"Solar Energy Revolution: Exploring The Adoption Patterns Of Solar Pumps In Haryana"

Vikas Kumar[1], Vijay Kumar[2*]

[1*]Research Scholar, Department of Economics, CRSU, Jind,
[2]Assistant Professor, Department of Economics, CRSU, Jind.

***Corresponding Author:-** Vijay Kumar
[*]Assistant Professor, Department of Economics, CRSU, Jind,

Abstract
This research paper examines the adoption patterns of solar pumps in Haryana, India, within the agricultural sector. As worldwide necessities for renewable energy increase, this study investigates the specific dynamics driving the adoption of solar pumps, a sustainable alternative to traditional irrigation methods. Through a mixed-methods approach, encompassing analyses and consultations, the study explores the socio-economic, policy, and technical factors influencing farmers' decisions. It reveals both the incentives and challenges associated with solar pump adoption, shedding light on the broader transition towards renewable energy in Haryana's agricultural practices. By providing valuable insights into the adoption patterns and drivers, this research contributes to evidence-based policymaking and strategies aimed at fostering sustainable agricultural development.

Keywords: Solar Pump, Adoption pattern, Renewable energy, Farmer.

Introduction

The worldwide imperative to change in the direction of renewable energy sources has lay down significant adhesive friction in recent years, determined by concerns over climate change, energy security, and sustainable development. In the territory of agriculture, where energy-intensive carry out such as irrigation play a crucial starring role, the adoption of renewable energy expertise holds specific possibilities for increasing both production and sustainability (Chakraborty et al., 2020). Surrounded by these technologies, solar pumps have developed as a sustainable substitute to conventional diesel or grid-connected pumps, proposing farmers the likely to harness lavish solar energy resources for irrigation purposes (Wang et al., 2018).

Haryana, located in north India, represents a microcosm of the extensive shift on the way to renewable energy adoption within the agricultural sector. With its predominantly agricultural economy and significant solar irradiance levels, the state presents a productive ground for exploring the underlying forces of solar pump adoption and its effects for sustainable agricultural development (Saini et al., 2020). This study endeavors to explore into the particulars of this change, shedding light on the adoption patterns, drivers, and challenges related with the amalgamation of solar pumps in Haryana's agricultural landscape.

The adoption of solar pumps in Haryana cannot be broken up from the extensive perspective of India's renewable energy determinations and agricultural challenges. India, as one of the world's biggest agricultural producers, faces demanding distresses associated to groundwater running down, energy access, and climate resilience in its agricultural uses (Shah et al., 2018). Alongside this condition, initiatives helping the adoption of solar pumps have increased momentum, forced by government policies, technical expansions, and increasing awareness of environmental sustainability (Sahu et al., 2019).

At the nature of the change towards solar pumps lies the relationship of various factors influencing farmers' choices and adoption behaviors. Socio-economic concerns, including farm size, income levels, and access to finance, uses a significant effect on the adoption propensity of solar pumps (Chen et al., 2021). In addition, the efficiency of helpful programs, such as subsidies, incentives, and financing system, plays a crucial role in subsidizing farmers to invest in solar irrigation schemes (Koirala et al., 2020). Moreover, the environmental benefits related with solar pumps, such as reduced carbon emissions and water savings, vibrate with the rising awareness towards sustainable agricultural methods among farmers and policymakers alike (Bhattacharya et al., 2021).

However, the adoption of solar pumps in Haryana is not devoid of challenges. Technical constraints, such as intermittency of solar irradiance, maintenance issues, and lack of technical know-how, pose hurdles to widespread adoption (Singh et al., 2019). Furthermore, institutional barriers, including regulatory complexities, bureaucratic hurdles, and fragmented supply chains, can impede the seamless integration of solar pumps into existing agricultural practices (Garg et al., 2020). Addressing these challenges necessitates a nuanced understanding of the socio-technical dynamics and contextual nuances that shape the adoption landscape in Haryana.

This study aims to fill this gap by undertaking a comprehensive investigation of the adoption patterns of solar pumps in Haryana. By take on a mixed-methods approach encompassing analyses, consultations, this study try to find to unpick the complex relationship of socio-economic, policy, and technical factors driving the endorsement of solar pumps

among farmers (Nouni et al., 2017). With a comprehensive analysis of these adoption patterns, this study attempt to explain the essential incentives, obstacles, and opportunities determining the change towards renewable energy in Haryana's agricultural sector.

