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Impacts of Solar Energy on Agriculture: A Comparative Study of Anand and Narmada Districts

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Abstract :

This study provides a comprehensive overview of the socio-economic impacts of solar irrigation on farmers in the Anand and Narmada districts and changes in agriculture.

- **Purpose**: The main objective of this study is to know the socio-economic impacts on the farmers due to the use of solar irrigation pumps in the Anand and Narmada districts and to examine the changes in agriculture due to the use of solar energy.
- **Design:** During the year 2024-25, a total of 124 farmer-beneficiaries from Anand and Narmada districts adopting solar irrigation pumps have been selected. Primary Data has been collected through a structured questionnaire using the stratified random sampling method.
- **Findings**: The findings of this study are that beneficiary respondents are socially and economically prosperous compared to non-beneficiaries of Solar Irrigation Pumps. Compared to the Anand District, the cultivated area of the Narmada District increased After Solar Irrigation. Further, summer acreage increased significantly After Solar Irrigation due to the earlier unavailability of Irrigation facilities in the Narmada District. In Anand and Narmada Districts, solar irrigation has had a positive effect on Cropping Intensity. In addition, Cropping Intensity has changed more in the Narmada District than in the Anand District. After the Solar Irrigation in the Narmada District, there has been a massive increase in the area under summer cultivation.
- **Keywords**: Solar-Powered Irrigation, Cropping Intensity, Cropping Pattern.
- **JEL Code**: Q01, Q15,Q16, Q42.

1. Introduction :

Indian Agriculture is Dependent on the erratic natural climate. If a sufficient water supply is available in the Agricultural Sector, Development can be achieved to a good extent. India's state of Gujarat has to depend on groundwater with the help of Electricity or Diesel Pumps to overcome the shortage of water supply. At present, there are more than 30 million Agricultural Pumps installed all over the country, of which 8 million are Diesel Pumps (Mishra, 2022) and more than 220 lakh grid-connected Agricultural Pumps in the country. Its annual Electricity Consumption is 18% i.e. about 213 billion units. Farmers using electric Pumps face insufficient hours of Electricity received from the grid and farmers using Diesel Pumps face high fuel costs. Approximately 8 to 12 percent in India and 50 to 70 percent in China fuel-driven Pumps Increase greenhouse gas emissions.[1] Solar-powered Irrigation system that generate carbon-free Electricity are an excellent solution to the problem of Greenhouse Gas emissions. Keeping this problem in the Center, the Government of India has started the work of providing Solar Pumps to the farmers by releasing different schemes including Subsidies to ease the grid load and the welfare of the farmers. The Installation Cost of Solar Irrigation Pump sets is about 55% higher as compared to Diesel or electric Pumps but, in the long run, becomes profitable. Recent estimates show that 5 million Solar Pumps in India could save 10 billion liters of Diesel and 26 million tonnes of CO2 per year. Diesel Pumps are cheaper compared to Solar Pumps in terms of Capital Cost, but the Maintenance Cost of Solar Pumps is minimal and the Maintenance Cost of Diesel Pumps is approximately five times higher than Solar Pumps with a life span of around 20-25 years. The use of Solar Energy for unlimited and free as well as Environmentally friendly Agricultural Irrigation is currently the best Energy alternative against limited and expensive fuel.

[1] Nicole Lefore (2021) "Solar for all: A framework to deliver inclusive and environmentally sustainable solar irrigation for smallholder agriculture"

The estimated number of Electric Pumps increased from 0.2 million in 1962 to over 11 million in 2007 and Diesel Pumps from 0.6 million to 6.3 million (Tamoor, 2021). Utilization of Solar Energy enables saving of chemical fertilizers and an estimated 22.92% water saving as well as improvement in product quality. According to the MNRE 2020-21 Annual Report, India's installed Renewable Energy Capacity increased by 2.50% from April 2014 to January 2021, and the installed Solar Power Capacity increased by 15 times currently, 37 Countries in the world are leading in the use of Solar Energy. By the end of 2019, a cumulative amount of 629 GW of Solar Power had been installed worldwide, currently, China, the US, and India are the world leaders in Solar Production. China was the first Country in early 2020 to generate 200 GW, a third of global installed Solar Capacity. China uses Solar Pumps for Irrigation in 99% of the area and Installed 18,1000 Solar Pumps for Solar Irrigation in Agricultural areas. (Nitin Bassi-2017). Anand, Borsad, Khambhat, Petlad, Sojitra, and Tarapur of Anand District of Gujarat State, thus, 06 Talukas a total of 37 off-grid Solar Irrigation Pumps have been installed under the PM-KUSUM scheme in Different villages.[2] Also, a total of 178 grid-connected Solar-Powered Irrigation Pumps have been installed in different villages of Sojitra taluka, and a total of 31 Grid-Connected Solar-Powered Irrigation Pumps in installed in different villages of Petlad taluka.[3]

