Integrated Research and Action for Development (IRADe) — 20 Years

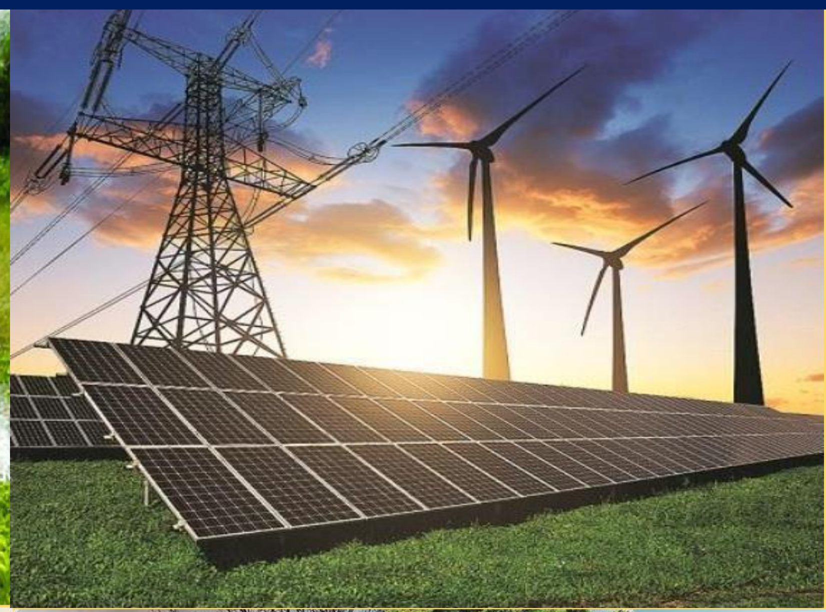
MacArthur Foundation

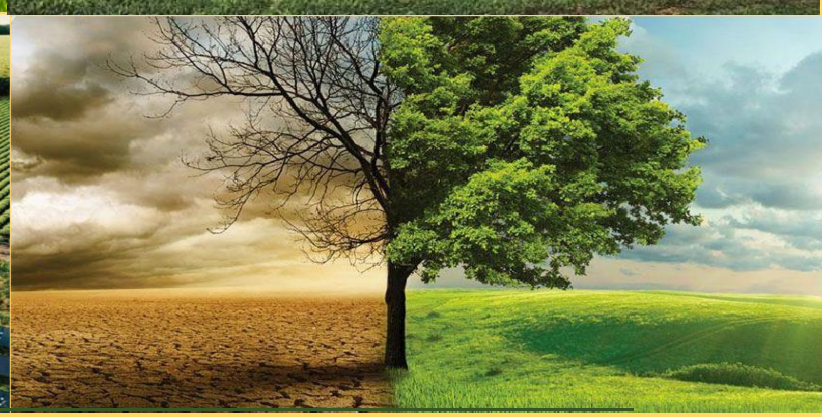
Discussion Paper

Gujarat

IRRIGATION SECTOR

ENABLING STATE LEVEL CLIMATE MITIGATION ACTIONS





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1. Introduction

The semi-arid state of Gujarat in western India was at the forefront of India's groundwater revolution. The Colonial drive for canal irrigation had largely bypassed Gujarat and left the state extremely prone to droughts and famines. During the 1950s and 1960s, Gujarat farmers took to groundwater irrigation in a big way with oil engines. However, as rural electrification progressed, they began switching to submersible electric pumps which were cheaper to operate and could better chase declining water levels. The major expansion in the use of electric pumps occurred during the late 1980s as the Gujarat Electricity Board (GEB) changed to flat tariffs linked to the horsepower of pumps. Until 1988, farmers were charged based on metered use of electricity. However, as electric tube-wells increased to hundreds of thousands, meter reading and billing involved rampant corruption. Farmers also complained about the tyranny and arbitrariness of GEBs meter readers and poor quality of power supply. This gave rise to an invidious nexus which, by 2000, left Gujarat's electricity industry in a near state of bankruptcy, its aquifers depleted and farmers unhappy.

The ideal way out would be to meter tube-wells and charge farmers a consumption-linked power tariff. However, this was politically infeasible due to strong farmer opposition. During 2003-6, the Gujarat government implemented a revolutionary campaign called Jyotigram under which entire rural Gujarat was rewired at a cost of Rs 1250 crore. After its completion, all tube-wells were connected to a separate feeder while all non-farm consumers were put on the Jyotigram feeder providing a 24*7 3-phase power supply. The farm power supply was much improved in quality but was put on an 8-hourly daily ration, during the day one week and during the night the following week (Shah et al 2001).

In the years that followed, studies showed that Jyotigram had multiple beneficial effects. Farmers grudged rationed power supply but were happy about full voltage, uninterrupted supply on a predictable schedule. Gujarat's were among the few DISCOMs in India that turned profitable and stayed so. Gujarat was also the only state where the groundwater regime improved between 2000 and 2015 and farm power consumption fell 30 percent. Finally, and yet, its agricultural economy grew at a breakneck rate of 9.5%/year during 2000-2014. The only downside was that Jyotigram hit the poor hard. Rationing of farm power supply hardened Gujarat's pervasive village-level water markets in which marginal and tenant farmers purchased irrigation from tube-well owning elite farmers. With reduced daily hours of power, tube-well owners refused to sell irrigation or demanded higher prices. A buyers' water market turned sellers (Shah and Verma 2008; Shah and Chowdhury 2017). The government took this feedback to heart and began issuing small tube-well connections exclusively to SC/ST farmers. This policy has continued thus far. In December 2019, Gujarat's current chief minister issued a full-page newspaper advertisement announcing the pro-poor initiatives of his government: one of the long litanies of achievements was the issue of 463,000 new tube-well connections in just past 4 years (taking Gujarat's total electric tube-wells to 1.6 million) (Sunday Express, December 29, 2019). Over time, this reduced the effectiveness of energy rationing to limit groundwater draft and brought to the fore new tensions between the goals of saving water, reducing losses of electricity utilities, containing carbon footprint, and providing succor to the poor.

The DISCOMs were also worried about the burgeoning bill of farm power subsidy, thanks to the doubling of tube-wells. Having succeeded with Jyotigram, these began looking for politically acceptable ways of reducing present and future farm power subsidy burden. One opportunity they spotted was in the arrival of solar irrigation pumps (SIPs). Solarizing a grid-connected tube-well meant a reduction in annual power subsidy burden of the order of Rs 45-55 thousand average per connection per year for a long time to come. In groundwater-stressed western states of India, electricity utilities began aggressively promoting SIPs to reduce their subsidy burden on-grid power supply to tube-wells. Capital cost subsidies ranging from 60-95 percent got offered on SIPs to applicants long waiting for a grid power connection (Shah et al 2018). The apprehension was SIP's implications for groundwater depletion. Once installed, SIP's offer reliable daytime electric power for free given India's high solar insolation for over 320 days/year. In many states, high diesel cost and poor quality, nightly power supply are irksome to farmers but the only check on unbridled groundwater pumping. By offering reliable daytime free power, SIPs may arguably exacerbate the pressure on groundwater resources (Kishore et al 2014; Gupta 2017; FAO). Gujarat was particularly worried. The issue of numerous new tube-well connections had eroded the 'rationing' role of Jyotigram. Daytime power supply offered by SIPs increases annual hours of usable power supply compared to grid connections which deliver difficult-to-use night power supply half of the year.

In 2015, a group of researchers in Gujarat piloted a village-scale model to explore if farmers can be persuaded to 'grow' solar energy as a cash crop (Shah et al 2017a; Shah et al 2019). They began with the proposition that small farmers' demand for water is a derived demand for food, income, and livelihoods. Solar energy generation requires land; and farmers own half of India's land. If they could use their land to grow solar power to irrigate their land as well as earn income by selling their surplus solar energy at a remunerative price, it can arguably incentivize water and energy conservation. In a pilot experiment in Dhundi, small villages in Gujarat, 11 farmers were provided SIPs to replace their diesel pumps at a capital cost of US $ 147,000 (INR 92, 00000). They were formed into a micro-grid managed by Dhundi Solar Pump Irrigators' Cooperative, the world's first such cooperative (Shah et al 2017b). The state electricity utility connected the cooperative to the 11 kV line, formally accepted it as an Independent Power Producer (IPP), and signed with it a 25-year power purchase contract at INR 4.63/kWh on pooled energy evacuation by the cooperative members metered at a single point. The only condition was that the cooperative members formally surrender their right to grid power connections for 25 years. Figure 4 presents the monthly results of the Dhundi cooperative for 45 months during which its members sold over 2,50,000 kWh of solar electricity and earned Rs 1.6 million as net income (Figure.1). Dhundi farmers used just about 35 percent of solar energy production for irrigation. Were they not paid for selling the energy, they would have surely used some or all of their solar energy production for irrigating more of their own fields and selling water to neighbours.

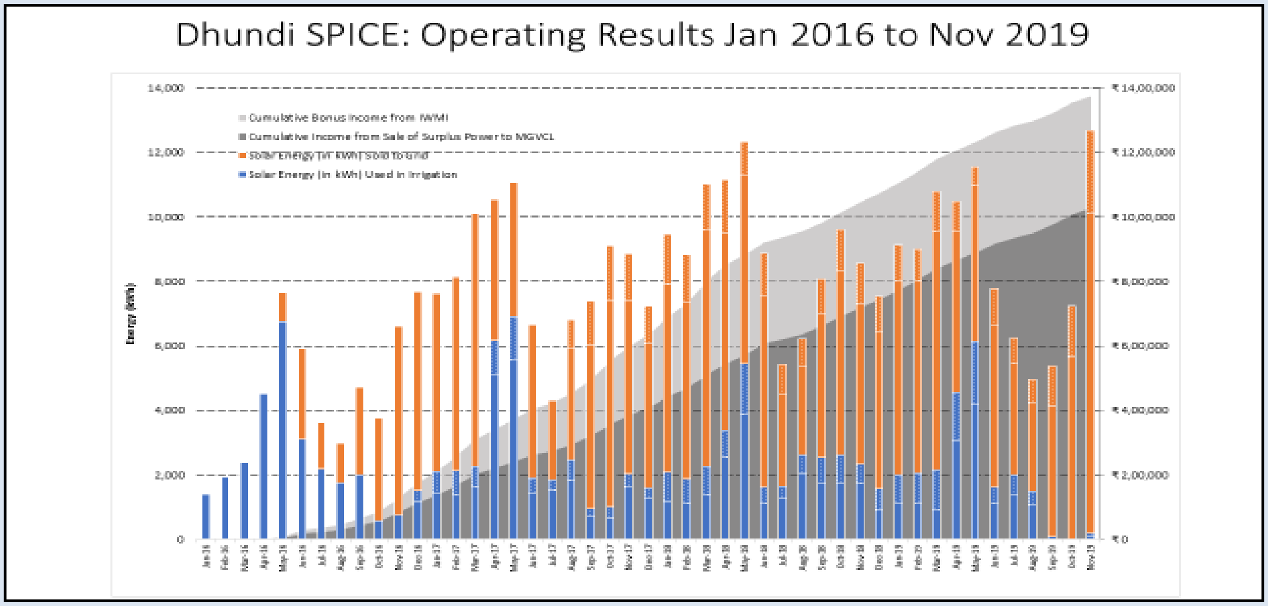

Figure 1: Dhundi SPICE operating results

By 2016, Dhundi cooperative had become a national media hit, with hundreds of farmers, electricity utility officials, politicians, and bureaucrats flocking there to see how marginal farmers made money by 'growing' and selling solar energy. A dozen stories about the 'Dhundi model' in national and state television news channels put its potential in bold relief. Electricity officials saw in it potential to reduce subsidy burden, achieve energy audit as well as curtail massive line losses in providing farmers grid power from generating stations hundreds of miles away. Environmentalists raved about clean and green irrigation with a reduced carbon footprint. Development professionals found here a way to put cash in the hands of the poor not as a giveaway but for valuable energy the economy needs. Farmers were happy because they got uninterrupted daytime power for irrigation, additional income for selling electricity, and could raise high-value shade-loving crops underneath the panels. All these years, farmers offered stiff resistance to metering tube wells; now they embraced meters since they got paid based on the metered evacuation of solar energy to the grid. Above all, political leaders saw in the Dhundi model an opportunity to create a new, benign WEF nexus while also reaping political dividends.

