail scheme of solar Irrigation Pump Sets for Agriculture purpose from 10.12.2014 to 09.01.2015 and further extended up to 31.01.2015. In order to attract more beneficiaries for Solar Irrigation pump sets for Agriculture purpose for the year 2014-15, the State Govt. vide G.R. dated 02.02. 2015 (copy enclosed) has modified some of the terms and conditions of the original G.R. dated 25.09.2014. The Competent Authority has also approved to extend the time limit for accepting switch over applications from agriculture applications up to 20.02.2015.

In view of above, you are requested to direct the concerned to publish advertisement as attached in the news papers from your end for wide publicity of the scheme and direct field offices to inform the registered agriculture applicants, falling under their area to avail benefit of the scheme and accept switch over application up to 20.02.2015.

Thanking you, yours faithfully

(Y.D. Brahmbhatt)
I/c. Chief Engineer (Tech)

Encl. As Above

Copy fwcs to:

- The M.D.GUVNL Vadodara
- E.D. (F & A), GUVNL, Vadodara

GUJARAT URJA VIKAS NIGAM LTD.
(An ISO 9001:2008 Company)
Registered and Corporate Office:
Sardar Patel Vidyut Bhavan Racecourse, Vadodara-390007
CINU40109GJ2004SGC045195
Tele: (Dir) 2340205 PBX: 2310582 to 86
FAX: 2337918, 2338164
Email: cetech.guvnl@gebmail.com

No. GUVNL/Tech./AKF/Solar/929 Date: 02/05/2015

FAX MESSAGE

To,
The Managing Director,
DGVCL/ MGVCL/PGVCL/UGVCL
Corporate Office,
Surat/Vadodara/Rajkot/ Mehsana

Sub: Scheme of Solar Pump Sets (3 HP and 5 HP) for Agricultural Purpose for the FY 2015-16.

Respected Sir,

GoG vide GR dated 09.04.2015 has approved a budgetary provision of Rs.60 crores for implementation of scheme of Solar Pump Sets for Agricultural purpose for the year 2015-16. Accordingly, in line with the GR dated 25.09.2014 and 02.02.2015; and considering the availability of grant from MNRE, following procedures are to be initiated at DISCOM level, as approved by the Competent Authority.

1. To invite applications for the period from 05.05.2015 to 30.06.2015 for selecting beneficiaries by publishing an advertisement in the newspapers and displaying the same on the website of the DISCOM as per the indicative target given below:

DISCOMs	No. of Solar Pumps as per Target
DGVCL	200
MGVCL	400
PGVCL	1500
UGVCL	200
TOTAL	2300

2. The guidelines for publishing the advertisement in the newspapers are

attached here with.

3. The Competent Authority has further decided to entrust the responsibility of inviting and finalizing the tender for the supply, erection, testing and commissioning of the Solar Pump Sets for agricultural purpose in line with CPP, on behalf of all DISCOMs for the year 2015-16 to MGVCL.

This is for your kind information and further necessary action, please.

Thanking you,

Yours faithfully
SE (Tech)

Encl. As Above

Copy fwcs to:

- The M.D.GUVNL Vadodara
- The Director (A), GUVNL, Vadodara
- The E.D. (F&A) GUVNL Vadodara

Correction in the Scheme for providing solar energy
Powered irrigation pump sets to the farmers in the state.

Government of Gujarat
Energy & Petrochemicals Department
GR No.BJT-2014-1447-B
Sachivalaya, Gandhinagar
Date: 02/02/2015

Read: 1. Energy & Petrochemicals Department's GR No.BJT-2014-1447-K1, dated 25/09/2014
2. Energy & Petrochemicals Department's GR No.BJT-2014-1447-K1, dated 26/11/2014
3.Letter by GUVNL, Vadodara, Letter No. GUVNL/Tech./AKF/Solar/187,dated 26/01/2015

Preamble:

The scheme for providing solar power operated irrigation pump sets has been implemented from the financial year 2014-15 for the state's agricultural consumers, subject to the specifications set by the state government's GR no. 1 and 2.

The terms and conditions of the present scheme set by the State Government have not been found acceptable in order to make the scheme successful and useful. Considering the poor feedback received from the applicants for the scheme; as well as to make the scheme more successful and useful, the need for cancellation of certain terms and conditions of the scheme as per Government Resolution No. 1 as well as the partial amendment of few other conditions was under the consideration of the government of Gujarat.