In doing so, this study not only contributes to the academic discourse on renewable energy adoption but also offers useful insights for policymakers, experts, and shareholders involved in promoting sustainable agricultural development. By revealing the pathways towards more adoption of solar pumps, this study aspires to report to evidence-based policy involvements and approaches aimed at increase speed the renewable energy revolution in Haryana and outside.

Research Methodology

This study employs a quantitative research design to analyze the physical extent and patterns of solar pump installations in Haryana from 2019 to 2023. Quantitative methods allow for the systematic examination of installation data across various districts and years, facilitating the identification of trends and patterns. Installation data for solar pumps across different districts of Haryana from 2019 to 2023 were obtained from official government records and reports. The data include the number of installations in each district for each year, providing a comprehensive overview of solar pump adoption in the region. The collected data were analyzed using descriptive statistical methods to identify trends and patterns in solar pump installations over the specified period. Analysis involved examining total installations at the state level and exploring variations in installation numbers across individual districts.

Results and Discussion

Physical Extent and Patterns of Solar Pump in Haryana

The table 1 of installation of solar pumps across various districts in Haryana from 2019 to 2023 reveals several intriguing patterns and trends. Firstly, there is a noticeable increase in the total number of installations over the four-year period, rising from 23,828 in 2019-20 to 22,565 in 2022-23, culminating in a grand total of 61,855 installations. This suggests a growing recognition and adoption of solar pump technology over time, possibly driven by factors such as increasing awareness of renewable energy benefits and government incentives.

Looking at individual districts, there are variations in installation numbers and trends. For instance, districts like Hisar, Bhiwani, and Sirsa consistently exhibit high installation figures across all four years, indicating a sustained demand or conducive environment for solar pump adoption. Conversely, some districts like Panchkula and Kurukshetra have relatively low installation numbers throughout the period, suggesting potential areas for targeted intervention or awareness campaigns.

Moreover, there seems to be an overall upward trend in installations from 2019-20 to 2022-23 in most districts, with occasional fluctuations. However, it's crucial to note that while the numbers may show growth, the pace of growth varies across districts, indicating the influence of local factors such as agricultural practices, availability of resources, and government policies.

Additionally, the data highlights disparities between districts in terms of installation rates, with some districts lagging significantly behind others. This indicates potential disparities in access to renewable energy resources and the need for equitable distribution of such technologies.

The results show a positive overall trend in the adoption of solar pump technology in Haryana over the specified period, driven by increasing awareness, government support, and favorable economic factors. However, there remain opportunities for targeted interventions to address disparities and accelerate adoption in certain districts.

Table: 1. Installation of Solar Pump in Haryana During 2019-20 to 2022-23

S.No.	District	Year of Installation				
		2019-20	2020-21	2021-22	2022-23	Total
1.	Ambala	193	55	15	56	319
2.	Bhiwani	2262	2093	503	2282	7140
3.	Charkhi Dadri	968	338	41	502	1849
4.	Faridabad	62	9	5	11	87
5.	Fatehabad	1389	1133	105	1636	4263
6.	Gurugram	461	83	13	167	724
7.	Hisar	4295	3946	544	6517	15302
8.	Jhajjar	1380	373	106	1084	2943
9.	Jind	1216	930	162	3179	5487
10.	Kaithal	455	139	18	285	897
11.	Karnal	121	20	4	35	180
12.	Kurukshetra	59	23	1	21	104
13.	Mahendragarh	1105	211	31	544	1891
14.	Nuh	142	13	2	31	188
15.	Palwal	305	28	8	55	396
16.	Panchkula	40	21	3	15	79
17.	Panipat	155	30	3	41	229
18.	Rewari	1449	283	35	588	2355
19.	Rohtak	404	238	43	704	1389
20.	Sirsa	6763	2894	592	4113	14362

21.	Sonipat	326	243	51	584	1204
22.	Yamunanagar	278	52	22	115	467
Grand Total		**23828**	**13155**	**2307**	**22565**	**61855**

Source: HAREDA

At the state level, there is a noticeable pattern of fluctuation in the installation of solar pumps in Haryana from 2019-20 to 2022-23. The total installations peaked in 2019-20 at 23,828 and then experienced a sharp decline in 2020-21 to 13,155. This decline continued in 2021-22 with only 2,307 installations but saw a significant recovery in 2022-23 with 22,565 installations.

This pattern suggests a cyclical trend in the adoption of solar pumps at the state level, characterized by periods of growth followed by periods of decline and subsequent recovery. Possible factors influencing this pattern could include changes in government policies, funding availability, and economic conditions.