In the Narmada District of Gujarat, there are five Talukas: Nandod, Dediapada, Tilakwada, Sagbara, and Garudeshwar. Currently, out of a total of 214 Villages in Dediapada taluka, 40 villages have a total of 1,018 Solar Energy-operated Irrigation Pumps installed under the PM-KUSUM Scheme that are not Connected to the Grid. Additionally, in the Narmada District, there are a total of 51 Solar Irrigation Pumps Connected to the Grid installed in four Villages of Nandod taluka: Varkhad, Ori, Navapara, and Nikoli.[4]

2. Review of Literature :

Solar Technology has proven convenient for Increasing Productivity and Environmental Protection through Solar-Powered Irrigation Pumps (Lefore et al. 2021). The use of Solar Irrigation Pumps has reduced Irrigation Costs, enabled adequate Irrigation had a positive effect on Production, and improved the standard of living of the people (KalamKar & Bhatt, 2017). Change in Cropping Patterns, the minimum cost is possible, and Farmer's Income is doubled and Beneficiaries of Solar Irrigation Pumps become financially viable (Singh et al. 2017, Kalamkar et al. 2019, Sharma et al. 2022). Irregularity of rainfall, weather fluctuations, and depleting Water table are one of the biggest challenges for farmers, hence Solar Energy is a great option for small and marginal farmers against rising Irrigation Costs and low ability to purchase equipment (Jain & Shahidi, 2018). The life of a Solar panel is 20 years and Diesel Pump is 5 years and the Maintenance Cost of a Diesel Engine and Solar Panel is 15% and 0.5% per year respectively (Nowar & Mousa 2020). The Capital Cost of Solar Pumps is high but, in the long run, Solar Pumps have lower cost as compared to Diesel Pumps (Anoop & Reema, 2017), (Kanna et al. 2020) as well The use of Solar Irrigation Pumps reduces weeds, increases yield, and limits carbon dioxide emissions (Atiqul 2014, Raut et al. 2017). The life cycle cost of a Diesel-Powered Pump is lower than that of a Solar Pump for up to 5 years and After 5 years the life cycle cost of a Solar Pump becomes lower than that of a Diesel Engine-powered Pump (Hossain et al. 2015, Bassi 2017). Also, Solar-Powered Irrigation Pumps can eliminate Unemployment and save Electricity (Sharma, 2022), and the use of Solar Irrigation Pumps can save Labor (Kishore et al. 2014). Some of the earlier studies suggest that the height of the Solar Panels should be slightly higher so that the ground below can be used and that the service Center at the local level, Solar Panel Replacement should be automatic rather than manned. (Bhatt et al. 2019). Solar Pumps in Sudan and Egypt have proven to be able to provide efficient Consumption and low Operating Costs, and Pumps in Nigeria and Algeria have proven satisfactory performance. In Algeria, Solar Pumps have been proven to provide sufficient water even for small farmers with 2 hectares of land. Cost and Water Savings are possible as a result of Solar Pumps (Wazed, et al. 2018). In South Punjab, the Socio-Economic well-being of farmers who Installed Solar Pumps was found to be better than those who did not use Solar Energy. Also, Marginal Costs and Income-Savings differed more, and user health and Education levels remained high. Also, users have benefited from zero operating costs as well as, a change in Cropping Pattern on the other hand, some areas have seen high Installation Costs, low efficiency, and a lack of awareness towards non-users (Zaka, et al. 2020).

3. Data and Research Methodology:

3.1 Objectives of the Research Study:

1) To know the effects of the use of Solar Energy on the Socio-Economic Sector of the farmers
2) To examine the changes in Agriculture due to the use of Solar Energy in Agriculture.

