Working Paper 2016/04

Decentralised Solar Power Generation and Usage: A Study of Dhundi Solar Irrigation Cooperative in Gujarat, India

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December 2016

Agro-Economic Research Centre

For the States of Gujarat and Rajasthan

(Ministry of Agriculture & Farmers Welfare, Govt. of India)

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Decentralised Solar Power Generation and Usage: A Study of Dhundi Solar Irrigation Cooperative in Gujarat, India

Sonal Bhatt[1] and S.S. Kalamkar[2]

Abstract

A novel solar irrigation cooperative was started in Gujarat state in India; where solar power is generated and used at the farm level for irrigation. The surplus power is sold to the state electricity enterprise under a guaranteed power buyback arrangement. This study found that solar-powered irrigation is an economically viable solution for energy needs of irrigated agriculture; but the extraction of ground water had increased manifold. However, its impact on ground water markets and potential long term damage to ground water tables raises questions about its sustainability as an energy solution for irrigation. Strong policy intervention to regulate ground water extraction through solar pumps is required for them to become a sustainable solution for energy needs in irrigated agriculture.

Keywords: decentralized generation; solar power; solar irrigation; cooperative

JEL Classification: Q15, Q25, Q28

1. Introduction:

In India which is country fret with an irregular and ill-spread monsoon; irrigation is the mainstay of agriculture. Particularly in western India, canal irrigation is scarce and mostly unreliable in terms of time and duration. This makes irrigation largely dependent on ground water withdrawal; using driven with either electricity or diesel.

India currently has about 15 million electrified irrigation tube wells; with an estimated power subsidy of about 70,000 crores (Shah et al., 2016). State governments dare not cut these subsidies owing to their political compulsions. Besides, the existing electricity supply is insufficient, non-reliable, fluctuating in voltage and often available only at inconvenient hours. New electricity connections are hard to get, with a waiting list running into lakhs. In eastern India also, in spite of the abundance of ground water, it cannot be harnessed due to the shortage of electricity.

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As a result, irrigation in India is done mainly through about 9 million diesel-run pumps (Chawla and Agrawal, 2016). This burdens the exchequer with huge subsidies given on diesel; and also generates environmental pollution.

Solar power generation on the farm itself through installation of solar PV (photovoltaic) panels; and using the same for extracting groundwater could just be the solution to address these 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, without voltage fluctuation and available during the convenient day-time. India is blessed with more than 300 sunny days in the year that are ideal for solar energy generation; aptly supported by promotional policies of the Government of India (Chawla and Agarwal, 2016).

2. Review of Literature:

Literature suggests that application of solar energy in irrigation could have myriad benefits. The primary benefit is that it is 'free'. However, the generating apparatus comes with high initial fixed costs like that of equipment, installation, depreciation, interest, expenses on protection from theft, vandalism etc. Nevertheless, the marginal costs are indeed 'near zero' (operation, maintenance, repairs). The costs of expansion in irrigated area such as procuring of hose pipes to transport water across fields etc. is also much lesser compared to that for 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. Farming could be extended beyond the kharif season (monsoon); thus aiding 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, thus supplementing their incomes. Solarized pumps could promote conjunctive irrigation by promoting ground water extraction in flood-prone regions like north Bihar, coastal Orissa, north Bengal, Assam and eastern Uttar Pradesh (Shah and Kishore, 2012).

Electricity provision in India is the responsibility of the State governments and a majority of them have been unable to keep up with the growing needs of irrigated agriculture. Hence they seem to have lapped up the idea of solar-based irrigation with zest. The Government of Rajasthan (GoR) began an aggressive promotion of solar irrigation pumps, offering a subsidy of as much as 86 per cent for the adopters. Governments of Bihar and West Bengal also rendered active support for supplying solar pumps to small farmers (Shah and Kishore, 2012).

