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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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Sardar Patel University
Vallabh Vidyanagar 388120, Anand, Gujarat

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Prepared by

Dr. Sonal Bhatt, Assistant Professor, PG Department of Economics, SPU
Dr. S. S. Kalamkar, Director and Professor, AERC, SPU, VVN
Shri Manish Makwana, Research Associate, AERC, SPU, VVN

Research Team

Shri Thansingh B. Parihar, Research Associate, AERC, SPU, VVN
Shri Manish Makwana, Research Associate, AERC, SPU, VVN
Ms. Kalpana Kapadia, Research Associate, AERC, SPU, VVN
Dr. M. R. Ojha, Research Associate, AERC, SPU, VVN

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The Director
Agro-Economic Research Centre
For the states of Gujarat and Rajasthan
(Ministry of Agriculture & Farmers Welfare, Govt. of India)
Sardar Patel University,Vallabh Vidyanagar, Anand, Gujarat.
Ph. No. +91-2692-230106, 230799, 9408374268 (direct)
Mobile- 09822437451; 7383554616; Fax- +91-2692-233106
Email: director.aerc@gmail.com; directoraercgujarat@gmail.com

Printing and Circulation In-charge:
Shri Deep K. Patel, *Research and Ref. Assistant (Lib.)*

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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.

Agro-Economic Research Centre
(Ministry of Agriculture and Farmers Welfare, Govt. of India)
Sardar Patel University, Vallabh Vidyanagar 388120

(Dr. S.S. Kalamkar)
Director & Professor

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S. S. Kalamkar
Team Leader

Agro-Economic Research Centre
For the states of Gujarat and Rajasthan
(Ministry of Agriculture, Govt. of India)
Sardar Patel University,
Vallabh Vidyanagar 388120, Anand, Gujarat.

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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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