3.2 Sample Selection :

Anand and Narmada districts have been selected to evaluate this study. To know the impact of solar energy on the agriculture sector, 02 talukas where solar energy has been used more were selected from Anand district. Also, 18 samples out of 04 selected villages in which solar irrigation pumps are most installed in the selected taluka have been selected using the stratified demonstration method. Similarly, 02 talukas have been selected from Narmada district where solar energy has been used more. Also, 18 samples out of 04 selected villages in which solar irrigation pumps are most installed in the selected taluk have been selected using the stratified demonstration method.

Also, a total of 09 Farmer Respondents adopting (non-solar) electric irrigation pumps of selected Anand district have been selected through a stratified demonstration method. Also, a total of 04 non-beneficiary Farmer Respondents from 02 talukas of Anand district who are not using any type of irrigation pump have been selected. Also, a total of 09 Farmer Respondents using (non-solar adopter) Diesel-powered irrigation pumps of selected Narmada district have been selected through stratified demonstration

[2] Anand Divisional Office, MGVCL
[3] Petlad Divisional Office, MGVCL
[4] DGVCL - Divisional Office, Rajpipla

method. Also, 04 non-beneficiary Farmer Respondents from 02 talukas of Narmada district who are not using any type of irrigation pump have been selected.

Thus, a total of 124 Farmer Respondents have been selected as a sample in this study using a stratified sampling method.

04. Statistical Analysis :

Table No. 01 Working Agricultural implements owned by the Respondents in Anand and Narmada districts :

(Year 2024-25)

	1	2	3	4	5	6	7
Agricultural Implements possessed by the Beneficiary Respondents	District	Anand		Narmada		Total number of tools	Average Cost of Equipment
	Agricultural implements	Total count	Average Price (Rs.)	Total count	Average Price (Rs.)		
	Electric Powered Pump	18	72800	0	0	18	36400
	Diesel-Powered Pump	0	0	08	45486.31	08	22,743.16
	Tubewell	15	742244.2	0	0	15	371122.1
	Borewell	03	81727.27	18	61719.57	21	71723.42
	Bullock cart	0	0	03	48666.67	03	24333.34
	Tractor	12	701535.62	02	702000	14	701767.8
	Thresher	04	118111.22	01	148000	05	133055.6
	Trolley	03	140500	02	148000	05	144250
	Rotavator	04	116900	0	0	04	58450
	8	9	10	11	12	13	14
Agricultural Implements held by non-beneficiary Respondents	District	Anand		Narmada		Total Number of tools	Average Cost of Equipment
	Agricultural Implements	Total Count	Average Price (Rs.)	Total count	Average Price (Rs.)		
	Electric Powered Pump	09	68000	00	00	09	34000
	Diesel-Powered Pump	00	00	09	43620	09	22,744.16
	Tubewell	09	673424	00	00	09	336712
	Borewell	00	00	00	00	00	00
	Bullock cart	00	00	03	5167.69	03	2583.845
	Tractor	05	360000	00	00	05	180000
	Thresher	00	00	00	00	00	00
	Trolley	03	58000	00	00	03	29000
	Rotavator	00	00	00	00	00	00

Source: Primary Data

The above Table No. 01 gives the details of the working agricultural implements owned by the beneficiary respondents and non-beneficiary respondents of Solar Irrigation Pumps in the Anand and Narmada districts. According to this, the beneficiary farmers of Anand district have a total of 18 electric-powered pumps with an average cost of Rs.72800 (total set). As selected villages of Narmada district are not provided with agricultural electricity lines provided by the grid some farmers depend on diesel pump and some farmers depend on rainfed. So, earlier in the Narmada district, no farmer was using an electric pump. As a result, only 08 Farmer Respondents of Narmada district have an average price of Rs. 45486.31 were diesel-powered pumps. The respondents of Anand district have a total of 15 tube wells with an average cost of Rs.742244.2. Overall, Farmer Respondents from the Anand and Narmada districts have a total of 21 borewells. Out of which, Farmer Respondents of Anand district have 03 borewells with an average cost of Rs.81727.27 and farmers of Narmada district have 18 borewells with an average cost of Rs.61719.57. A total of 03 Farmer Respondents own bullock carts in Narmada district, The average price of which is Rs.47866.67. The farmer respondent of the Anand and Narmada districts has a total of 12 and 02 tractors respectively. The average price of which is Rs.701535.62 and Rs.702000 respectively. Besides, the Farmer Respondents of the Anand and Narmada districts also own some other agricultural implements such as threshers, trolleys, and rotovators. Overall, in Anand and Narmada districts, respondents have a total of 05 threshers and 05 trolleys. Additionally, only 04 Farmer Respondents in the Anand district possess rotovators with an average price of Rs. 116,900.