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

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

Apart from the implicit and realized advantages of solarized irrigation, there are concerns also. Bassi (2015), fears an increase in ground water extraction. This is due to the fact that the marginal cost of solarized irrigation is near-zero, with no incentive for farmers to save power and in turn, economize on the use of groundwater. Shah and Kishore (2012) also flag the dangers of solarized irrigation pumps that could encourage completely unrestrained ground water extraction, leading to unprecedented harmful impact ground water tables and worsen the situation in northern and western India. They advocate the prior formation of an effective demand management regime for ground water before promoting the replacement of diesel pumps with solar pumps. They suggest that instead of allowing the farmers to generate and use solar power freely, they should be organized for collectively evacuating their surplus power into the grid of the power distribution companies. The supplementary income that accrues to them in this manner could incentivize them to economize on their own power use as well as ground water extraction. It could also insure them against a failed agricultural season.

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

Kishore et al., (2014) found that solar pumps replaced mainly replaced diesel pumps and not electrical ones. Therefore, consumption of state-supplied electricity may fall with the spread of solar pumps, particularly in those areas where agricultural power was non-metered and highly subsidized.

The promotion of solar powered irrigation based on a huge state-supported subsidy regime in states such as Rajasthan has been widely criticized, even though the GoR tried to address the possible harmful impact on ground water extraction by laying that subsidy could be given only to the farmer having a drip irrigation system as well as a farm-pond on his land. Kishore et al., (2014) argued that a subsidy to the extent of 86 per cent on solar pumps was inefficient and misdirected. Bassi (2015), fears that the gains from subsidy would accrue mainly to resource rich farmers who could meet its eligibility conditions. Besides, the welfare gains of this subsidy are too little compared to the burden it would entail on the tax payers.

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

Tewari (2012) notes that empanelled firms charged prices higher than the market, while unregistered suppliers charged much lesser. In fact, if farmers purchased non-subsidized pumps on their own, they would be installed without any delay, cumbersome formalities or corruption. Hence, savings on diesel costs would begin almost straightaway, compensating for the subsidy foregone. Kishore et al., (2014) suggests that if the farmers were given remunerative prices for selling the surplus power to the grid, self-investment on solar pump-sets would increase, resulting in lesser dependence on subsidies in the long run. Shah and Kishore (2012) opined that subsidies in solar pumps would be meaningless and contradictory if they enriched supplier firms rather than farmers.

Bassi (2015) vehemently argued that solar pumps are economically unviable because they are less efficient than diesel pumps and also do not bring any net environmental gain.

In light of the above, this paper attempts to study the Dhundi Solar Irrigation Cooperative (DSIC). It is the first ever cooperative of farmers for decentralized solar power generation and usage in irrigation formed in 2015 in Gujarat, India. The study aims to explore the formation of DSIC, its functioning and economic benefits as well as the experiences of its member and non-members.

3. Data and Methodology

Data from Census of India (GoI, 2011) regarding population, agricultural land; and caste-wise distribution of land holding in Dhundi etc. were used. Initially, a pilot visit was made to Dhundi. The placement, condition and functionality of solar panels were observed. Informal discussions were held with the members of DSIC, on the basis of which, a detailed questionnaire was prepared, which was administered to the respondents. The field survey was conducted in May, 2016.

All the 6 members of DSIC were included in the sample. Besides, 6 non-members of DSIC (who were part of initial discussions with IWMI, but dropped out subsequently) were randomly selected from the names of non-members provided by the DSIC members. Thus,

Total Number of Respondents (12) = Members (06) + Non-members (06)
With the help of information collected from the respondents, simple tabular

analysis was done in order to understand the economic viability and sustainability of the DSIC. A SWOC analysis of the DSIC was also attempted, which has been presented in this paper.