For the Energy Minister of Gujarat, who spent half a day interrogating members of Dhundi cooperative in late 2017, promoting solar power as a remunerative crop (SPARC), was an even better idea than Jyotigram for all concerned: electricity companies, farmers, groundwater as well as climate change, but above all for his politics. In 2018, the Gujarat government launched SKY (Surya Shakti KisanYojana), a large pilot scheme to replicate the Dhundi model on 12400 tube wells on 136 agricultural feeders in 33 districts at a total outlay of INR 7.8 billion. The basic Dhundi features that farmers generate their own power in situ and they get a 25year surplus power purchase guarantee at a remunerative price were the core of SKY. Other features changed somewhat. Instead of village-level micro-grid, SKY took a multi-village agricultural feeder as the unit of solarisation and mandated feeder-level management committees elected by SKY farmers. The financial model was different too. Farmers contribute 5 percent of the capital cost upfront. The balance is covered by 30 percent central government subsidy and 65 percent loan taken by the state government on behalf of the farmers. The solar energy purchase price—the so-called Feed-in Tariff (FiT)—offered too is higher than in Dhundi at INR 7/kWh. However, farmers get Rs 3.50/kWh in cash while the government retains Rs 3.50/kWh towards loan servicing. At least 70 percent of tubewell owners must join to enroll the feeder for SKY. The SKY feeder is to be kept live for 12 hours during the day (instead of 8 hours during day and night in alternative weeks that Gujarat farmers get). Each SKY tubewell is net-metered. A farmer can use a mobile app to monitor his daily power generation, consumption, and evacuation.

The SKY scheme is just a few months into implementation and not quite ready even for a preliminary assessment. However, electricity utilities can already see the benefits in terms of reduced line losses and subsidy saving. Farmers are happy too with day time uninterrupted power for longer hours. The litmus test, however, is energy use in pumping groundwater. The expectation is that solar farmers on SKY feeders will reduce pumping significantly to enhance their income from energy sales compared to grid-farmers on SKY feeders. Data on 59 completed SKY feeders between May 2019 and October 2019 show little difference: 2190 SKY farmers used an average of 246 kWh/HP for irrigation while 908 grid farmers on SKY feeders used 235 kWh/HP. With time and more rounds of payments for energy sales, there will be clear evidence to show whether or not SKY produces behavioral change among farmers. Because it has no losers, SKY is likely to get scaled out even faster than feeder-separation under Jyotigram; and to the extent, perverse incentives through power subsidies have fueled groundwater overdraft in India, SKY can reverse this trend by providing small farmers strong incentive to conserve water and energy.

SKY competes with another model of solar irrigation being implemented in Maharashtra. This model invites private investors to build tail end solar power plants (1-2 MWs in size) on government land to energize an entire separated agricultural feeder. The Utility offers investors Feed-in Tariff (FiT) on total generation, while farmers get free daytime solar power. Surplus power would flow back into the grid; and the deficit would be provided by the grid. This model, preferred by Utilities, will arguably offer them cost-savings, upscaling potential, and mobilize private capital in solarization. Its drawback is that farmers have no skin in the game; it provides no incentive for energy and water conservation to farmers who continue to get free daytime power for irrigation.
Given this background we conducted this study with flowing three specific objectives follow:

- To promote low carbon irrigation, which may assist in achieving India’s NDC targets through the adoption of solar water pumps
- To assess a viable state-level policy to incentivize both farmers and DISCOMs.
- To analyze market-based solutions that would facilitate effective implementation of irrigation policies.

Section 1 provides a detailed introduction of the study and specific research questions this study tries to answer in subsequent sections, the rest of the report is organized as follows. Section 2 provides details about our data-collection strategy and the methodological approach adopted for analysis. Sections 3 dwell on the financial models and also calculate the emission savings under different solar pump deployment scenarios. Section 4 reports the findings emerging from the qualitative and quantitative data gathered from the survey of farmers in Gujarat. Section 5 synthesizes the key findings emerging from the qualitative and quantitative analysis of primary data and secondary data. Section 5 provides the implementation pathways for scaling up the deployment of solar pumps. Section 6 lists the major policy recommendations for key stakeholders and policymakers.

2. Methodology

The study utilizes both qualitative and quantitative methods. While the qualitative methods involve stakeholder consultation, expert interviews, and group interviews of farmers, the quantitative method comprises data analysis using both primary as well as secondary data. To achieve the purpose of the study and aforementioned objectives, a framework comprising stakeholder consultations, district selection, survey designing followed by an appropriate analysis had been chosen (Figure 2).

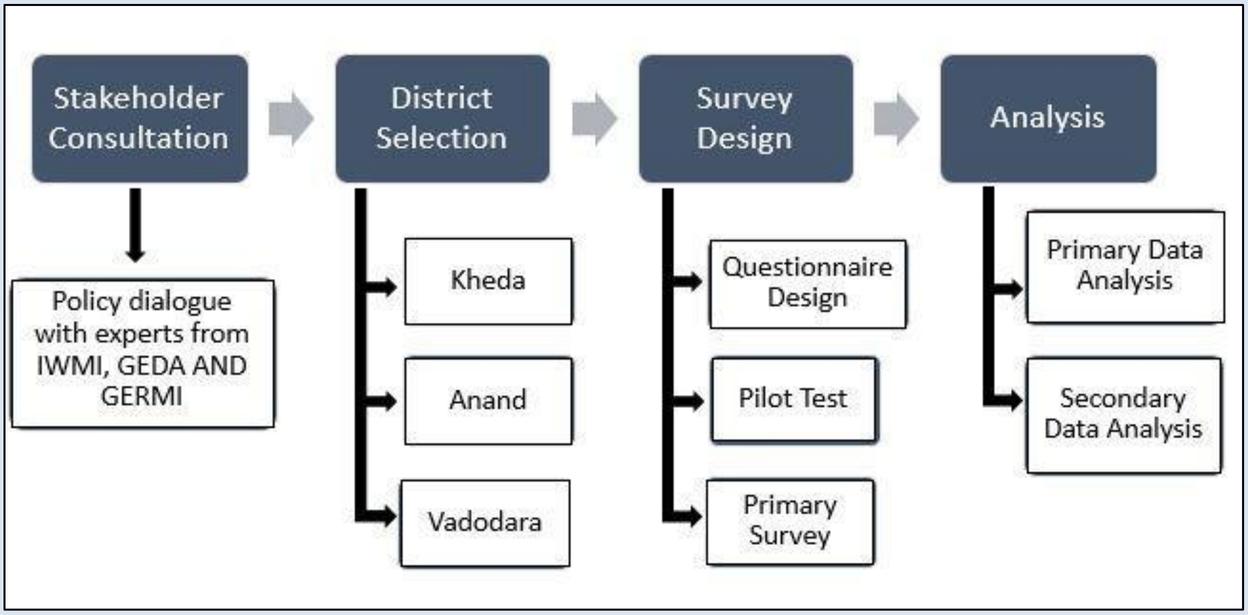

Figure 2: Research Design
Source: Created by IRADe

An inception meeting for stakeholders was organized on 5th March 2019 at Gandhinagar, Gujarat. The scope of the study was discussed at the inception meeting. The panelists for irrigation session from IWMI, GEDA, GERMI, and Central University of Gujarat, shared their valuable insights. Subsequently, the district wise long period average annual rainfall (in mm) from Rainfall Statistics of India - 2017 (IMD, 2017) was compiled to understand the groundwater recharge, as presented in Figure 3. From the list of the districts receiving an average annual rainfall of 800 mm and above, three districts were randomly selected for conducting farmer survey to understand their perception.

Randomly selected districts were Vadodara, Kheda, and Anand. GUVNL, MGVCL, and Dhundi Solar water cooperative were consulted (Dhundi Saur Urja Utpadak Sahakari Mandali or

DSUUSM) to prepare a list of SKY feeders in these three districts to carry out the farmer's survey. The SKY feeder becomes operational only if at least 70% of the agriculture consumers on that feeder agree for solarisation of water pumps. Therefore, it may be possible that in a SKY feeder up to 30% of agriculture consumers may continue with an old arrangement of grid electricity.

The questionnaire used for this study aimed to collect data on cropping patterns, pump types (diesel, electric and (or) solar), irrigation methods, costs, etc. In addition, data on electricity generation from SWPs and energy used for irrigation was also collected. All this would help in understanding the potential of solar water pumps and farmers' willingness to adopt the SWP.

A pilot survey was then conducted to improve our questionnaire. Post that, a CAPI based primary survey was conducted in districts of Kheda, Anand, and Vadodara. Respondents for this survey comprised of farmers having electric pumps or SWPs in a particular SKY feeder. The feeders surveyed during this study were as follows: Ojarada, Sandeshra, and Golaj feeder in district Kheda; Palaj and Ashapura feeder in district Anand; Padra I and Padra II feeder in district Vadodara.

In this study, we have analyzed the impact of farmers switching to SWPs under five different scenarios. We developed an economic model to calculate the annual cash flows for farmers, government, and DISCOMs. We discounted future cash flows and use the net present value (NPV) of cumulative cash flows. The model is an MS Excel-based spreadsheet tool designed to have the flexibility to analyze different scenarios. Each scenario analyzed the impact of replacing a fixed proportion of grid electricity supply to agriculture with solar electricity. Under each of these five scenarios, we have assessed the required solar PV capacity, energy generation, financial aspect as well as environmental impact.

The cost of power supply to the DISCOMs for agricultural connections is Rs. 6/unit while the average tariff charged is Rs. 0.60/unit (UGVCL, 2018). The difference between the price and cost was considered as the loss to the utilities. Therefore, the proportion of the electricity supplied to the agriculture sector through SWPs would imply a saving for the DISCOMs. This saving of Rs. 5.40/unit was used to estimate the subsidy savings of DISCOMs.

We have calculated the net return from the solar water systems under various subsidy scenarios and different tariff rates (by DISCOM as well as government) for selling energy to DISCOMS with reference to the current SKY scheme in Gujarat. This net return has been calculated for farmers, DISCOMS as well as the government under five different scenarios.