Updated Resolution

Accordingly, after intensive consideration by the State Government, the following amendments are made in the provision of the Resolution No. 1 in the declaration.

Under this scheme, every beneficiary farmer will be provided three to five hp solar photovoltaic submersible pump sets (AC power current or brushless direct current (DC) motor pump sets- BLDC) as per their requirement. However, any price difference between AC and BLDC will not be receivable. Apart from this, the applicants that have demanded ten hp solar pumps will also able to additionally apply for solar pump sets of three or five hp.

In addition, the condition No. 5 of the above Resolution is cancelled herewith; whereas the following amendments are made in conditions No. 1, 2 and 11:

Condition no. 1: Those applicants who have at least one acre of land in their own name possess a bore/well on that land, can get benefit of this scheme. However, if the applicant's land does not have bore/well, he/she is given a time period up to two months get the bore/well constructed, after the date of reporting the payment made as beneficiary contribution.

Condition no. 2: In addition, those applicants who have applied for agricultural power connection as on 31/12/2014; those applicants who have already received the estimated cost statement for the same; as well as those applicants who have already paid the amount indicated in estimated cost statement but have not yet received the agricultural power connection; would be able to take benefit of this scheme.

Condition No. 11: The Solar Pump and all its related equipment will be owned by the respective power distribution company up till a period of five years. After five years, the ownership will be transferred to the beneficiary subject to the condition that the beneficiary will not be able to raise a demand for getting a conventional agricultural power connection for a period of the next five years.

It is also decided to take the following details into cognizance instead of the details given in G and JH of the procedure mentioned in the order of Gujarat Urja Vikas Nigam Limited and the power distribution company designated by the Resolution No. 1:

(1) Point No. G: The bidders participating in the tender should be a partner of an approved SPV recognized by the Ministry of New and Renewable Energy (MNRE), GoI OR should be included in the list of National Bank for Agriculture and Rural Development (NABARD)'s Schemes AND have adequate experience and good track record.

(2) Point No. JH: Instead of completing the entire process namely, 'after receiving the list of beneficiaries and getting possession of the premises where the pumps are to be installed, the suppliers must supply the pump sets within 60 days; complete their installation within the next 30 days'; the suppliers must now complete the entire process of installing the solar pumps on the bore/well of the beneficiary, testing it and making it operational within a total period of 90 days.

By the order and in the name of Governor of Gujarat,

(H.F.Gandharv)

Joint Secretary

Correction in the Scheme for providing solar energy
Powered irrigation pump sets to the farmers in the state.

Government of Gujarat
Energy & Petrochemicals Department
GR No.BJT-2014-1447-B
Sachivalaya, Gandhinagar
Date: 19/08/2015

Read: 1. Department's GR No.BJT-2014-1447-K1, Dated 25/09/2014
2. Department's GR No.BJT-2014-1447-K1, Dated 26/11/2014
3. Department's GR No.BJT-2014-1447-B, Dated 02/02/2015
4. GUVNL, Vadodara Letter No. GUVNL/Tech./AKF/Solar/1463, Dated 21/07/2015
5. GUVNL, Vadodara Letter No. GUVNL/Tech./AKF/Solar/1481, Dated 23/07/2015

The scheme for providing solar power operated irrigation pump sets has been implemented from the year 2014-15 for the State's farmers vide the specifications set by the State government's resolutions Number: 1, 2 and 3.

Correction in Resolution

After careful consideration on the recommendations made in the letters by the Gujarat Urja Vikas Nigam Limited, Vadodara dated 21/07/2015 and 23/07/2015, the Government has decided to make the following changes in the aforementioned scheme:

1. Those applicants who were registered for getting agricultural power connections as on 31/12/2014, to whom, the statement of estimated cost has already been sent and have already paid the amount payable for the same; are also eligible to receive the benefit of this scheme. The applicants who have completed the above procedure, will be benefited by this scheme even if the above procedure has been completed up to 31/07/2015, instead of the earlier date, i.e. 31/12/2014.
2. The applicants who have not previously registered for agricultural power connection can also get the benefit of this scheme. The applications received from these applicants by the end of this financial year shall be considered under this scheme.

Other terms and conditions of the three resolutions passed by the Government will remain unchanged.

By the order and in the name of Governor of Gujarat,

(Shobhna Desai)

Additional Secretary

Correction in the Scheme for providing solar energy
Powered irrigation pump sets to the farmers in the state.