4. Findings:

4.1 About Study Area:

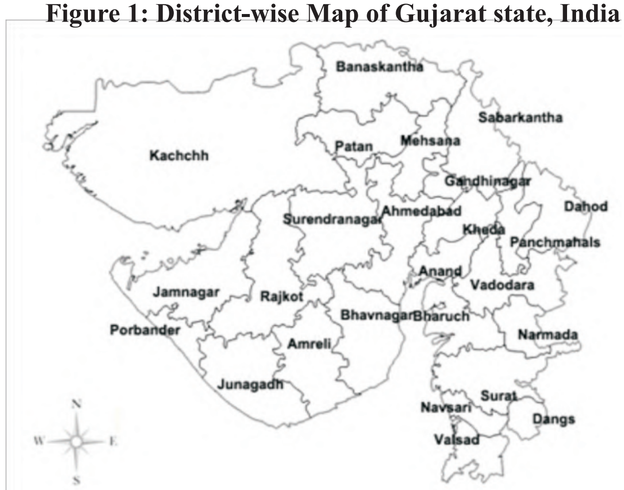
Dhundi is located in Thasra taluka (Block) of Kheda district in Gujarat state, India; about 90 km. east of Ahmedabad (Figures 1& 2). It has a total of 309 families, with a population of 1,473 persons and literacy rate of 74.88 percent. The proportion of Scheduled Castes (SCs) population was only 0.54 per cent and that of Scheduled Tribes (STs) was nil. Most of the farmers are small and medium land holders. Paddy and pearl millet are major kharif crops while wheat is the major rabi (winter) crop followed by amaranth and tomatoes. During summer, depending on the availability of water, crops like pearl millet, green gram and long beans/snake beans are grown.

Ground water is the major source of irrigation. Out of the 40 bore wells in the village, 39 run on diesel and only one is electrified. This is because electricity connections are not easily forthcoming, leaving the farmers with no choice but to operate diesel pumps. All the cultivated land in Dhundi village is irrigated.

A cooperative institution is not a rarity in Dhundi, which is not far from Anand, the cradle of the cooperative dairy revolution in the world. Also, internationally renowned NGOs like the International Water Management Institute (IWMI), Anand and Foundation for Ecological Security (FES), Anand etc. are located in the vicinity.

The DSIC was started in Dhundi due to the active role of IWMI, Anand, who were the promotors for DSIC and saw it right through its conception to actual formation.

Figure 1: District-wise Map of Gujarat state, India



Source: https://www.google.co.in

Figure 2: Block-wise Map of Kheda District in Gujarat, India

Source: http://www.mapsofindia.com/maps/gujarat/tehsil/kheda.html

4.2 Nature of Respondents:

The average education of DSIC members was just 7.5 years (Table 1). In spite of not being highly educated, they exhibited the will to become part of a novel experiment like DSIC. Farming was the major occupation of all the respondents followed by animal husbandry and dairying.

Table 1: Social Characteristics of Selected Respondents

Sr. No.	Characteristic	Members of DSIC	Non-Members
1	Gender	Male (100%)	Male (100%)
2	Average Years of Education	7.5	6.16
3	Religion	Hindu	Hindu
4	Caste	SC-50%; OBC-50%	OBC-100%
5	Major Occupation	Farming (100%)	Farming (100%)
6	Minor Occupation	Animal Husbandry and Dairying (100%)	Animal Husbandry and Dairying (100%)

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

As shown in Table 2, a majority of members of DSIC belonged to BPL (Below Poverty Line) category, while most non-members were of the APL (Above Poverty Line) category. The average family size was quite large at around 8 persons per household. All of the land in Dhundi is irrigated; therefore, rental value of land was reported to be quite high between Rs. 77,500-85,000 per bigha** per year. All the respondents were so far happy with the fertility of their land. The ground water table was also favorable at 35-65 feet. Irrigation was completely dependent on ground water. Each respondent owned a diesel-operated pump to withdraw water.

Table 2: Economic Characteristics of Selected Respondents

Sr. No.	Socio-Economic Characteristic	Members of DSIC	Non Members
1	Income Group	APL: 33.33% BPL: 66.66%	APL: 66.66% BPL: 33.33%
2	Quality of Residence	Pucca-50% Semi-pucca-50%	Pucca-83.34% Kuttcha-16.66%
3	Mean Family Size (No.)	08	8.5
4	Mean Land Ownership (Bigha)	2.375 bigha	3.95 bigha
5	Irrigated Land (% to total land)	100%	100%
6	Rainfed Land (% to total land)	Nil	Nil
7	Main Source of Irrigation	Tube well	Open well: 50% Tube well: 50%
8	Average Leased-in Land (bigha)	1.5 bigha	1.16 bigha
9	Rental Value of Leased-in Land (Rs./bigha)	Rs. 77,500/bigha/year	Rs.84,375/bigha/year
10	Leased-out Land (% to total land)	Nil	Nil
11	Perception about Soil Fertility Status	Good (100%)	Good (100%)
12	Depth of Ground Water Table (feet)- range	35-65 feet	35-70 feet
13	Source and Method of Irrigation	Ground water- 100%; canal water- Nil; Flood Irrigation-100%;	Ground water- 100%; canal water- Nil; Flood Irrigation-100%;
14	Distance from canal (meters)	500-1500 meters	500-1500 meters
15	Ownership of diesel-operated pump set (self)	100%	100%
16	Capacity of motor in the pump-set (hp)	10 hp-80% 07 hp-20%	12 hp: 80% 05 hp:20%