1. The government provides no subsidy on SWP but the farmers get a tariff rate of Rs. 3.5/ unit by DISCOMS and government support through the EBI incentive mentioned under the SKY scheme.
2. No capital subsidy as well as no EBI incentive of Rs. 3.5 /unit for the initial seven years by the government. The farmer only receives the tariff rate of Rs. 3.5/unit by the DISCOMS.
3. 30% capital subsidy with DISCOM tariff and government EBI support as per the rate under the SKY scheme.
4. 60% capital subsidy by the government along with DISCOM tariff and government EBI support as per the rate under the SKY scheme.
5. 15% capital subsidy with no government support but a tariff of Rs. 5.75 per kWh by the DISCOM.

Along with these, emission reduction from the use of SWP has been calculated for solar water pumps of varied capacities.

In the analysis, 5 sizes of solar water systems have been considered- 10.2kW, 12.6 kW, 15 kW, 20.1 kW, and 25.2 kW with solar modules of 10200 W, 12600 W, 15000 W, 20100 W, and 25200 W respectively. The cash flow from the project is considered for 25 years as mentioned in the SKY scheme. It has been assumed that for the first seven years, system maintenance costs for the farmers are negligible as system integrators would provide free maintenance under the installation contract. But after the 7th year of installation, every year farmers spend 15% of revenue as the maintenance cost under all five scenarios.

Table 1: SWP cost considered for IRR calculation

Module	Solar Pump - Cost (Rs.)	Solar pump effective cost under SKY with 30% subsidy (Rs.)
10.2 kW	4,89,600	3,42,720
12.6 kW	5,54,400	3,88,080
15 kW	6,60,000	4,62,000
20.1 kW	8,84,400	6,19,080
25.2 kW	11,08,800	7,76,160

Source: (GEDA, 2018)

To estimate the energy produced by a panel of different capacities, the formula given below in equation [1] has been used.

$$E = A * r * H * PR \text{ ....[1]}$$

Where,

E = Energy (kWh) produced by the panel

A = Total solar panel Area (meter^2)

r = solar panel yield or efficiency (%) considered as a constant 15 percent

H = Annual average irradiation on tilted panels (shadings not included).

To calculate "H" we have used average solar radiation received by Gujarat i.e. 5.6 kWh/ Sqm/day for 300 sunny days in a year.

PR = Performance ratio, to estimate the PR we have used coefficient for different types of losses which range between 0.9 and 0.5 and a default value = 0.75.

As per our calculations, 1 kW solar panel generates 1470 kWh. However, accounting for the losses depending on factors such as site, technology, and size of the system, the study took the performance ratio as 0.78. Hence, considering the transmission, invertors, and other losses, 1 kW solar panel generated 1149 kWh in our calculations (see Table 2).

Table 2: Losses details (depend on site, technology, and sizing of the system)

Types of losses	% Assumed
Inverter losses (6% to 15 %)	6
Temperature losses (5% to 15%)	8
DC cables losses (1 to 3 %)	2
AC cables losses (1 to 3 %)	2
Shadings 0 % to 40% (depends on the site)	3
Losses weak irradiation 3% to 7%	3
Losses due to dust, snow... (2%)	0
Other Losses	0

Source: IRADe's Analysis

The annual solar energy used for irrigation has been considered to be 40%[1] of the total energy generated by the panels. The effective price of using DISCOMs' electricity in agricultural connections is INR 0.60/kWh (UGVCL, 2018). This has been considered a positive cash flow from irrigating land using SWP. The surplus electricity available for sales to DISCOMs is considered to be the difference between total generation by a farmer and his consumption for irrigation. Depending on the DISCOM tariff and government support as per scenario, farmers' cash flow from selling energy back to the grid would be calculated. Present discounted value (PDV) of both the savings in irrigation cost and income from energy sales is calculated at a 6% rate of interest. Excess of this over the capital investment of farmers has been considered as the net return of farmers.

The DISCOMs benefits from subsidy savings have also been calculated. DISCOM's average cost of purchase of electricity is Rs. 3.5/ kWh while the average cost of supply is Rs. 6/kWh (UGVCL, 2018). State government subsidy to DISCOMs is twofold: 1) assistance to electricity board- a subsidy to GUVNL for Horse Power-based tariff on agriculturists, and 2) compensation in GERC Agricultural Tariff. As per tariff order 2017, subsidy to DISCOM on account of Horse Power Based tariff on Agriculturists was Rs.1100 crores and compensation in GERC tariff was Rs. 1206.75 crores. Considering the total electricity supply (unit) to agriculture in FY 2017 total government's subsidy to DISCOMs works out to be Rs.1.38/kWh. (Government of Gujarat, 2018)

Thus, net DISCOMs subsidy savings per unit electricity supply to agriculture is the difference between unrealized per unit cost of supply and per unit government subsidy which is Rs 4.02/kWh.

Moving on to the government whose savings would be subsidy provided to DISCOMs for providing a subsidized electricity supply to agriculture (Rs 1.38/kWh, as mentioned above). Net return for the government is considered to be the excess of PDV of subsidy savings over the capital cost subsidy on solar water systems by the government. Moreover, this financial analysis overlooks the fact that farmers put a very high premium on daytime, uninterrupted power Solar pumps offer. Assigning quantitative values to each component of this premium is cumbersome for example labour charges are generally high in the night than daytime. Figure 3 suggests the methodology for calculating net returns.

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[1] SPICE cooperative, Dhundhi data suggests that nearly 35% of solar energy, of the total generation, is used for irrigation. We have kept it slightly on the higher side (40%) for our analysis.

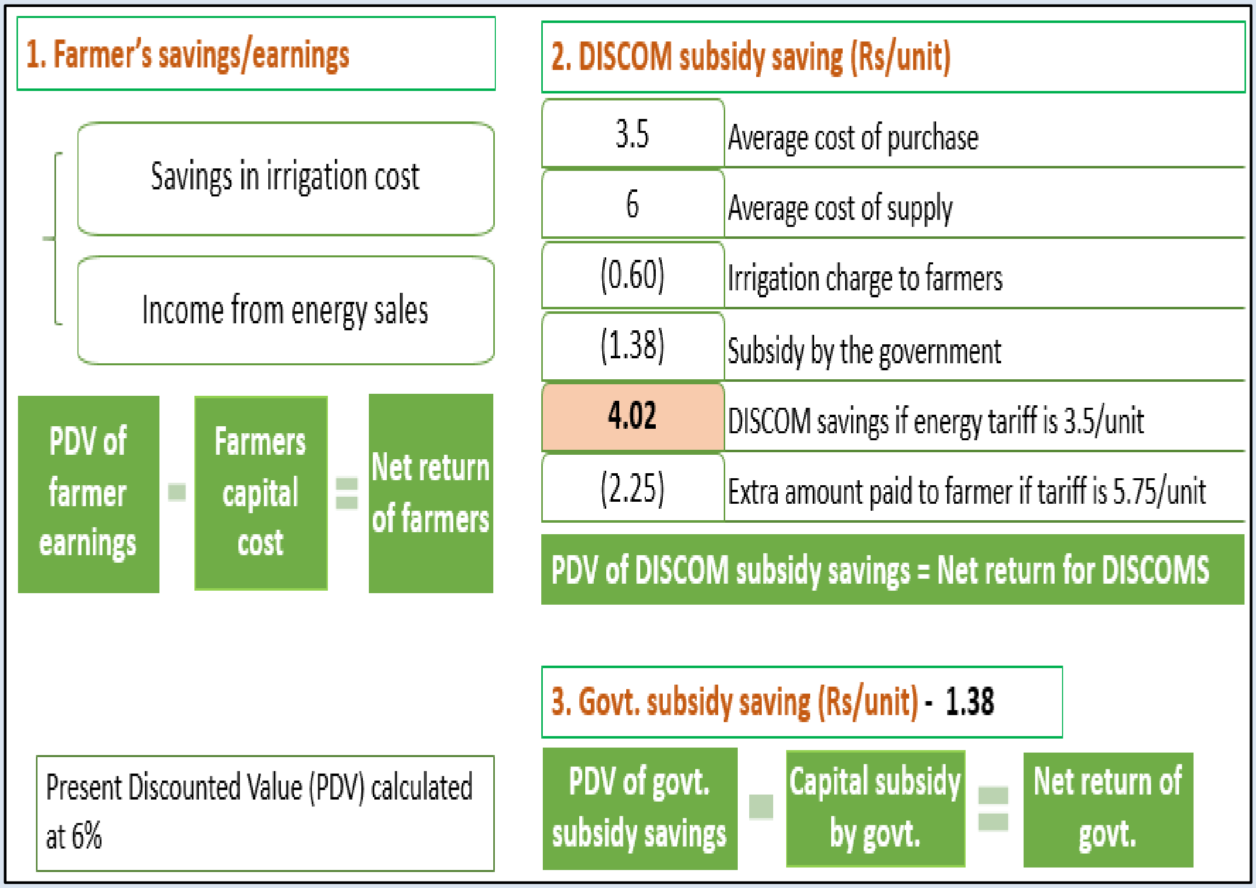

Figure 3: Method for calculating net returns
Source: IRADE's Analysis

3. Analysis and Results

3.1 Scenario analysis for SWPs adoption

In this section, the study analyses five scenarios under which a proportion of electricity consumed in the agriculture sector would be sourced from grid-connected solar PV irrigation systems. For all the five scenarios, subsidy savings by DISCOMs and emission reduction from the agriculture sector have been estimated. The solar panel load requirement for such a shift has also been calculated along with the required upfront capital cost.

3.1.1 Clean Energy Generation

As per CEA- Ministry of Power (2018), Gujarat DISCOMs supplied 16758GWh electricity to the agriculture sector in the year 2016-17. The five scenarios assumed for supplying electricity to agriculture sector through solar water systems are:

a) 10% of annual electricity supply for the agriculture sector
b) 20% of annual electricity supply for the agriculture sector, similarly
c) 25%,
d) 30% and
e) 35%

By using the estimate that 40% of the electricity generated by the solar water pump system is consumed for pumping water; surplus electricity availability for feed into the grid has also been calculated. Figure 4 below depicts the solar electricity consumption by the agriculture sector and the availability of surplus energy for the grid under these scenarios.