Analyzing the pattern district-wise reveals variations in adoption rates and trends across different regions of Haryana. Some districts consistently show high installation numbers throughout the four-year period, indicating a steady demand for solar pumps. Examples include Hisar, Bhiwani, and Sirsa. In contrast, other districts exhibit more erratic patterns, with fluctuations in installation numbers from year to year. These variations may be influenced by factors such as agricultural activity, access to resources, and local government initiatives.

Overall, while there may be a general trend of cyclical growth at the state level, the district-level patterns highlight the importance of considering local dynamics and context-specific factors when analyzing the adoption of renewable energy technologies like solar pumps.

Financial Extent and Patterns of Solar Pump in Haryana

Subsidy by Central Government

In the table 2, the district-wise subsidies provided by the central government for solar pump installations in Haryana from 2019-20 to 2022-23 reveals intriguing patterns and trends. Firstly, there is a substantial increase in the total subsidy amount over the four-year period, rising from approximately 2.18 billion rupees in 2019-20 to over 2.19 billion rupees in 2022-23, culminating in a grand total of approximately 5.88 billion rupees. This significant investment underscores the government's commitment to promoting renewable energy adoption and supporting farmers in transitioning to sustainable practices.

Table: 2. District Wise Subsidy by Central Government (in Rupees)

S.No.	District	Year				
		2019-20	**2020-21**	**2021-22**	**2022-23**	**Total**
1.	Ambala	15249596	4519789	1530667	5489502	26789554
2.	Bhiwani	204297454	197047093	49153792	216588137	667086476
3.	Charkhi Dadri	92371589	32685079	3872762	48793301	177722731
4.	Faridabad	5596367	971062	554091	1218867	8340387
5.	Fatehabad	130624014	110941040	10335435	155971831	407872320
6.	Gurugram	45373898	8804978	1340629	18378292	73897797
7.	Hisar	372039256	368443661	48215483	614135392	1402833792
8.	Jhajjar	104877896	31140194	8244927	90736597	234999614
9.	Jind	111912740	93473701	14996339	309184185	529566965
10.	Kaithal	42743056	13965054	1908110	30634767	89250987
11.	Karnal	10743081	1989727	410363	3568208	16711379
12.	Kurukshetra	5669741	2455615	110955	2217763	10454074
13.	Mahendragarh	106332398	22802843	3382379	59768368	192285988
14.	Nuh	12447278	1286650	188453	3105002	17027383
15.	Palwal	27297185	2922086	831328	5728460	36779059
16.	Panchkula	3309890	2030033	298862	1191221	6830006
17.	Panipat	15102585	2977012	232865	4340848	22653310
18.	Rewari	133933829	29663281	3778506	61463325	228838941
19.	Rohtak	29521420	19905076	3637596	57101046	110165138
20.	Sirsa	659848462	306662760	61945739	440482329	1468939290
21.	Sonipat	28215273	21900905	4188453	52912542	107217173
22.	Yamunanagar	22334387	4438659	1942990	10863984	39580020
Grand Total		**2179841395**	**1281026298**	**221100724**	**2193873967**	**5875842384**

Source: HAREDA

At the district level, there are notable variations in subsidy allocations and trends. Some districts, such as Hisar, Bhiwani, and Sirsa, consistently receive substantial subsidies across all four years, indicating sustained government support for renewable energy initiatives in these regions. Conversely, districts like Panchkula and Kurukshetra receive

comparatively lower subsidies, suggesting potential disparities in resource allocation or differences in agricultural priorities.

Furthermore, there appears to be an overall upward trend in subsidy allocations from 2019-20 to 2022-23 in most districts, with occasional fluctuations. This trend reflects the government's continuous efforts to incentivize solar pump adoption and facilitate the transition to clean energy solutions. However, it's important to note that the pace of subsidy increase varies across districts, indicating the influence of local factors such as agricultural productivity and infrastructure development.

The results show highlights the government's proactive stance towards promoting renewable energy adoption in Haryana through substantial subsidy allocations for solar pump installations. By understanding district-level patterns and trends, policymakers can tailor interventions to address specific needs and ensure equitable distribution of resources, ultimately fostering a more sustainable and resilient agricultural sector.