The selected non-beneficiary farmers of Anand and Narmada districts have a total of 09 electricity-operated pumps, 09 Diesel-operated pumps 09 Tube wells, 03 Bullock carts, 05 Tractors, and 03 Trolleys.

Table 02. Total owned land by Selected farmers in Anand and Narmada Districts:

(in Hectares per family, Year 2024-25)

	Details of land				Land Per Capita		
Beneficiary Respondents	**District**	**Anand**	**Narmada**	**Total Land**	**Anand**	**Narmada**	**Total land**
	Rain dependent	0.4	358.75	359.15	0.01	5.13	2.57
	Irrigation based	136.49	160.03	296.52	1.95	2.29	2.12
	Total land owned	136.89	518.79	655.67	1.95	7.41	4.69
	Details of land				**land Per Capita**		
Non-beneficiary Respondents	**District**	**Anand**	**Narmada**	**Total Land**	**Anand**	**Narmada**	**Total land**
	Rain dependent	0.00	55.39	55.39	0.00	0.79	0.39
	Irrigation based	37.57	30.77	68.35	0.54	0.44	0.49
	Total land owned	37.57	86.17	123.74	0.54	1.23	0.88

Source: Primary Data

Based on the information about the total land ownership of the selected Beneficiary and non-beneficiary Farmer Respondents of the Anand and Narmada Districts in Table 02 above, the Beneficiary Respondents of the Anand District have a total of 136.89 hectares of Land. Out of which, 136.49 hectares of land is Irrigated Dependent and only 0.4 hectares of land is Rainfed. Besides, Narmada District the Beneficiary Respondents have a total of 518.79 hectares of land. Out of which, 160.03 hectares of land is Irrigated Dependent and 358.75 hectares is Rainfed. Also, the non-beneficiary Respondents of Anand District have 37.57 hectares of Irrigated land only and the non-beneficiary Respondents of Narmada District have 30.77 hectares of irrigated land and 55.39 hectares of rain-fed land out of a total of 86.17 hectares of land. Thus, the Beneficiary farmers in Anand District have a total of 1.95 hectares of land per head, and the Beneficiary farmers in Narmada District have a total of 7.41 hectares of land per head. Additionally, the non-beneficiary farmers in Anand District have a total of 0.54 hectares of land per head, and the farmers in Narmada District have a total of 1.23 hectares of land per head.

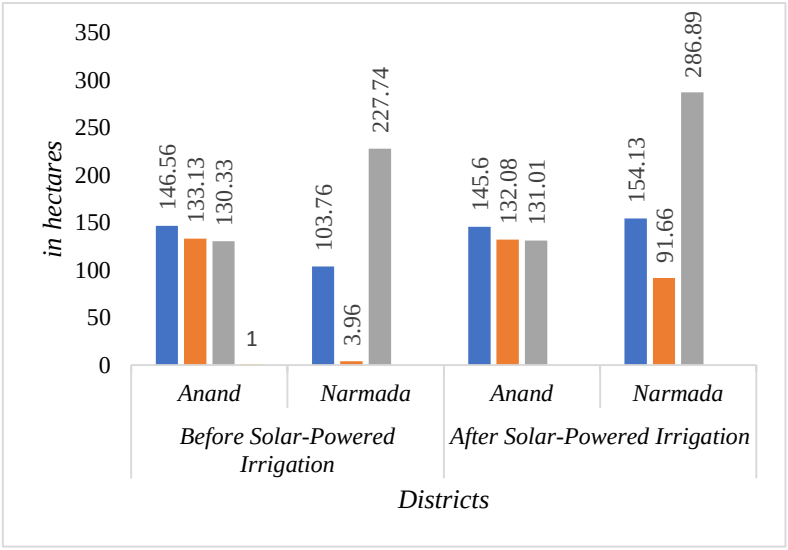
Table No. 03 Seasonal total cultivated land area before and after Solar Irrigation :

(in hectares, Year 2024-25)

No	**Detail**	**Before Solar-Powered Irrigation**		**After Solar-Powered Irrigation**		**Difference (%)**	
		Anand	**Narmada**	**Anand**	**Narmada**	**Anand**	**Narmada**
01	Winter - Total Land Area	146.56	103.76	145.6	154.13	-0.66	48.55
02	Summer - Total Land Area	133.13	3.96	132.08	91.66	-0.79	2214.65
03	Monsoon – Total Land Area	130.33	227.74	131.01	286.89	0.52	25.97
04	**Total land Area**	**410.03**	**335.46**	**408.69**	**532.6867**	**-0.93**	**2289.168**