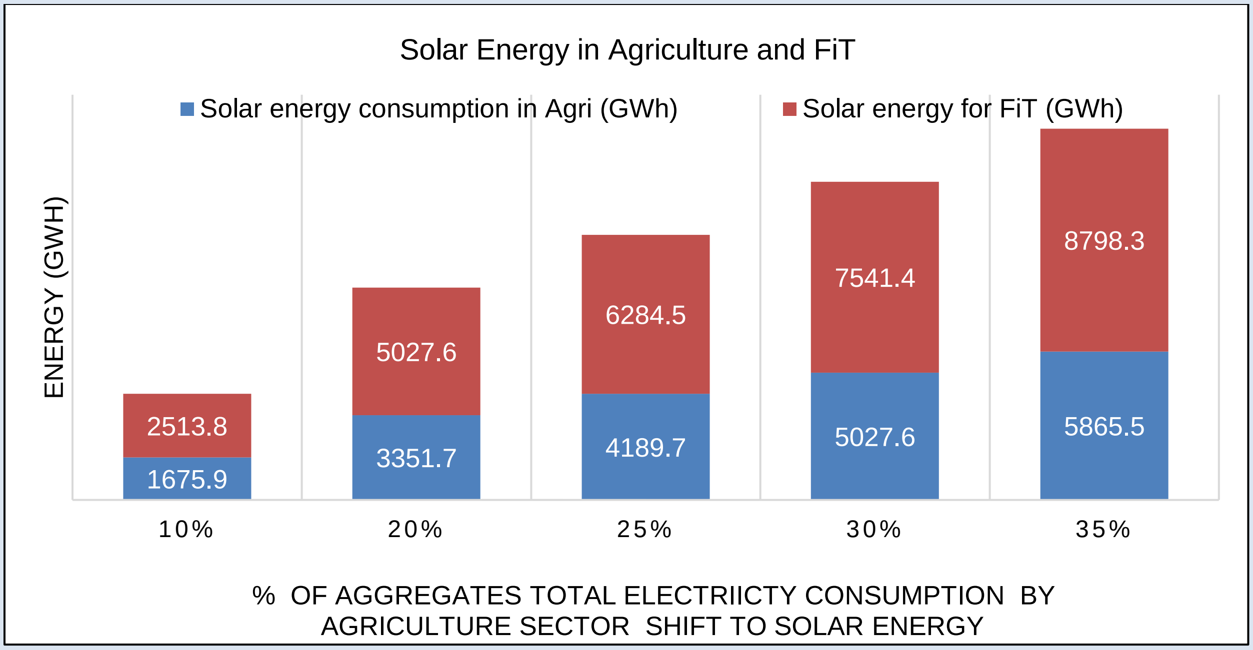

Figure 4: Solar energy used in agriculture and available for getting FIT (GWh)
Source: IRADe's analysis

Based on our calculation that on average 1 kW panel generates approximately 1149 kWh per annum, the solar PV panel capacity required for the energy generation under 5 scenarios was estimated. Figure 5 depicts the solar panel load requirement. Further, the upfront capital investment for the required panel at the panel installation cost of Rs 44000 per kW is calculated and showed in Figure 6.

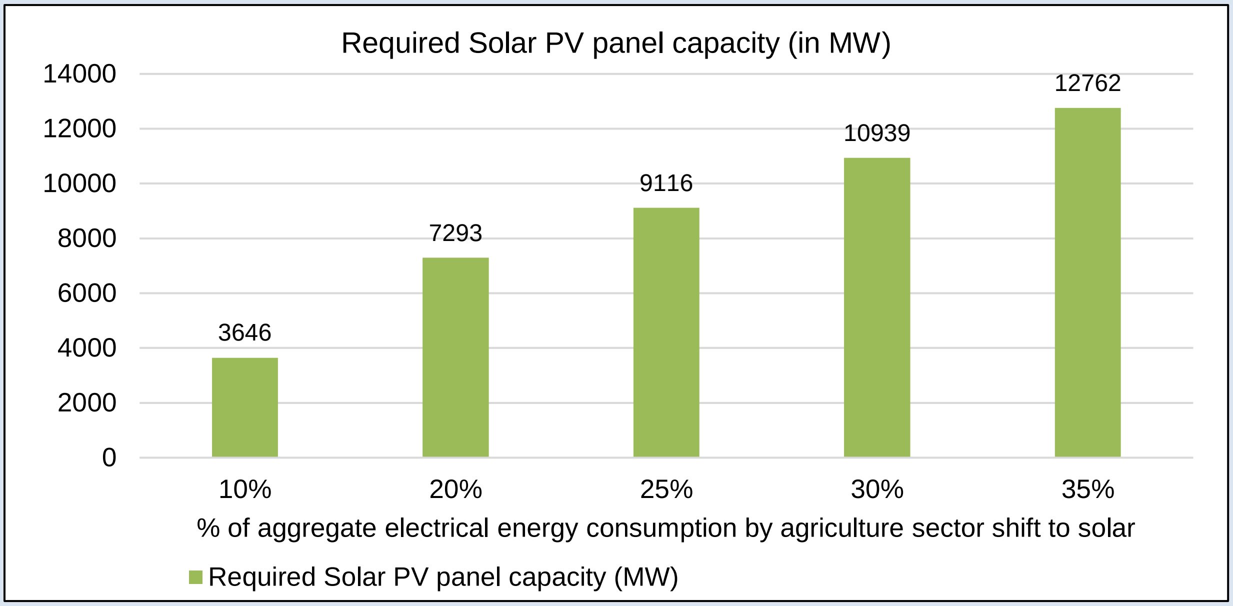

Figure 5: Required Solar PV panel capacity (MW)
Source: IRADe's analysis

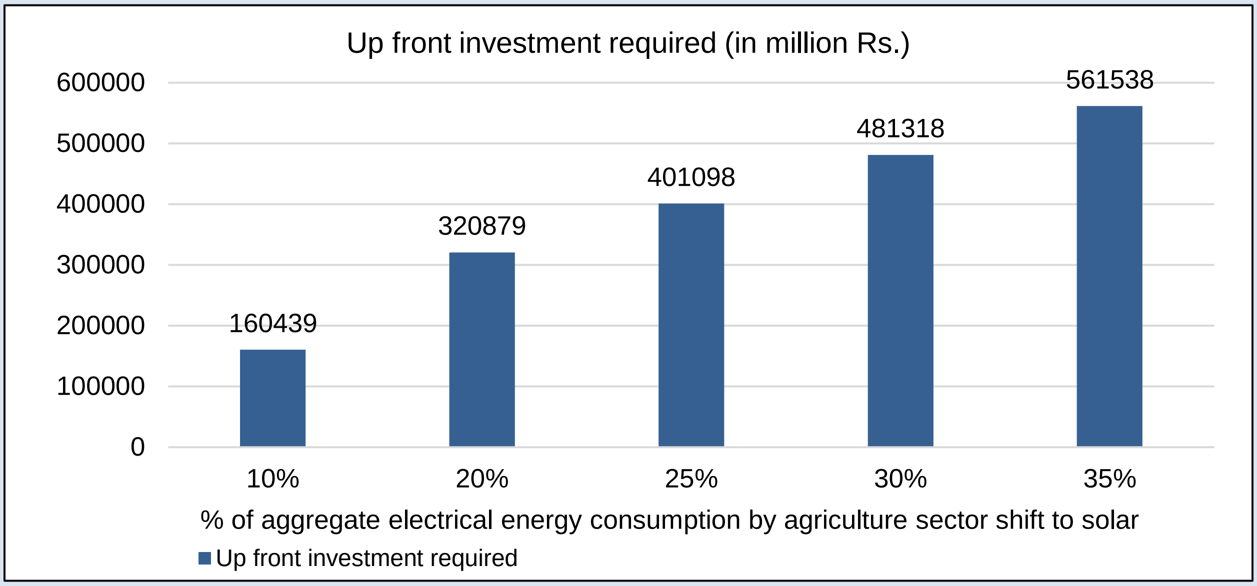

Figure 6: Upfront capital requirement for generating the solar PV capacity (in million Rs.)
Source: IRADe's analysis

3.1.2 Economic impact on DISCOMs

Figure 7 depicts the present discounted value of subsidy savings for 25 years for DISCOMs and state government with solarisation of the grid-connected electric pumps. The discounted value of subsidy saving by DISCOMs and government combined during the project lifecycle life term is more than 75 percent of the total required capital investment for the installation of a solar water pump system.

As per REC data at Indian Energy Exchange (IEX) simple average cleared price for monthly traded solar REC in January 2020 was Rs.2400/MWh. Considering this as a constant price for REC the discounted value of REC generated for 25 years for surplus electricity evacuated by DISCOM is shown in Figure 8.