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

4.3 Inception of Dhundi Solar Irrigation Cooperative (DSIC):

The DSIC was registered on February 16, 2016; while solar energy generation and its use for irrigation started much earlier on November 23, 2015. IWMI did considerable ground work in Dhundi for about a year prior to its formation. The first meeting with the village farmers was held on March 5, 2015; followed by many more meetings to propagate solar power generation and its economic benefits. Long term obligations and legal implications of the formation of DSIC were also discussed in detail. Initially about 15 odd farmers had shown their readiness, but finally a group of six farmers remained to become actual members.

It is noteworthy that one of the farmers of Dhundi, namely Pravinbhai, was formerly associated with the FES, Anand and was therefore, well-known also at IWMI. Besides, the village folk also trusted him as one of their own. Therefore, through his involvement, the initial ice-breaking and trust development between the Dhundi farmers and IWMI became much easier. Pravinbhai became the first member of the DSIC and encouraged others to join as well. He currently acts as its de facto secretary cum public relations officer.

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

Table 3: Motivating Factor/s to join DSIC

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

Source: Data from primary survey

Table 4 shows the ranking of reasons expressed by non-members for not joining DSIC. They hesitated to join mainly because of the requirement to make initial financial contribution when they were not sure about its success. The other two reasons mentioned were the lack of funds for making a contribution and doubts about the credibility of IWMI.

Table 4: Non-Members' Reasons for Not Joining DSIC

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

Source: Data from primary survey

4.4 Financial arrangements of DSIC

The total capital expenditure on setting up PV panels and connecting them to the grid was close to Rs. 6,000,000. The cost of connecting the solar panels on the farms with the grid is estimated to be Rs. 100,000 for a 1 KV panel, which would go up in proportion to the distance from the grid. The members of DSIC were convinced by IWMI to initially contribute a sum of Rs. 54,666 per head (Table 5), which comes to only about 5 per cent of the total project cost. The rest was borne by the donor agency CCAFS (CGIAR1 Research Programme on Climate Change, Agriculture and Food Security) as reported by Shah et al., (2016). Expenditure was done on beneficiary-survey, technical survey, capital equipment like solar panels, pipelines, meters etc., installation and operationalization of the solar pumps etc. Electricity generation and input in the grid was overseen by IWMI. The funds collected initially from the members were deposited as a corpus in its bank account. Thus, the only real contribution of the farmers to this venture was of the land for erecting the solar panels and connecting them with their already existing bore well on the farm.

Table 5: Members' contribution to DSIC

Sr. No.	Particulars	Amount in Rs/Share in percentage
1	Mean financial contribution to DSIC	Rs. 54,666 (one time)
2	Members willing to contribute additional amount to DSIC	33.33
3	Additional amount that members are willing to contribute to DSIC (per member)	Rs. 40,000

Source: Data from primary survey

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

4.5 Functioning of DSIC

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

Table 6: Installation of Solar Panel and Generation of Power

Farmer No.	No. of solar panels	Size of each panel (ft x ft)	Power generation capacity (units/ day)	Power generated with solar units/day (November 2015 to May 2016)	Area covered by panel (ft x ft)	Panel Distance from Grid (Meters)	
				Winter	Summer		
1	4	3 x 5	40	30	40	60	400
2	6	3 x5	70	35	65	90	200
3	6	3 x 5	55	40	55	90	0
4	6	3 x 5	62.5	40	62.5	90	0
5	6	3 x 5	55	40	55	90	1000
6	6	3 x 5	60	35	55	90	900

Source: Data from primary survey

Table 6 shows the details regarding number of solar panels on the farm of each member, its size, power generation capacity, units of power generated per day in different seasons viz. winter and summer [from November, 2015 (winter) to May, 2016 (summer)]. It also shows the distance of panels on each farm to the power evacuation point to the grid. This represents requirement to lay wires, pipes etc. and the cost entailed therein.