Note: Leased land in Anand district is also included. Source: Primary Data

Table No. 03 and Chart No. 01 detail the season-wise total cultivable land area Before and After the Solar-powered Irrigation system of the Beneficiary Respondents in the Anand and Narmada Districts. According to this the total area under winter tillage in the Anand District decreased by -0.66% and increased by 48.55% in the Narmada District After Solar-powered Irrigation Compared to Before. Thus, in Anand District, the area under cultivation has decreased marginally, and in Narmada District, there has been a significant increase. Anand District showed -0.79% decrease in summer total tillable land area and a 2231.48% increase in Narmada District Thus, huge increase in Total tillable land area After Solar-powered Irrigation system in Narmada District. In Monsoon, the total cultivated land area increased by 0.52% in Anand District and 25.97% in Narmada District. Overall, the availability of Irrigation facilities in Anand District has resulted in marginal change in the area under cultivation. Whereas in Narmada District, an increase has been seen in every season.



4.1 Cropping Intensity of Land Area of Respondents in Anand and Narmada Districts:

Crop Intensity Index of Cultivated Land held by Beneficiary Respondents of Anand and Narmada Districts Table No. 04 is given.

Table No. 04 Index of Cropping Intensity :

No	*Crop Intensity Index*	
1	Very high crop intensity	> 175
2	High crop intensity	150-175
3	Medium cropping intensity	125-150
4	Low crop intensity	< 125

Source: Crop Intensity Index

If cropping intensity is defined, how many crops can be grown on a piece of land during a year is called cropping intensity. According to Table 04, if the cropping intensity score is more than 175, it is considered a very high cropping intensity. A score of 150-175 is considered high crop intensity a score of 125-150 is considered medium crop intensity and a score less than 125 is considered low crop intensity.

Table No. 05 Crop Intensity Before and After Solar Powered Irrigation of Anand and Narmada Districts: (Year 2024-25)

Cropping Intensity					
No	**Season**	**Before Solar Irrigation**		**After Solar Irrigation**	
		Anand	**Narmada**	**Anand**	**Narmada**
01	Winter Crop	280	323	281	346
02	Monsoon Crop	315	147	312	186

Source: Primary Data

According to the above table 05, the crop density figure of Anand District was 280 in winter before Solar-powered Irrigation which increased to 281 After Solar-powered Irrigation. which is a figure with very high cropping intensity. Thus, Cropping Intensity After Solar Irrigation has Marginally Increased in the Anand District as Before Irrigation facilities were sufficiently available. The crop density figure of Narmada District was 323 in Winter Before Solar-powered Irrigation which increased to 346 After Solar-powered Irrigation system, which is a very high Cropping Intensity figure. Earlier, in the Narmada District Irrigation facilities were not sufficiently available so Cropping Intensity has increased drastically After the Solar Irrigation.

The Cropping Intensity figure of Anand District in monsoon fell from 315 before Solar Irrigation to 312 After Solar Irrigation. Thus, the Cropping Intensity After Solar Irrigation is marginally reduced in Anand District as Irrigation facilities are sufficiently available. During data collection, it was learned that the Beneficiaries of Solar-powered Irrigation Pumps in Anand District (with grid connection) were dissatisfied with the high Electricity bills of the Irrigation Pumps which had a negative impact on the Agriculture Sector. Narmada District had a medium crop intensity figure of 147 in monsoon Before Solar-powered Irrigation which increased to a very high crop intensity figure of 186 After Solar-powered Irrigation. In the Narmada District, Cropping Intensity has increased drastically After Solar Irrigation as Irrigation facilities were not available earlier.