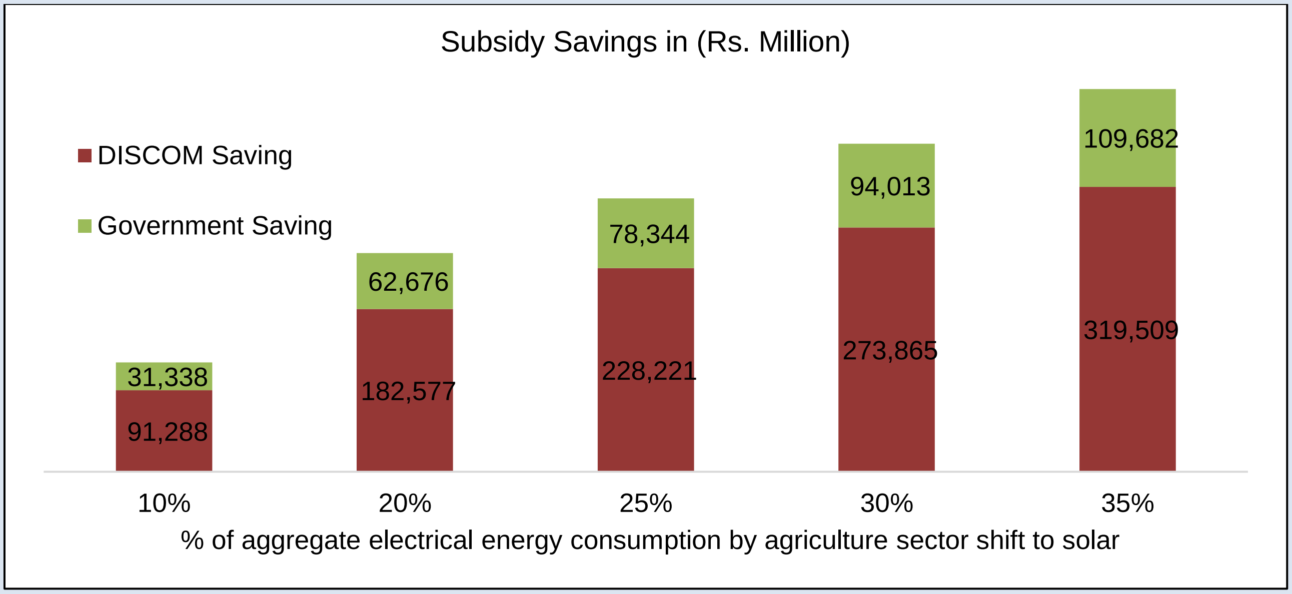

Figure 7: Subsidy savings in (Rs. Million)
Source: IRADe's analysis

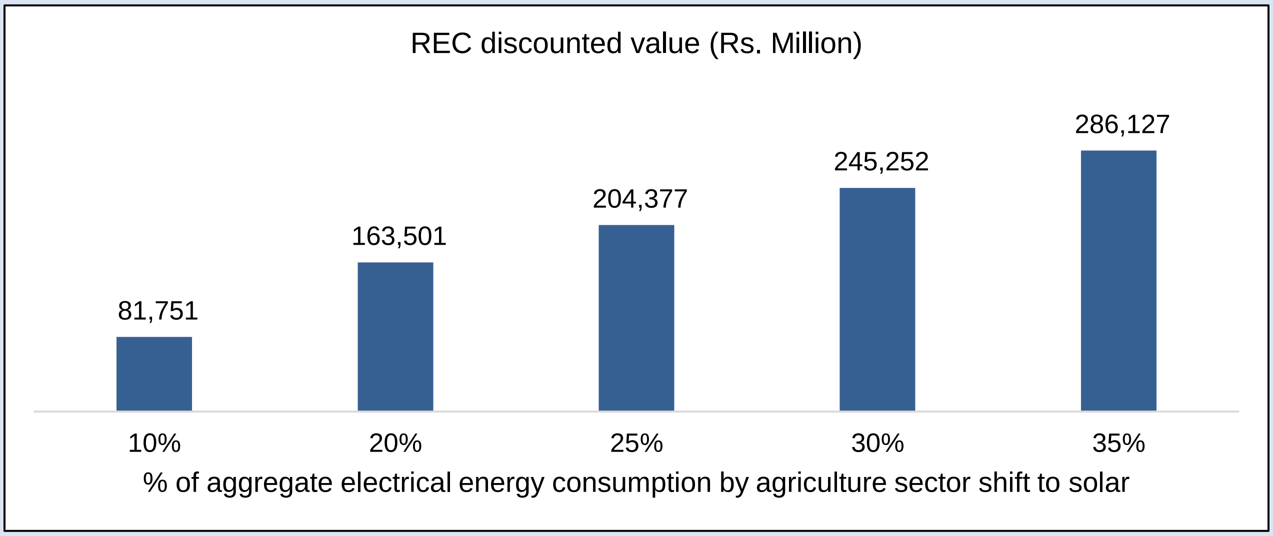

Figure 8: REC discounted value (Rs. Million)
Source: IRADe's analysis

3.1.3 Environmental impact

The shift in the source of energy from conventional to solar would result in emission savings. Under the mentioned scenarios, there would be two-fold emission savings: 1) emission reduction from irrigation energy use where SWP will replace fossil fuel-based grid electricity and 2) emission reduction from the use of the surplus energy generated by the systems and sold to DISCOMs at a pre-determined FiT. In Figure 9, emission savings per annum from both have been estimated using the Weighted Average Emission Rate of India to be 0.82 tCO2/MWh for 2013-14 (CEA-GoI, 2014).

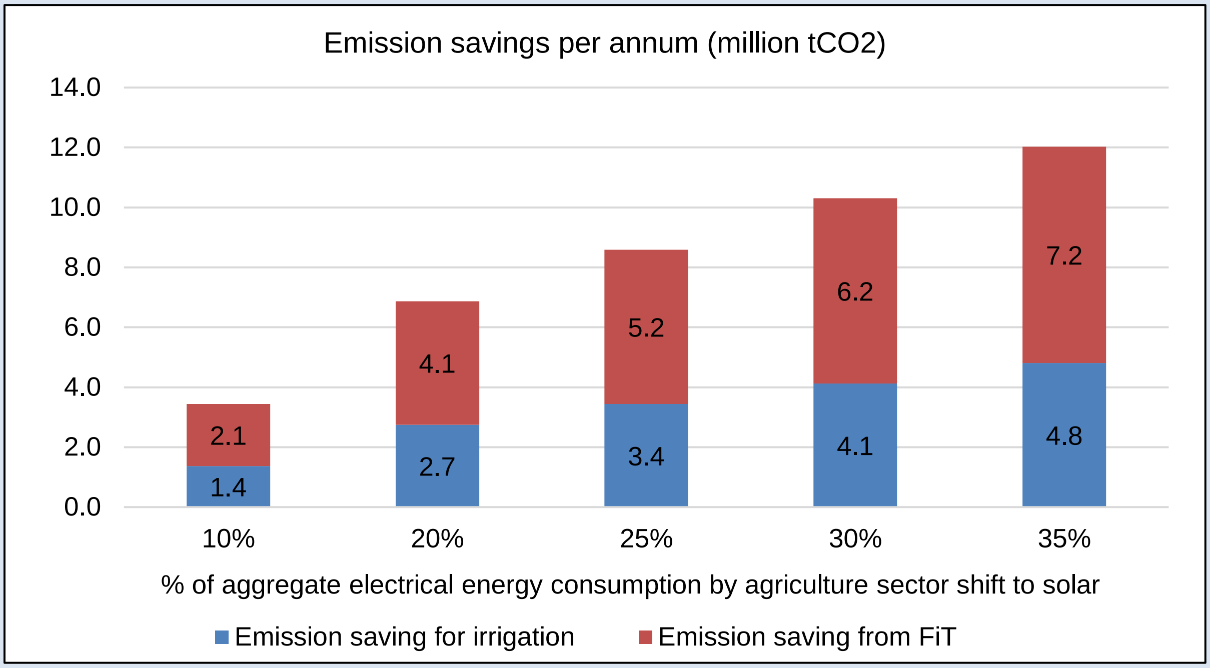

Figure 9: Emission savings per annum (million tCO_2)
Source: IRADe's analysis

3.2 The economic viability of grid-connected SWPs for farmers, DISCOMs and government under different financing mechanism

Figure 10 presents the schematic framework for grid-connected SWP and interlinkage among stakeholders involved. The study focuses more on the financial aspects of SWP adoption. The principal motivation is to understand GHG emission reduction potential, identify avenues for sustainable income for the farmers, and optimize the use of groundwater for irrigation.

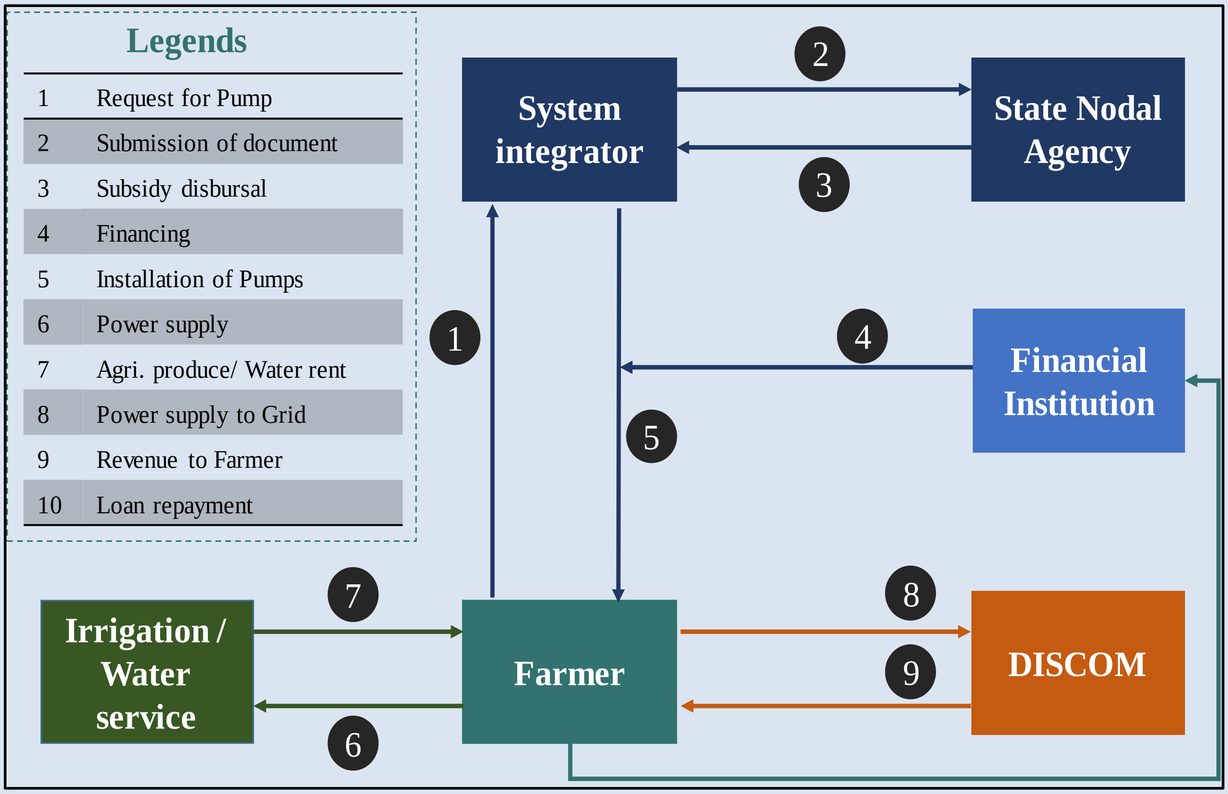

Figure 10: Schematic framework of grid-connected SWP
Source: Created by IRADe

Under this framework, customers (farmers) own and partially finance and manage the operation of the SWP system. The system integrator's role is limited to the installation of the SWP system and the provision of technical service in demand to the customer. The government representative, state nodal agency, facilitates the adoption of SWP by formulating suitable policy. The role of a financial institution (Scheduled Commercial Bank/Private financer/any other government-designated agency) would be to provide a part of initial capital for SWP purchase and installation. DISCOM plays an important role in providing SWP installation permits, evacuation of surplus electricity from SWP, payment for the same to the pump owners, and resolving technical issues related to electricity evacuation. The repayment of interest and capital to the financial institution remains a farmer's responsibility. A farmer may either use generated electricity for irrigation, selling water to irrigate fields, or supply it to DISCOMs.

As mentioned previously, five scenarios (see Table 3) for the financial evaluation of net returns from SWP among the three stakeholders have been considered. Scenario I (SI): Solar water system is bought at the market price (no subsidy). Scenario II (SII): Neither capital subsidy nor EBI tariff support by the government for the solar water system. Scenario III (SIII): Farmers receive a 30% capital subsidy on the solar water system. Scenario IV (SIV): Farmers receive a 60% capital subsidy on the solar water system. Scenario V (SV): Farmers receive 15% capital subsidy on SWP, no EBI tariff support of government but a tariff rate of Rs. 5.75 per kWh by DISCOMs. While the energy selling revenue under SI, SIII, and SIV follows the tariff schedule under SKY scheme i.e. Rs 7 per kWh for the first seven years (summation of DISCOM and government EBI support) and Rs 3.5 for subsequent years (DISCOM tariff), SII and SV do not receive the government support of Rs 3.5/kWh given for initial seven years. In SV's case, the DISCOM tariff rate has changed from Rs 3.5/kWh to Rs 5.75/kWh. Further, it has been assumed that after the 7th year of installation, every year farmers spend 15% of revenue as the maintenance cost under all five scenarios.

Table 3: Scenarios under which net returns have been calculated

Scenario (S)	Capital subsidy (%)	DISCOM tariff rate (Rs./unit)	Govt. support-EBI (Rs./unit)
I	0	3.5	3.5
II	0	3.5	0
III	30%	3.5	3.5
IV	60%	3.5	3.5
V (Proposed)	15%	5.75	0

Source: IRADe's Analysis

The net return has been shown only for a 15 kW system as our survey suggested that 15kW is the size of a solar water system in the majority under the SKY scheme. Thus, for illustration, Figure 11 depicts the net return for farmers, DISCOMS, and government for a 15 kW solar water system. The figure suggests that while one of the stakeholders is facing losses in scenarios I to IV, a win-win situation for all three stakeholders exist in the proposed scenario (Scenario-V). In Scenario-I, while the government suffers only a mild loss due to the government support on energy selling and no capital subsidy, farmers incur a negligible profit due to zero capital subsidy. The adoption of SWP would be challenging under such a model. In Scenario-II, removal of government tariff support has created huge losses for farmers worsening the conditions for the adoption of SWP. With 30% capital subsidy and EBI tariff support, the government faces huge losses in Scenario-III which increases in S-IV when capital subsidy increases to 60%. However, the adoption of SWP would be easier in S-III and S-IV, the government would be facing huge losses. Only S-V seems to be profitable to all the three stakeholders. With a 15% capital subsidy and tariff rate of Rs 5.75, the discounted payback period at a 6% interest rate came out to be 3.49

years for a 15 kW solar water system. Thus, adoption should not be very challenging under this proposed scenario as well.