Post the generation of solar power, the pump connected to the bore well which earlier worked on diesel, started running on solar power. The farmer irrigated his own land during the convenient daylight hours. He could then sell his surplus power for which, he had two options. One, he could empty it into the grid of Madhya Gujarat Vij Company Limited (MGVCL, a government of Gujarat owned company for electricity production and transmission). He earned an income at the rate of Rs. 4.63 per unit for selling power as per the 25-year power purchase agreement (PPA) between the DSIC and the MGVCL.

A consolidated (master) meter was installed by DSIC for recording the total power emptied by DSIC to the grid. Individual meters were also installed on individual farms, in order to record their individual contribution of solar power. The MGVCL would use the records of the consolidated meter for the purpose of billing and payment for power to the DSIC, which in turn, would distribute it to its members according to their respective contributions. Since the readings of the individual meters collectively tally with that in the DSIC, the whole process becomes transparent, reliable and easy to understand for the members.

Second option with the member was to use his surplus solar power in order to withdraw more ground water from his bore well and sell it to his neighboring farmers. The rate of buying water for irrigation is Rs. 100 per hour, using a 5 hp pump. It takes approximately four hours to irrigate 1 bigha of land. Hence, the prevalent price of irrigating 1 bigha of land is around Rs. 400. Approximately 20 units of power are consumed to irrigate 1 bigha of land. If the member were to sell 20 units to MGVCL, he would get (20 x 4.63) a total income of Rs. 92.6/- only. However, if he were to sell ground water to a water buyer, he stood to get Rs. 400 at the prevalent market rates. Hence, contributing surplus power to the grid is not as profitable for him as is the sale of ground water using solar power.

Prior to power evacuation from the DSIC to the MGVCL having started, i.e. from November 2015 to mid-May 2016, the farmer could use the power either for his own needs or for selling ground water. If he did neither, it would be simply wasted. In other words, the opportunity cost of using power for ground water sale was zero during that time. It is but natural that he would use most of his surplus power for selling ground water, as noted in Table 7.

Table 7 shows the distribution of solar power generated by members of DSIC. While they empty only about 17 per cent of power to the MGVCL grid and use almost the same amount for their own irrigation needs; the bulk of the power is used for withdrawing ground water and selling it to their fellow farmers. Hence, value of solar power used for selling ground water is more than seventeen times that of the solar power emptied into the MGVCL grid. The implicit monetary value of the farmer's own consumption of power also stands at a paltry Rs. 3,386 in the scenario of him using grid power. It would be only slightly more than twelve thousand, even if he were using diesel.

During the survey, it was found that the DSIC members had resolved to charge Rs. 250 per bigha for solar-pumped groundwater instead of Rs. 400 per bigha by diesel pumps. They said that they reduced the rate out of goodwill for their fellow farmers and mainly because solar power was free of cost for them. Hence, ground water purchase had become de facto cheaper in Dhundi. This effectively means that the supposed benefit of free solar power is mainly accrued by water buyers in Dhundi. It does not significantly benefit either the MGVCL or the farmers themselves.

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

Table 7: Distribution of Use of Solar Power

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

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

4.6 Potential Benefits from DSIC

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

To the Members

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

To MGVCL

Due to the formation of DSIC, the MGVCL is saved from the prohibitory transaction costs and well as a variety of hassles of getting individual farmers on board for purchasing solar power from them; paying them on an individual basis and collecting their small marketable surpluses through individual meters. Shah et al., (2016) show that power purchase from DSIC could also be cheaper for MGVCL because on an average, it buys power from solar power companies at the rate of Rs.13 per unit, whereas the PPA with DSIC freezes the price at only Rs. 4.63 per unit for 25 years.

Additionally, the DSIC would also enable the MGVCL to earn money from the sale of renewable energy certificates (RECs) against the 85,000 units of solar power that it would generate. Assuming a value of Rs. 3,500/megawatt hours for the RECs being traded on electricity exchanges; it comes to an income of almost Rs.3 lakhs. This translates into a gain of about Rs. 18.2 per unit for MGVCL (Shah et al., (2016)).