Government of Gujarat
Energy & Petrochemicals Department
GR No.BJT-2014-1447-B
Sachivalaya, Gandhinagar
Date: 27/05/2016

Read: 1. Department's GR No.BJT-2014-1447-K1, Dated 25/09/2014
2. Department's GR No.BJT-2014-1447-K1, Dated 26/11/2014
3. Department's GR No.BJT-2014-1447-B, Dated 02/02/2015
4. Department's GR No.BJT-2014-1447-B, Dated 19/08/2015
5. GUVNL, Vadodara Letter No. GUVNL/Tech./AKF/Solar/760, Dated 18/04/2016 and Letter No. GUVNL/Tech./819, Dated 28/04/2016

The state government has decided to provide solar power operated irrigation pump sets from the financial year 2014-15 to the farmers of the state vide Government Resolutions No. 1 to 4. The Gujarat Urja Vikas Nigam Limited, Vadodara had proposed to make some amendments in the scheme vide their letters dated 18/04/2016 and 28/04/2016, which were under the consideration of the government for some time.

Correction in Resolution

As per the amendments proposed by the Gujarat Urja Vikas Nigam Limited, Vadodara vide their letters dated 18/04/2016 and 28/04/2016, the Government has decided to make the following amendments in the scheme:

1. If the beneficiary has a minimum of one acre land in the same survey number or joint survey number while also considering the adjacent land under his/her ownership, then he/she will be able to register for this scheme. In this case, it will be compulsory that the land parcels are adjacent to each other. Moreover, the applicant must agree that the water withdrawn with the help of the solar pump on his/her land will not be used or accessed for other land owner/s in the neighbouring survey numbers. In none of the land parcels taken into consideration while allotting the solar pump, an application to get agricultural power connections can be made for a period of the next five years.
2. All the applications that are registered for demanding agricultural power connections; all applicants who have received the statement of estimated cost as well as all applicants who have paid up the amount of estimated cost but

have not yet received the connection; shall get the benefit of this scheme. Farmers who have not applied for agricultural power connections can also register under this scheme.

3. Solar PV-powered grid-based agricultural irrigation pumps of 3 hp, 5 hp and 7.5 hp. Can be included under this scheme. In this context, the beneficiaries of Scheduled Castes and Scheduled Tribe will have to pay Rs.1000 per hp of pump capacity, while other beneficiaries will have to pay Rs. 5000per hp of pump capacity; as 'contribution from the consumer'.

Other terms and conditions of the three resolutions passed by the Government will remain unchanged.

These orders are published following the files of the same number of this Department as well as the Finance Department's consent vide their Note dated 23/05/2016.

By order and in the name of the Governor of Gujarat,

(Shobhna Desai)

Additional Secretary

Correction in the Scheme for providing solar energy
Powered irrigation pump sets to the farmers in the state.

Government of Gujarat
Energy & Petrochemicals Department
GR No.BJT-2014-1447-B
Sachivalaya, Gandhinagar
Date: 10/02/2017

Read: 1. Department's GR No.BJT-2014-1447-K1, Dated 25/09/2014
2. Department's GR No.BJT-2014-1447-B, Dated 02/02/2015
3. Department's GR No.BJT-2014-1447-B, Dated 27/05/2016

The plan to provide solar energy operated irrigation pump sets has been implemented from the financial year 2014-15 for the state's farmers for the decisions made by the state government.

In this scheme, the solar pumps are provided by central government subsidy, state government subsidy and beneficiary contribution. For this purpose procedure for demanding of tender for solar pump is setting up by transparent method is to be done by GUVNL. In this tendering process, more companies could take part in the bid and get competitive pricing and also improve the technical requirements of the Central Government's plan. Therefore it was a matter of considerable concern for past time.

Correction in Resolution

Therefore, after intensive consideration by the State Government, it is decided that the work procedure designated in the resolution of the dated 25/09/2014 is correct with the date of 2/2/2015 resolution. In this case, issue of work method "G" will have to read the following provisions instead of the existing provisions.

Bidders participating in this tender will have to submit the all test certificate as per the technical norms, technical criteria of Tender Bid in the Solar Pump Scheme of the Ministry of New and Renewable Energy (MNRE). The Central Government has to set up high-specification machinery as per the technical specification of the times or so.

Other terms and conditions of the three resolutions passed by the Government will remain unchanged.

By the order and in the name of Governor of Gujarat,

(Anita Jhula)

Under Secretary

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 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 XIII

Action 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.

Authors