Similar results (only proposed scenario profitable for all the three stakeholders) have been observed for other system sizes as well which has not been shown in the report to avoid repetition.

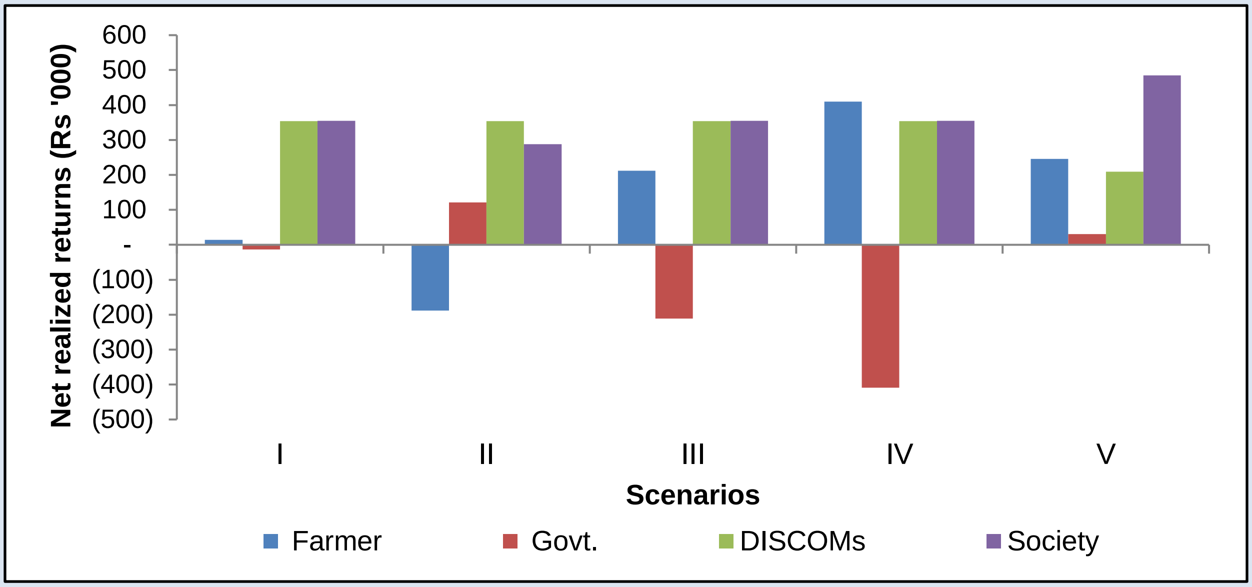

Figure 11: Net return for a 15 kW system among farmers, DISCOM, and government (in Rs.)
Source: IRADe's analysis

Further, the annual emission savings (t/CO_2) under the different solar pump capacities have been calculated as shown in Figure 12.

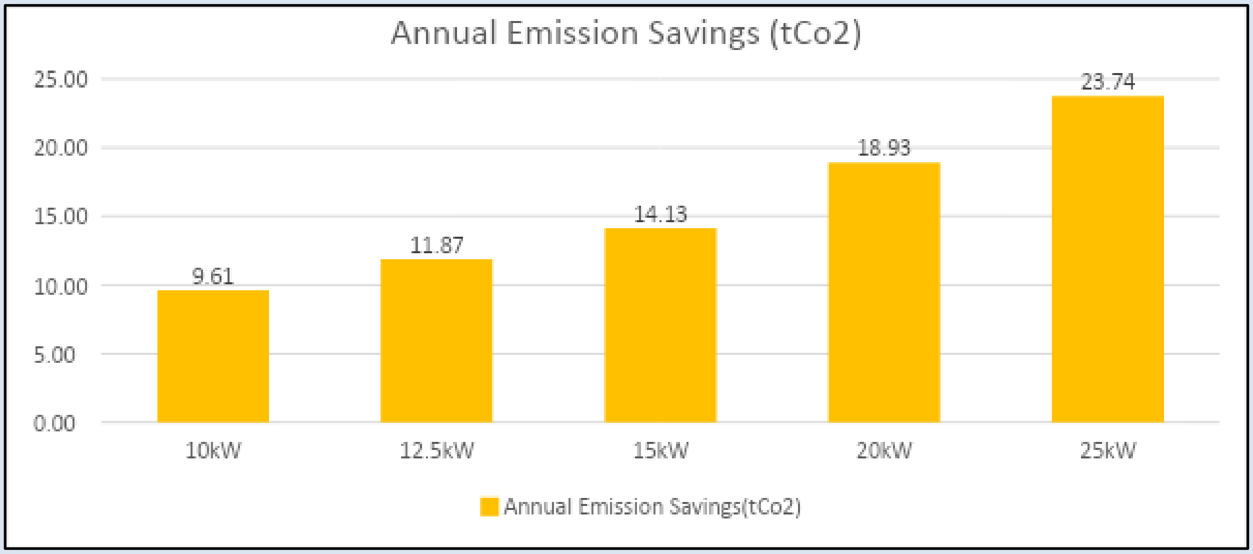

Figure 12: Annual Emission Savings under various solar module capacity
Source: IRADe's analysis

4. Findings from farmer's perception survey

4.1 Need for Solar irrigation system

Farmers in Gujarat mainly grow two crops in a year, one each during Rabi and Kharif (the two important cropping seasons) seasons. Cash crops such as cotton, castor are important crops grown during Kharif season while tobacco, Saunf, and potato are grown in the Rabi season. Figure 12 shows that small and marginal[2] farmers have a higher percentage of irrigated land to their total landholding size. The distribution of landholdings and the average size of operational holdings also indicates the financial wherewithal of the farmers and their willingness to adapt to expensive irrigation techniques. More than 25 percent of large farmers reported the use of drip irrigation facility whereas the share of drip irrigation among the small and marginal farmers was found to be merely 3 to 4 percent (see Figure 13).

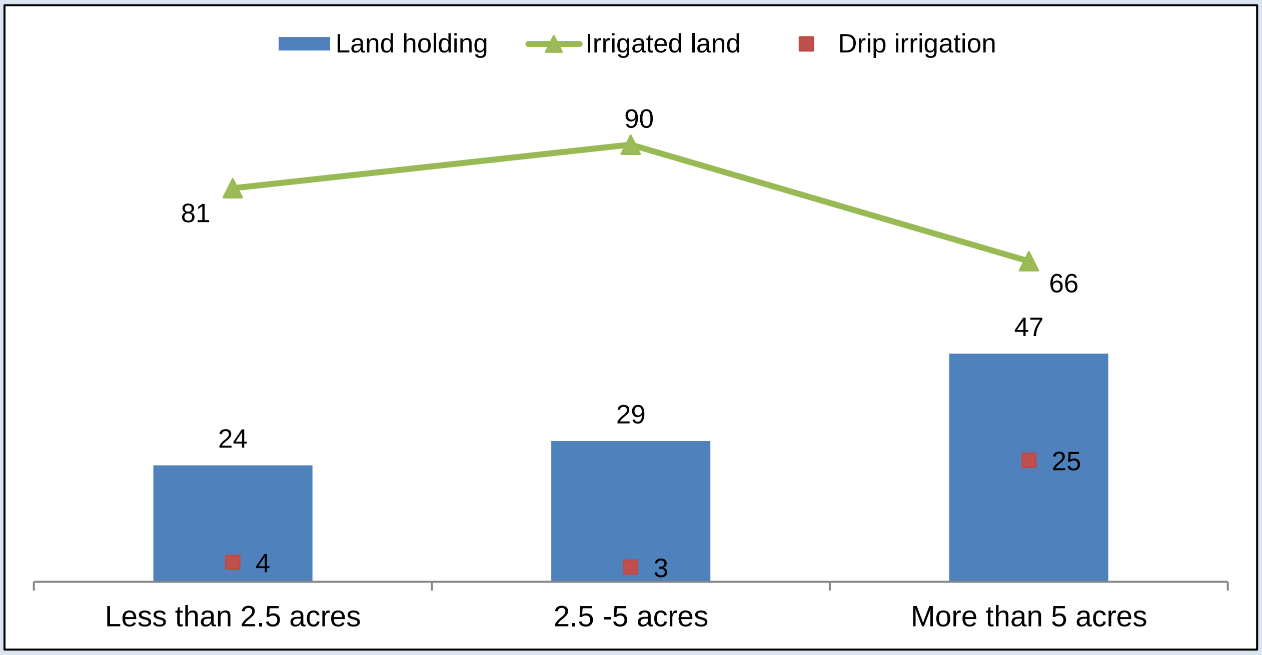

Figure 13: Operational and irrigated land holding distribution
Source: IRADe's analysis

Groundwater is the primary source of irrigation due to the unavailability of canal water irrigation, especially at the tail end. Farmers far from the canal system largely rely on groundwater. Owing

[2] 'Marginal farmer' means a farmer cultivating (as owner or tenant or sharecropper) agricultural land up to 1 hectare (2.5 acres). 'Small Farmer' means a farmer cultivating (as owner or tenant or sharecropper) agricultural land of more than 1 hectare and up to 2 hectares (5 acres). 'Large farmer' means a farmer cultivating (as owner or tenant or sharecropper) agricultural land of more than 2 hectares (more than 5 acres).

to the prevalence of groundwater irrigation, SWP can set off to be an environment-friendly and economical option for the farmer.

The overall cropping intensity for the surveyed farmer was found to be 162 percent. Small and marginal farmers have high cropping intensity (see Figure 14). Cropping intensity is the ratio of gross cropped area to the net sown area.