To the exchequer

The subsidy outgo on provision of agricultural power could be reduced considerably; as under the PPA, the six DSIC members have surrendered their right to apply for grid power connections for a period of 25 years. If they did not do so, the MGVCL would have been obliged to supply power to them at Rs. 0.70/unit, while purchasing the same at an average of Rs. 5/unit. Moreover, the grid power consumption of Dhundi farmers would have been 162,000 units, assuming an 8-hour supply for 360 days @Rs.0.70 per unit. Besides, the cost of delivery of power borne by MGVCL would have been much more, at Rs. 4.50 per unit. In this way, even if only two-thirds of the power supplied was used, the annual subsidy burden of MGVCL would have worked out to be well over Rs. 4 lakh per farmer. Besides, it would have had to invest Rs. 2 lakhs for connecting every new connection with the grid through poles and cables. The annual interest and depreciation of this investment even at conservative estimates would be 20,000 per year. All these expenditures stand to be wiped out with the inception of DSIC.

4.7 Impact of DSIC

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

(a) On Water Markets

The prevailing rate of buying water for irrigation through a 5 hp solar pump is Rs. 400 per bigha. If the water seller were to withdraw water with the help of a diesel pump, he would be spending on diesel as well as occasional maintenance costs of the pump-set. It was estimated that approximately 5 liters of diesel were consumed in irrigating 1 bigha of land. If the price of diesel were Rs. 50/litre, he would be spending around Rs. 250 to sell water worth Rs. 400. Hence, the net profit per bigha would be around Rs. 150. On the other hand, if he sold water withdrawn through the solar pump, operating costs were near-zero, while the price that he could charge could be anywhere between Rs. 400 (the going rate) and Rs. 250. If he were to charge Rs. 400, his net profit would be more than doubled. Alternately, if he were to charge a reduced rate of Rs. 250 per bigha (as resolved by DSIC members), net profit would still be Rs. 250; which is more than that accrued by using a diesel pump. Hence, it is but natural that DSIC members were encouraged to extract more ground water and sell it, albeit at a lower price than before. This would result in expanded demand for ground water in Dhundi.

This happens because ground water is 'free' and extraction of the same is not regulated by the state. Hence, it would be economically very profitable for DSIC members, given the fact that they are ground water rich and are able to find enough buyers for their water. In fact, geographical distance between the water buyer and water seller is the only factor that could put a tab on the unabated extraction of ground water in Dhundi. However, if the government were to bring in stringent laws and regulations for groundwater extraction, unabated expansion of groundwater demand could be controlled. In another scenario, if the farmers were using more diesel to extract and sell more ground water, the precarious situation of ground water extraction would be more or less similar. However, it could be said that due to the onset of solar pumps, ground water extraction is perceived to have become much cheaper and easier, encouraging the farmers to gear up their water sales.

Table 8 represents the change in sale of ground water in Dhundi after the formation of DSIC. It can be seen that the total hours of water extraction for sale has increased by more than 135%. However, the number of pumping hours per day was reported to have reduced. The reason for this as explained was that solar pumps extracted more water per unit of time. Also, instances of break down, heating up of the motor etc. were found to be rare to nil. The number of water buyers has more than doubled after the solarization of irrigation pumps, increasing the income of water sellers in DSIC by more than 400%.

Table 8: Water Sale to Fellow Farmers through Solar Power

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

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

(b) On Saving in Costs of Irrigation

Earlier, farmers incurred high direct costs on buying diesel, repairs and maintenance of pump-sets; as well as indirect costs in terms of time and effort to procure diesel on a regular basis. These costs have disappeared after they moved from diesel-powered to solar-powered pump-sets. These savings are presented in Table 9.