Table No. 06 Change in Total Crop Pattern Before and After Solar Irrigation in Anand and Narmada Districts :

(in Quintals, Year 2024-25)

No	**Detail**	**Before Solar Irrigation**		**After Solar Irrigation**		**Change (%)**	
		Anand	**Narmada**	**Anand**	**Narmada**	**Anand**	**Narmada**
01	Winter Total Crop	6601.1	2625	6629.1	3801	0.42	44.79
02	Summer Total Crop	5691.5	18	5414.1	500	-4.87	2677.78
03	Monsoon Total Crop	6208.9	8624	5396	9133	-13.09	5.90
					Total	-17.54	2728.47

Source: Primary Data

Table No. 06 above gives the detail of Cropping Patterns Before and After Solar Irrigation of the Beneficiary Respondents of the Anand and Narmada Districts. According to this the winter total Crop Production in Anand District before Solar Irrigation was 6601.1 quintals which increased to 6629.1 quintals After Solar Irrigation thus, the total Crop Production in Anand District increased by 0.42%. Total winter Crop Production in Narmada District was 2625 quintals before Solar Irrigation which increased to 3801quintals After Solar Irrigation. Thus, the total crop has increased by 44.79% in the Narmada District. Anand District showed marginal change due to adequate Irrigation facilities before Solar Irrigation whereas, in Narmada District, the production increased drastically After Solar Irrigation, and the total Summer Crop decreased by -4.87% in Anand District. Earlier, as Irrigation facilities were not available in Narmada, very few farmers used to harvest crops in summer. However, due to the availability of sufficient Irrigation facilities After Solar Irrigation in Narmada District, there has been an increase of 2677.78% in production. In the Anand

District, there was a decrease of -13.09% in the total monsoon crop After Solar Irrigation, while in the Narmada District, there was an increase of 5.90%. Thus, solar irrigation pumps have proved beneficial in the Narmada district as compared to the Anand district.

05. Interpretation of Result:

5.1 Conclusions:

- Beneficiary farmers with Solar-powered Irrigation Pumps in the Anand and Narmada Districts have a higher proportion of Agricultural tools compared to non-Beneficiary farmers. Thus, it can be said that farmers with Solar Irrigation Pumps are economically more stable than non-beneficiary farmers.
- The selected beneficiaries in the Anand and Narmada Districts have a higher per capita land ratio compared to the non-beneficiaries. Additionally, farmers in the Narmada District have more land compared to farmers in the Anand District. Due to the availability of Irrigation facilities in Anand District, a greater area of land under Irrigation has been observed in Anand compared to Narmada District.
- After Solar-powered Irrigation the cultivated area has increased manifold in Narmada District as compared to Anand District. Thus, Solar-powered Irrigation Pump have proved to be more beneficial in the Narmada District. As Irrigation facilities were not available in the Narmada District before Solar Irrigation, the area under summer cultivation has increased manifold After Solar Irrigation. Thus, Solar Irrigation has proved to be very fruitful in summer.
- In Anand District, there has been a slight increase in winter Cropping Intensity figure After Solar Irrigation due to adequate availability of Irrigation facilities before Solar Irrigation. Whereas, a grid line is not available in the Agricultural sector in the Narmada District and as sufficient Irrigation facilities are not available, the intensity of cropping in the Narmada District has greatly increased After Solar Irrigation.
- has a total of -17.54% decrease in crop yield in the after Solar Irrigation Anand District and a 2728.47% increase in the Narmada District After Solar Irrigation as compared to before Solar Irrigation. Thus, Solar Irrigation has become very beneficial for Narmada District. Due to the non-availability of Irrigation facilities in the Narmada District, the area under cultivation has increased massively in the summer.

5.2 Suggestions :

Considering some of the problems faced by the farmers during this study, the following suggestions have been made.

Most of the Beneficiary Respondents in the Anand and Narmada Districts do not have adequate guidance on meter readings of Electricity generated by Solar. Therefore, the Beneficiary Respondents should be given proper guidance by arranging guidance or training Also, a center should be set up at the local level to troubleshoot Solar-powered Irrigation Pump sets and the insurance company should protect rapidly damaged panels. Under the PM-KUSUM scheme, (Human operated) direction replaceable panels are provided. Whereas fixed panels are provided under the Suryashakti Kisan Yojana (SKY). Instead, panels should be provided with innovative technology that can automatically change direction according to the sun's rays. In the Narmada District, farmers face many problems including Irrigation due to the lack of grid connection in Agricultural areas. Hence, the government should make efforts to connect the Agricultural sector to the grid line in Narmada District. So necessary Irrigation is possible in monsoons because the efficiency of Solar panels is less due to cloudy weather in monsoons. In the Narmada District, water irrigated in summer does not reach plant roots due to drying up. In the Narmada District, very few sections practice drip Irrigation. Hence, the government should provide subsidized financial support so that the drip method is used and the height of the panel should be high so that the lower part of the panel can be used.

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