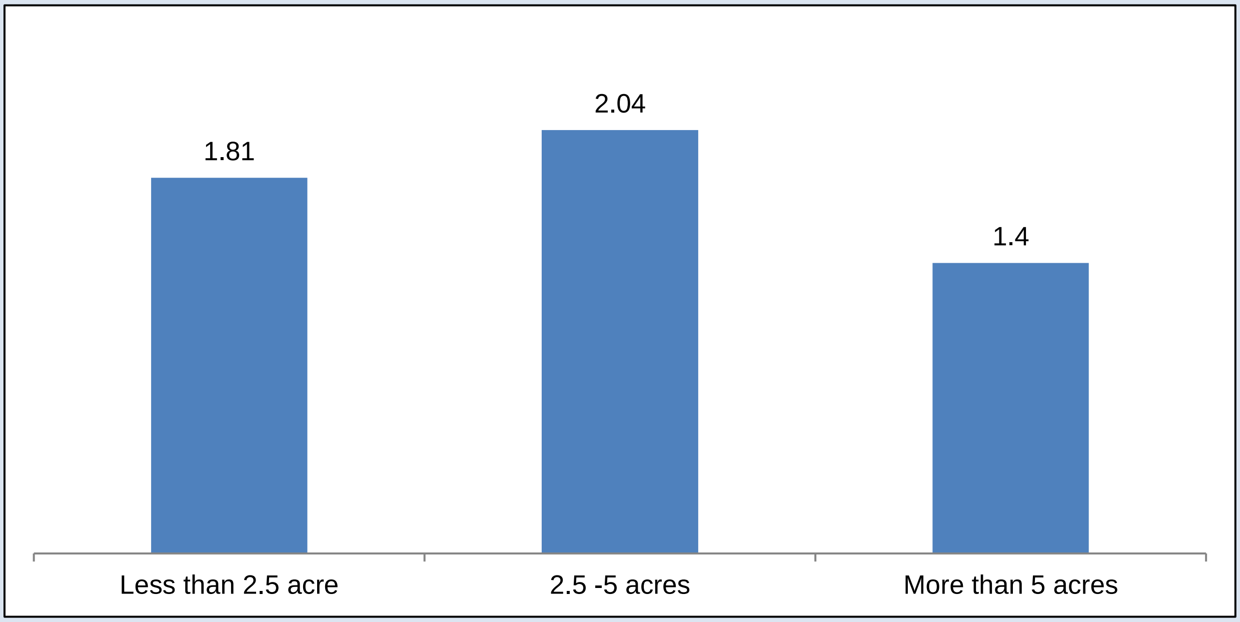

Figure 14: Cropping intensity by landholding type
Source: IRADe's analysis

4.2 Decentralized surplus power available for DISCOM

The study followed a purposive sampling technique. The survey was conducted only in areas, which had solarized feeders under the SKY scheme, 87 farmers in a sample of 102 farmers, owned SWPs. The distribution of SWP installed capacity is shown in Figure 15. Merely 10 percent of farmers own the SWP with less than 10 kW of generation capacity[3], 10-15 kW, and 15-25 kW are the preferred SWP solar capacity installed by the majority of farmers. The net metering facility is used by the DISCOMs to measure the surplus energy sold by farmers. Figure 16 presents the generation and consumption of electricity by solar panel load capacity since the time of system installation.

[3] To calculate the SWP generation capacity for each farmer we had taken count of the number of solar panels installed by each farmer and multiplied it by an average generation capacity (considered as 315 KW per panel). Under the SKY scheme, the generation capacity of a solar panel varies between 310 KW to 330 KW per panel

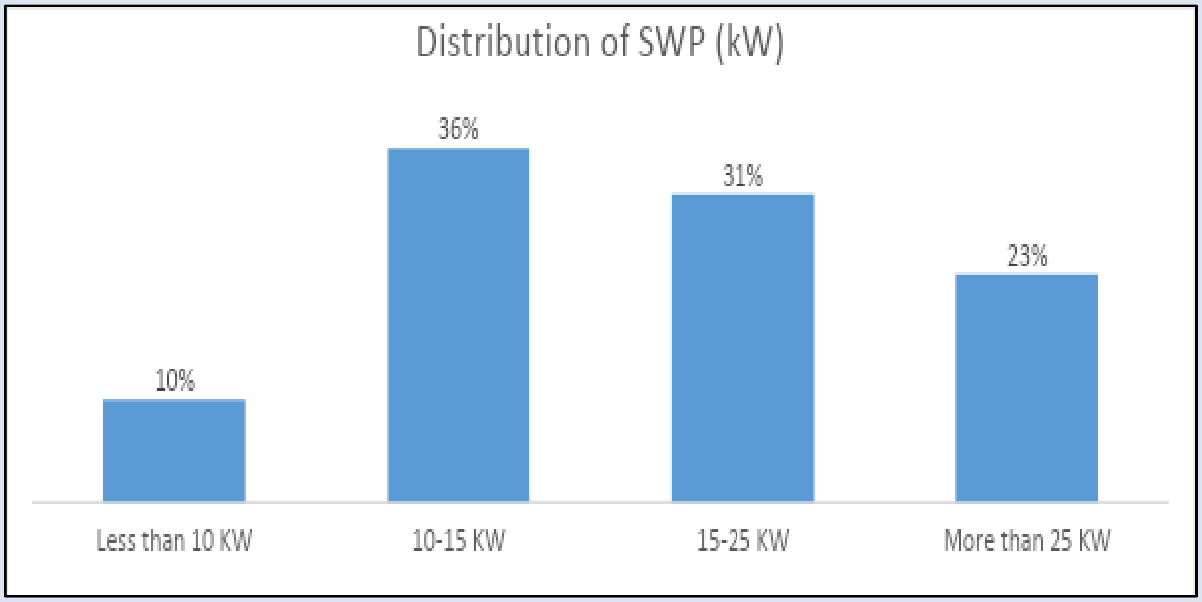

Figure 15: Distribution of Solar pump set
Source: IRADe's analysis

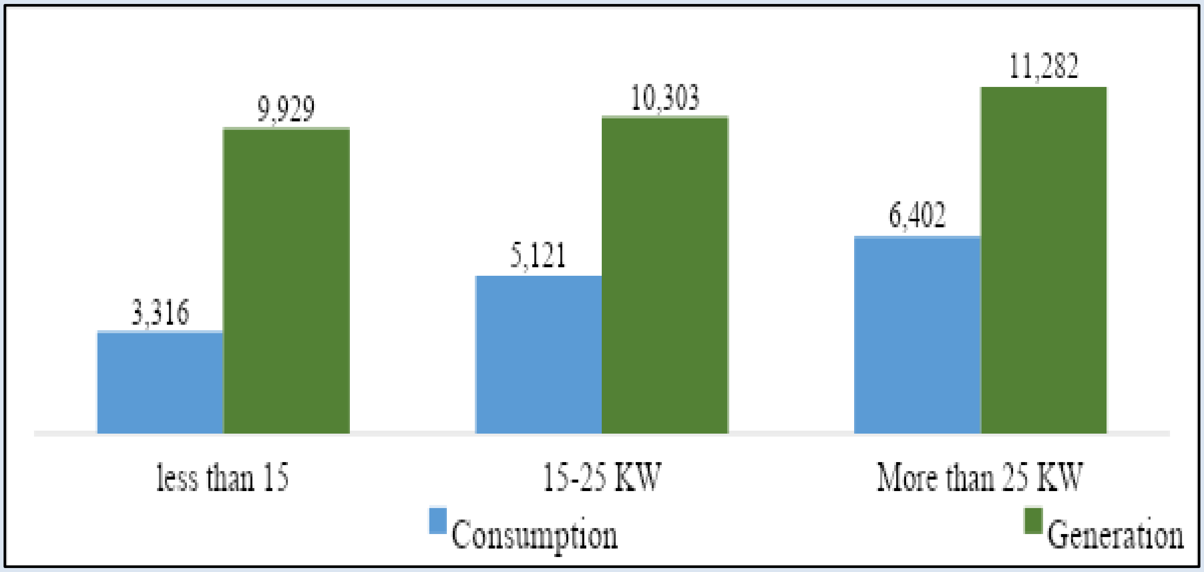

Figure 16: SWP set energy generation and consumption (kWh) across farmer groups
Source: IRADe's analysis

4.3 Qualitative findings

It has been observed that farmers in Gujarat were satisfied and pleased with the concept of the state's solar irrigation policy. SKY proved to be a reliable source of twelve hours of electricity throughout the day sparing the farmers, the pain, and danger associated with visiting the fields at night. However, problems were observed in a few feeders with respect to the implementation of the policy (see Box 1).

Moreover, it was observed that requisite training[4] programme to understand the working of solar PV water pumping system with the net metering facility was inadequate or completely missing in some areas. In our survey, we found that only 45 percent of the farmers reported receiving basic training of operating SWP with less awareness about the quantum of electricity generated and supplied to the feeder. On the other hand, farmers who had undergone training reported it to be very useful in running the SWP system.

It was noticed that farmers with farmlands at a significant distance from their house remain unaware of any system breakdown leading to disruption of electricity supply to the grid for many days. Citing this reason, many farmers requested for an arrangement to get digital updates about the energy generated and supplied to the feeder on a real-time basis, as in the case of the rooftop solar program in Gujarat.

Farmers using SWP reported an increase in the area under irrigation owing to reliable energy supply. Many of them reported that they are sensitive towards the amount of water used for irrigation and are aware of the depleting groundwater table in their area.
Largely, all the sample farmers realized the economic benefits from the SKY scheme but reported that they would be unwilling to purchase it at the market price mainly due to the high upfront cost required for unsubsidized SWP. Further, they suggested that the operational and implementation issues are a major deterrent to the success of the scheme.

BOX 1: **Implementation problems in SKY**

In the Ujarala feeder of the Kheda district, farmers faced serious inconvenience owing to the non-fulfillment of promises made by the system manufacturer and integrator. The farmers complained of substandard material, usage of iron instead of aluminum (see Figure 1), and faulty structure (inappropriate thickness of the panel and its angle, the improper layout of the foundation) and machinery. These issues raise concerns about proper monitoring and invigilation of the vendors who are given the tender of setting up the system.

The farmers in another feeder Sandesra shed light on the frequent malfunctioning of jumpers and transformers for long durations alongside praising their system manufacturer and integrator for good quality material supply. They stated that the lack of technical

[4] understanding the energy units sold and (or) used.

5. Key Findings

The primary survey along with interviews of stakeholders-farmers who adopted SKY and DISCOM officials involved in the solarization of grids suggest that the SKY scheme has been perceived well by the majority. Farmers who have not been a part of the scheme so far are also willing to come on board.

The net return analysis suggests that out of the five scenarios, only the proposed scenarios (SV) with a 15% capital subsidy and a tariff rate of Rs 5.75 provide a win-win situation for all three stakeholders- farmers, DISCOMs and government. The discounted payback period at a 6% interest rate is only 3.49 years for a 15 kW solar water system under SV, suggesting its feasibility.

Our analysis encompassing economic sustainability of solar water system models under varied financing mechanisms in the context of institutional regulations and policy indicates that there is a strong possibility that SWP would become an inevitable and significant component of the electricity sector, especially if the technical improvements in future would sort out the difficulties in integration. Further, the annual emission savings (t/CO_2) calculated under the different solar pump capacities range from 9.61 tCO_2 for a 10 kW system to 23.71 tCO_2 for a 25 kW solar pump system (see Figure 12).

Thus, the financial viability analysis, estimation of emission savings, and net returns to the farmers, DISCOMs, and government (as discussed in section 3) suggests that SWP is a beneficial proposition for all the stakeholders – government, farmers, DISCOMs and environment. Though, the magnitude of benefits would vary as per the capital subsidy and tariff scheme.

However, several areas of caution mainly technical have been raised during the primary survey in the implementation of the SKY scheme. While the feeder under the Jyotigram Yojana had received new transformers and is maintained well, the existing feeders getting solarized under the SKY scheme are the much-neglected old lines with frequent high voltage issues and jumper problems. Moreover, these lines are long and scattered incurring a greater time of repair in case of breakdown. In such a case, if a fault occurs at a point, all the subsequent users would not be able to send energy back to the feeder suffering losses. Further, it was identified that the voltage problems are the result of unawareness/ obliviousness of the operators handling it. The supply of substandard material, incomplete foundation and other resources by the service provider as mentioned in Box 1 raised the concern of inadequate manpower for monitoring the implementation.