Table 9: Direct and Indirect Expenditure and Savings through Use of Solar-powered Irrigation Pumps

Sr. No.	Particulars	Before DSIC	After DSIC
(A) 1	Direct Costs on Irrigation Mean Expenditure on irrigation through diesel per month	Rs. 13,375/month)x 8** = Rs. 1,07,000 per	00
2	Mean Expenditure on repairs of irrigation pump (per year)	Rs.8,250	Nil
3	Direct Savings due to Solar Pumps	NA	Rs. 1,15,250
(B) 1	Indirect Costs of Irrigation Respondents feeling shortage of availability of diesel	100%	NA
2	Mean distance from sale point of diesel	700 meters	NA
3	Mean requirement of man-hours to procure diesel (hours per week)	1.6 hrs/week	NA
4	Indirect Savings on Irrigation		Time and effort for all of the above

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

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

(c) On the ground water level

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

(d) On Use of Diesel

Use of solar power reduced the dependence on diesel and resultant air and noise pollution. Table 10 shows the decrease in the usage of diesel post solarization of irrigation pumps.

Table 10: Impact of DSIC on Use of Diesel

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

Source: Data from primary survey

4.8 Price Intervention by IWMI

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

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

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

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

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

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

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

4.9 Sustainability of DSIC

The longevity of any institution depends upon wholehearted participation of its members; as well as their satisfaction in its activities. Since its inception, about 13 meetings in all were held in DSIC (Table 11). It was reported that all the meetings were attended by all 6 members. Each of them felt that at this stage, the decisions of the DSIC were taken by consensus. Elite capture was not apparent during the field survey. This may not be surprising, with the present total membership at a single digit. Members reported that they were involved in the functioning of DSIC only to the extent of cleaning and maintaining the solar panels on their own farms and rotating them regularly. They did not do any other work of technical nature like arranging meetings, preparing agenda and minutes of the meetings, maintenance of accounts, solution of problems faced by fellow members, handling and maintaining of various records and registers etc. All the above functions were currently handled by only one particular member only. Capacity-building of members for running and expansion on their own after the withdrawal of IWMI, was yet to be done. The DSIC had not yet decided its secretary, membership fee, yearly operation and maintenance charges etc. In case of a dispute in future, the DSIC may fumble to keep itself afloat due to a lack of competence of most of the members in crucial areas of operation.

Table 11: Participation of Members in DSIC

Sr. No.	Indicator of Participation	Extent of Participation
1	Number of Meetings held in DSIC since inception	13
2	Percentage of members who attended all the meetings	100%
3	Members who think that decisions in DSIC are taken after consulting everyone	100%
4	Functions undertaken by members of DSIC	Cleaning solar panels on their own farms, rotating them regularly

Table 12 shows transparency in the functioning of DSIC and satisfaction of members with the income from solar power. Members were satisfied by the maintenance of meters which recorded the emptying of power to the MGVCL. However, a majority (66.67%) of them were not satisfied with the price for power offered by MGVCL. This was because they were getting higher income by selling ground water to their fellow farmers instead of emptying it into the grid. Instead of the price of Rs. 4.63 per unit offered to them currently, they expected an increase up to Rs. 6-10 per unit (25-50%).

Table 12: Transparency and Satisfaction of Members in the Functioning of DSIC

Sr. No.	Indicator	Yes	No
1	Satisfaction with the maintenance of power meters by DSIC	100%	Nil
2	The meters record the units of solar power contributed by me correctly	100%	Nil
3	Satisfied by the payment offered for the sale of solar power	33.33	66.67
4	Willingness to contribute more to DSIC corpus	33.33	66.67

Source: Data from primary survey

4.10 SWOC Analysis of DSIC

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

Strengths

- The cooperative model of DSIC made decentralized solar power generation less complicated because the MGVCL was saved from having to engage with individual farmers. This brings speed and efficiency in solar power generation and its evacuation in the grid.

- It enabled the MGVCL to save on transaction and vigilance costs which could have been prohibitive if the farmers were not organized through DSIC.
- With the formation of DSIC, the MGVCL could evacuate power through a single point, which cuts down on transmission losses to an extent.
- Payment could be done to at a single point, i.e. DSIC, which saves on metering and monitoring costs and hassles of individual payments.
- It was able to create a substantial corpus from members' initial contribution.
- The process of emptying power to the grid was reported to be transparent and fair, which inspired confidence amongst members.
- Transparency ensures reliability; and hence lesser possibility of conflicts between the DSIC, its members and the MGVCL.
- Shifting to solar power brought substantial gains for the farmers in terms of savings on costs of diesel. This improved their returns from agriculture.
- Saving of diesel, a non-renewable resource, also contributes in reducing the carbon footprint of irrigation.