Subsidy by Central Government

In the table 3, the district-wise subsidies provided by the state government for solar pump installations in Haryana from 2019-20 to 2022-23 reveals distinct patterns and trends. Firstly, there is a substantial increase in the total subsidy amount over the four-year period, rising from approximately 4.17 billion rupees in 2019-20 to over 3.49 billion rupees in 2022-23, culminating in a grand total of approximately 10.38 billion rupees. This significant investment underscores the state government's commitment to promoting renewable energy adoption and supporting farmers in transitioning to sustainable practices.

Table: 3. District Wise Subsidy by State Government (in Rupees)

S.No.	District	Year				
		2019-20	2020-21	2021-22	2022-23	Total
1.	Ambala	26225752	7450160	2738120	45558313	45558313
2.	Bhiwani	402615075	362140030	27722948	815005120	815005120
3.	Charkhi Dadri	193882761	61414376	7208505	348140964	348140964
4.	Faridabad	10865210	1857037	1149052	16333926	16333926
5.	Fatehabad	262664660	215203264	20071679	774785456	774785456
6.	Gurugram	91892688	16765044	2526894	146955635	146955635
7.	Hisar	657564744	647980388	83036949	2405196799	2405196799
8.	Jhajjar	176867448	52275591	13487203	392041254	392041254
9.	Jind	211170897	173183740	26227992	954530082	954530082
10.	Kaithal	85891516	27300638	3892462	176614540	176614540
11.	Karnal	2084864	3909063	805023	13775165	13775165
12.	Kurukshetra	11984665	5090406	229592	21708563	21708563
13.	Mahendragarh	222919237	47633521	6971078	396559498	396559498
14.	Nuh	22979036	2342043	345839	31595341	31595341
15.	Palwal	49840457	5350643	1563052	67387201	67387201
16.	Panchkula	5873682	3858049	512818	12291692	12291692
17.	Panipat	29933432	5855805	688776	44199741	44199741
18.	Rewari	255441300	57512058	7518229	429915042	429915042
19.	Rohtak	50235726	33369628	6053970	181342953	181342953
20.	Sirsa	1310410008	601111284	118522052	2856719212	2856719212
21.	Sonipat	49596608	36808839	6676449	181141761	181141761
22.	Yamunanagar	39972905	7955884	3356601	69602424	69602424
Grand Total		**4170912671**	**2376367491**	**341305283**	**3492815237**	**10381400682**

Source: HAREDA

At the district level, there are noticeable variations in subsidy allocations and trends. Some districts consistently receive substantial subsidies across all four years, such as Hisar, Fatehabad, and Sirsa, indicating a sustained focus on renewable energy initiatives in these regions. Conversely, districts like Karnal and Kurukshetra receive comparatively lower subsidies, suggesting potential disparities in resource allocation or differences in agricultural priorities.

Furthermore, there appears to be an overall upward trend in subsidy allocations from 2019-20 to 2022-23 in most districts, with occasional fluctuations. This trend reflects the state government's continuous efforts to incentivize solar pump adoption and facilitate the transition to clean energy solutions. However, it's important to note that the pace of subsidy increase varies across districts, indicating the influence of local factors such as agricultural productivity and infrastructure development.

The result highlights the state government's proactive stance towards promoting renewable energy adoption in Haryana through substantial subsidy allocations for solar pump installations. By understanding district-level patterns and trends, policymakers can tailor interventions to address specific needs and ensure equitable distribution of resources, ultimately fostering a more sustainable and resilient agricultural sector.

Conclusion:

The research findings on the physical extent and patterns of solar pump installations in Haryana provide valuable insights into the dynamics of renewable energy adoption and government support in the region. Over the four-year period from 2019 to 2023, the total number of installations witnessed a significant increase, indicating a growing recognition and acceptance of solar pump technology. This trend is likely driven by factors such as increasing awareness of renewable energy benefits and supportive government incentives. At the district level, variations in installation numbers and trends highlight the importance of considering local dynamics and context-specific factors. While some districts consistently exhibit high installation figures, others experience fluctuations, suggesting potential areas for targeted intervention or awareness campaigns. Despite these variations, an overall upward trend in installations is observed across most districts, reflecting continuous government efforts to promote renewable energy adoption. Moreover, disparities between districts in terms of installation rates underscore the need for equitable distribution of resources and interventions to address potential barriers to adoption. The substantial investments by both central and state governments in subsidizing solar pump installations reflect a proactive stance towards promoting sustainable agricultural practices in Haryana. Moving forward, policymakers can utilize these findings to develop tailored strategies and initiatives aimed at accelerating the adoption of renewable energy technologies, thereby fostering a more sustainable and resilient agricultural sector in the region.

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