6. Implementation Pathway

Grid-connected solar irrigation may become a major positive disruption yet to happen in India. It holds immense potential to achieve saving electricity, saving water and augmenting farmer income as the direct benefits and emission saving as positive externalities. Recognizing the opportunity Gujarat state government launched the SKY scheme. The scheme tries to address multiple issues such as augmenting farmers' income, reducing recurrent subsidy outflow on electricity to agriculture, increasing the share of green energy in the agriculture sector, and many more. But feeder-level solarization of irrigation has many cost attached to it. Even though the SKY is in the early stages it may provide many useful lessons to improve the business models for accelerating the use of solar in agriculture in the country. From our study limited in scope we put forward followings points that need to be taken care of to optimize on our limited government resource at the same time maximize the benefits to all the stakeholders.

- **Rationalizing scheme subsidy outlay**: As per the scheme provision, 1.25times of the contracted load of the pump set in HP equivalent Solar PV system in kW shall be installed for each participating farmer. To reap higher benefits, farmers may get encouraged to increase their contracted load before applying under the SKY scheme. Therefore, to minimize subsidy leakages through such practices we recommend that the SKY scheme should consider providing a 1.25 kW PV system of the average contracted load of last 2-3 years. In addition, there should be a cap in the form of kW of load which will be eligible for subsidy under the scheme. Else we may have progressive subsidy rate (reducing subsidy rate) for each additional kW solar PV system installed beyond a floor capacity set for each geographical location based on the groundwater level condition in the location.

- **Electricity supply to the farmer**: On any SKY feeder, day time power supply should be restricted to 8 hours as for other feeders, and not 12 hours to have power supply period matching with solar energy generation Moreover, 8 hours of electricity supply is sufficient to meet the agriculture needs.

- **Electricity tariff rationalization**: GERC should be persuaded to notify that SKY farmers using more grid energy for irrigation than the solar energy they generate will have to pay the FiT for excess energy consumption on a monthly or bi-monthly basis.

7. Policy Recommendations

A well-designed policy can generate significant environmental social and economic benefits, which outweigh the costs of implementation and contribute to social well-being. The financial considerations for government-supported schemes are of utmost importance for a resource-constrained economy. At the same time other considerations, such as sustainability, environment, the pace of scaling out, minimizing inclusion and exclusion error, etc. should also is important.

Replacing diesel and electric water pumps with solar pumps will provide cheap and reliable energy for farmers to run a water pump during the daytime. This may have potentially adverse impacts on groundwater, scaling up of heavily subsidized schemes to large beneficiaries, the possibility of elite capture the heavily subsidized scheme, and exclusion of the poor. The probable business model and its implication for the stakeholders are discussed below.

- **No capital subsidy, no energy buy-back**: this would have slow uptake of solar pumps, subsidy bill for grid power will continue to be high; solar farmers will be under pressure to recover investment by selling water, and only resource-rich farmers will go solar. This option will take off only if grid power subsidies are abolished or grid power supply is allowed to deteriorate so much that farmers begin to look for the solar alternative as solar would be commercially cheaper than other available alternative diesel. But this will have a very high political cost.

- **95 percent capital cost subsidy, no buyback:** uptake will be fast; grid subsidy bill will come down to the extent that solar pumps are given in lieu of grid-connected pumps; pressure on groundwater will be high; rich and poor both will solarize unless the policy suffers elite capture.

- **60 percent capital subsidy and electricity buy-back at Rs 3.5**: uptake will be fast; grid power subsidy will decline over time; the scheme will moderately incentivize energy-water conservation; the water market would harden somewhat; rich and poor both will participate.

- **15 percent capital subsidy and buy back at Rs 5.75/kWh for 25 years**: this will be very good for groundwater conservation; it will also be very good for DISCOMs and government since the payout is spread over a long period and inflation will moderate it as years go by. However, the uptake will be slow because most small farmers will find it hard to invest Rs 3.5 lakh upfront for a 10 kWp solar tubewell. So the poor will tend to be hit both ways: tubewell owner small farmers will find it hard to solarise; and water buyers will have to pay a much higher water price. The pro-poor impact of this option will be strengthened by: [a] offering a priority sector loan to small farmers to solarize; and/or [b] provide higher capital cost subsidy (say 25%) to smaller than 7.5 HP tube wells. This can help realize the Government of India's objective of doubling farm incomes: after all, paying farmers a decent price for the energy they produce is a better way of increasing their incomes than providing doles under PM Kisan Yojana.

To implement the above-suggested business models there are some other related aspects to it that need to be taken care of for smooth implementation.

- SWPs' impact on groundwater needs to be monitored. With the increase in electricity access through SWPs, there has been an increase in water access as well. This creates a need for monitoring groundwater overuse. The policy should be implemented in a way to encourage prudential use of water. To this aspect, paying farmers for energy not used for pumping groundwater is a good way of incentivizing groundwater conservation. The high opportunity cost for using electricity for irrigation would persuade them to optimize water use and motivate them to use micro-irrigation techniques.
- To ensure regular and smooth payments to farmers, a formal Payment Security Mechanism should be set up. It was observed during the field visit that the payments to farmers by the DISCOMs had not started even after three months while they were being regularly charged for the fixed cost for the electricity connection. While the farmers had complained multiple times, no solution had emerged till survey dates.
  - Further, there exists a need to provide adequate training to the farmers. While operating SWPs is easy, understanding the energy trade with DISCOM requires some training in operating the meter.
  - Adequate resource for monitoring of each feeder in order for it to work as an express feeder should be provisioned by MGVCL. Agencies implementing SKY need to increase their manpower dedicated to addressing complaints within a short span.
  - Gujarat Energy Transmission Corporation (GETCO) operators need to be educated about the concerns with voltage shifts. Improving the infrastructure and educating the GETCO operators would assist in reducing frequent breakdowns.

- Prior to solarisation of the grid under SKY, maintaining and refurbishment of old lines is a necessity. If not, the problems such as power interruption, failure of inverters would persist. This would lead to losses both for DISCOM and farmers. Further, two subdivisions should not be combined together even if the population in each is low because a breakdown in one subdivision affects the working in another also.

- Similar to the facility in the solar rooftop scheme, farmers under the SKY should be given a facility to digitally keep a tab on the energy generation and use it on a real-time basis. This is of utmost importance to farmers whose farms lie at a significant distance from their houses. This would also inform them about the breakdowns especially in monsoons when they rarely visit fields.
- The maintenance (wear and tear cost) of the systems should be borne by the system manufacturer and integrator for an initial period of time. This would ensure quality equipment supply and infrastructure foundation by them which was missing in some areas as observed in the survey.

References

- Government of Gujarat. (2018). BUDGET ESTIMATES OF ENERGY AND PETROCHEMICALS DEPARTMENT FOR 2018-19. Retrieved from www.gujarat.gov.in: https://financedepartment.gujarat.gov.in/Documents/Bud-Eng_760_2018-2-20_884.pdf
- CEA- Ministry of Power. (2018). General Review 2018, All India Electricity Statistics. New Delhi: Government of India.
- CEA-GoI. (2014). CO2 Baseline Database CO2 Baseline Database- User Guide. New Delhi: Central Electricity Authority, Ministry of Power, GoI. Retrieved from http://cea.nic.in/reports/others/thermal/tpece/cdm_co2/user_guide_ver10.pdf
- CGWB. (2016). Groundwater Year Book – 2015 -16, Gujarat state, and UT of Daman & Diu. Central Ground Water Board, Ministry of Water Resources, River Development, and Ganga Rejuvenation.
- Eshita Gupta (2017) Extending Solar Water Pump Subsidies: Impact on Water use, Energy use and Cropping Patterns in Rajasthan: Difference in Differences Analysis, Working Paper, SANDEE, September 4, 2017
- GEDA. (2018). Salient Features of the scheme for Residential Rooftop Solar Projects – 2018 -19. Gujarat Energy Development Agency. Retrieved from https://geda.gujarat.gov.in/Gallery/Media_Gallery/Salient_features_of_the_Rooftop_Project_819.pdf
- GoI. (2017). 5th Census of Minor Irrigation Schemes. Minor Irrigation-Statistics Wing, Ministry Of Water Resources, River Development, and Ganga Rejuvenation.
- IMD. (2017). RAINFALL STATISTICS OF INDIA - 2017. India Meteorological Department.
- Kishore, A., Shah, and Tewari, N.P. 2014. Solar irrigation pumps: Farmers' experience and state policy in Rajasthan. Economic and Political Weekly, 49(10): 55-62.
- MNRE. (2019, July 22). KUSUM Guidelines. Retrieved from mnre.gov.in: https://mnre.gov.in/sites/default/files/webform/notices/KUSUMguidelines.pdf
- MoSPI. (2018). Statistical Yearbook India 2018. Ministry of Statistics and Programme Implementation. Government of India. Retrieved from http://mospi.nic.in/statistical-year-book-india/2018/177
- Neilsen. (2013). All India Study on Sectoral Demand of Diesel & Petrol. Petroleum Planning and Analysis Cell, Ministry of Petroleum, and Natural Gas.
- Sahasranaman, M., Kumar, M. D., Bassi, N., Singh, M., & Ganguly, A. (2018). Solar Irrigation Cooperatives Creating the Frankenstein's Monster for India's Groundwater. Economic and

Political Weekly, 53(21). Retrieved from https://www.epw.in/journal/2018/21/special-articles/solar-irrigation-cooperatives.html

- Shah, T. 2009. Taming the Anarchy? Groundwater Governance in South Asia, Washington D.C.: RFF Press.
- Shah, T., and Chowdhury, S. D. 2017. Farm Power Policies and Groundwater Markets: Contrasting Gujarat with West Bengal (1990-2015). Economic and Political Weekly, 52(25-26): 39-47
- Shah, T., and Verma, S. 2008. Co-management of Electricity and Groundwater: An Assessment of Gujarat's JyotirgramScheme. Economic and Political Weekly, Vol.43(7): 59-66
- Shah, T., Bhatt, S., Shah, R.K., and Talati, J. 2008. Groundwater Governance through Electricity Supply Management: Assessing an Innovative Intervention in Gujarat, western India. Agricultural Water Management 95(11):1233-1242'
- Shah, T., Durga, N., Rai, G.P., Verma, S., and Rathod, R. 2017. "Promoting Solar Power as a Remunerative Crop". Economic & Political Weekly, 52(45): 14-19
- Shah, T., Rajan, A., Rai, G.P., Verma, S., and Durga, N. 2018. Solar Pumps and South Asia's Energy-Groundwater Nexus: Exploring Implications and Reimagining Its Future. Environmental Research Letters Journal 13(2018) 115003 https://doi.org/10.1088/1748-9326/aae53f
- Shahidi, T., & Jain, A. (2018). Adopting Solar for Irrigation: Farmers' Perspectives from Uttar Pradesh. Council for Energy, Environment, and Water (CEEW). Retrieved from http://www.ceew.in/sites/default/files/CEEW-Adopting-Solar-for-Irrigation-Farmers-Perspectives-from-UP-Report-17Jan18.pdf
- UGVCL. (2018, June 19). Petition for SKY yojana. Retrieved from UGVCL: http://www.ugvcl.com/Petiton%20of%20'SKY'%20YOJANA.pdf