Weaknesses

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

Opportunities

- The DSIC promises to bring a win-win situation for both the farmers and the MGVCL. The farmers get free power for their irrigation needs and the MGVCL could buy power at a cheaper rate than that obtained from thermal plants.
- Removal of need to use diesel pumps for irrigation could go a long way in liberating the MGVCL and Gujarat state government from the heavy burden of agricultural power subsidies.

- The assured power buyback guarantee from MGVCL opens up another avenue of income generation for small-holder farmers and insures them against a failed agricultural season.
- In future, power sale by DSIC could be opened up for private electricity companies as well.
- If the farmer were to get a competitive price for power sale to the grid, he could be discouraged from over-extracting ground water.

Challenges

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

4.10 Conclusion

The DSIC 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 DSIC 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 DSIC to enforce a large amount of solar power which is made obligatory to be supplied to MGVCL.

Thus, DSIC 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.

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Notes:

1CGIAR is a Consortium of International Agricultural Research Centres

AERC Vallabh Vidyanagar- Research Studies/Reports Completed

Sr. No.	Report No.	Title of Report
1.	1.	A Study of Wheat Prices in the States of Gujarat and Rajasthan, by V. S. Vyas, 1963.
2.	2.	The Organization and Disintegration of a Collective Farming Society: A Case Study of a Gramdan Village, by K. M. Choudhary, July, 1966.
3.	3.	Economics of Well Irrigation in a Rajasthan Village, by K. R. Rakhral, published as an article in Artha Vikas, January 1967.
4.	4.	Agricultural Labour in Four Indian Villages, Ed. by V. S. Vyas, May, 1964.
5.	5.	Command Area of the Dantiwada Project (Socio-Economic Survey of Three Banaskantha Villages in Gujarat), by B. M. Desai, November, 1964.
6.	6.	Working of Fair Price Shops in Gujarat and Rajasthan (with Special Reference to Ahmedabad and Jaipur Cities), by R. M. Patel, March, 1965.
7.	7.	A Study of Pilot Co-operative Farming Societies in Gujarat and Rajasthan by M. D. Desai and K. S. Karanth, December, 1964.
8.	8.	Factors Affecting Marketable Surplus and Marketed Supplies (A Study in Two Regions of Gujarat and Rajasthan) by V. S. Vyas & M. H. Maharaja, January, 1966.
9.	9.	Factors Affecting Acceptance of Improved Agricultural Practices (A Study in an I. A. D. P. District in Rajasthan), by K. M. Choudhary, November, 1965.
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12.	12.	An Evaluation of Some Aspects of Hybrid Maize Programme in Dahod Taluka (Panchmahal District, Gujarat), by B. M. Desai, January, 1967.
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15.	15.	New Strategy of Agricultural Development in Operation (A Case Study of the Kaira District in Gujarat), by B. M. Desai and M. D. Desai, July, 1968.

Sr. No.	Report No.	Title of Report
16.	16.	Conditions of Stability and Growth in Arid Agriculture, by N. S. Jodha and V. S. Vyas, December, 1968.
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21.	21.	A Study of High Yielding Varieties Programme in the Kota District, Rajasthan (Rabi 1968-69), by D.S. Tyagi and V.N. Misra, October, 1969.
22.	22.	Prospects and Problems of Dairy Development in a Desert Region (A Study in the Bikaner District of Rajasthan) by N.S. Jodha and K.M. Choudhary, March, 1970.
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30.	29.	Drought Prone Area Programme : A Case Study of the Banaskantha District in Gujarat (Rabi 1971-72), by R.D. Sevak, May, 1973.

Sr. No.	Report No.	Title of Report
31.	30.	Saving and Investment in an Agriculturally Prosperous Area (A Study of Farmers in Surat District), 1969-70, by M.D. Desai, 1973. (Supplement) Employment, Income and Levels of Living of Agricultural Labourers (A Study in the Surat District, Gujarat), 1969-70, M.D. Desai, 1974.
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