Understanding the factors driving the deployment of solar irrigation pump-sets in India

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ABSTRACT. The research focuses on deriving the factors driving the deployment of solar pump-sets and understanding how these factors are dependent on each other. To understand these factors, a survey was shared with the experts in the field, and their responses were analyzed using IBM SPSS software by Pearson's bivariate correlation. An empirical study was conducted using factor analysis. The electricity consumption in agriculture is rising exponentially, and electricity consumption is highly correlated to the number of energized pump-sets. The analysis grouped these drivers into three components. This study emphasizes three factors identified by considering state government, different nodal agencies. Due to the electricity subsidy provided to agriculture and residential consumers, the difference between the average revenue realized, and the average cost of supply of the distribution company is also constantly increasing, which creates financial losses and virtual bankruptcy. Electricity supplied to this sector is subsidized, which creates financial losses to the distribution companies. Financial institutions, power distribution companies, and the role of farmers in the deployment of solar pump-sets for irrigation.

Keywords: Solar Pump Sets, Deployment, Renewables, Solar Irrigation, Distribution Companies.

INTRODUCTION

India's installed grid-connected renewable energy capacity is 84 GW as of December 2019. In INDC (Intended Nationally Determined Contribution), [1] India has stated the goal of installing 175 Gigawatts(GW) of renewable power capacity, including solar energy capacity of 100 Gigawatts by 2022. The cabinet has approved a grid-connected solar power target to increase from 20,000 MW of grid-connected solar power projects to 100 Gigawatt by 2022(Ministry of New and Renewable Energy, 2019b). [2] India also plans to increase its India will also scale up its installed non-fossil fuel capacity to 40% by 2022. To achieve these targets by solar PV-based power, India can develop solar parks, adopt solar energy for rooftop, develop canal top projects and promote irrigation practices employing solar water pump-sets.

India had only 5000 mechanized pumps in 1951, but their numbers have increased to 30 million pump-sets by 2019. [3] The electricity consumption in agriculture is rising exponentially, and electricity consumption is highly correlated to the number of energized pump-sets. India's 17% power utilization is done solely by the agricultural sector. Electricity supplied to this sector is subsidized, which creates financial losses to the distribution companies.[4] Due to the electricity subsidy provided to agriculture and residential consumers, the difference between the average revenue realized, and the average cost of supply of the distribution company is also constantly increasing, which creates financial losses and virtual bankruptcy.

By implementing and promoting schemes such as PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha UtthanMahabhiyan), which includes installing SPV (Solar Photovoltaic) power plant, off-grid and on-grid solar pumps for the agriculture sector, the government is trying to reduce the financial loss of distribution companies. [5] It also provides farmers opportunities to earn by selling surplus generated power and increasing the yield of crops on the farm where a constant supply of electricity is not available.

Dr. KeyurThaker also stated that Energy Companies, Distribution companies, and the Indian Government would be benefitted if farmers began to install solar water pump-sets.In a report conducted by Dr. Shikha Suman for Andhra Pradesh and Chhattisgarh, she has stated that there was a significant improvement in crop quantity and crop quality due to the installation of solar-powered pumps. [6] She has also found that due to solar-powered irrigation pumps, the number of farmers that earn more than Rs 100,000 per annum has more than doubled, from a mere 26% to a strong 58%. Hence the deployment of solar pump-sets can be advantageous for Distribution companies and farmers and other beneficiaries.

To enable the large-scale deployment of solar pumps, it is very important to understand the factors responsible. [7] This study aims to identify the drivers for the large-scale deployment of solar water pump-sets in India through an empirical model developed using IBM SPSS.

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LITERATURE REVIEW

India accounts for 30 million irrigation pump-sets and expects an addition of 1 million solar irrigation pumps every year. In an annual report published by the Ministry of New and Renewable Energy, it is stated that India has more than 0.247 Million solar pump-sets. There are numerous mechanisms to support Renewable Energy Technology development and deployment, such as grants, tax generation-based incentives. When considering the solar pump sets, other attributes discussed below also play an important role.

Attribute 1: Various state government initiatives in promoting and deploying solar pump-sets.

Apart from geographical feasibility, political feasibility is another important reason for the deployment of renewable energy. India follows the federal administration system where the central government focuses on policy-making, and the state government is responsible for both the policy-making and its implementation. [8] Therefore, the state government's initiative to deploy and promote solar pump-sets plays a crucial role. Moreover, the large-scale acceptance of sustainable land and water management practices needs a political push for encouraging financial and institutional support to enable widespread usage of sustainable agricultural practice, which implies that support from political and financial institutions plays a crucial role in deploying the large-scale adoption of solar pump-sets.

Busby and Shidorehave also pointed out that although the central government has effectively pushed the adoption of agricultural pump-sets, some states significantly lag behind others. Each state adopts a different strategy to push renewables in its territory. [9] Also, in another study, they have mentioned that the electricity sector shows fragmented governance. This is why different states are using different strategies for deploying solar pumps.

For instance, Madhya Pradesh has launched a solar pump scheme, Chhattisgarh has also launched Saur SujalaYojna. It has installed more than 60000 pump-sets which is the highest among all states in India. On the contrary, in the western part of India, specifically in Maharashtra, the government focuses on connecting on-grid pumps to feeder lines to solar generating stations at the district or sub-district level.

Attribute 2: Support from the financial institution for providing loans for Solar pump/panel manufacturers or service providers is important for driving the deployment of solar pumps in India.

Attribute 3: Distribution company's and state nodal agency's initiative in deploying and promoting solar pump-sets is important for driving the deployment of solar pumps in India.

According to the previously done studies on the successful development and deployment of renewable energy technologies.[10] It is stated that the acceptance of renewable energy is driven by support from different institutions such as local and state institutional bodies.

Studies also prove that loans and guarantees lower the uncertainty faced by the investors, which helps promote the deployment of renewable energy. Therefore financial institutions must be aware of existing policies in the sector. [11]Shalu Agrawal and Abhishek Jain also suggested that educational drives shall be conducted in which the focused audiences must include financial institutions and local knowledge networks.

As per the study by the United Nations University, World Institute in 2014, one of the few constraints in the transition of energy is that many distribution companies are still in debt with over US$2.5 billion. In work done by Busby and Shidore, they have also pointed out that distribution companies are important players who determine the scaling up of solar energy in India. Still, state nodal agencies have been assigned for their deployment when solar pump-sets are concerned, and promotion also plays a significant role.

Attribute 4:Awareness and confidence among the farmers and other beneficiaries for solar pump-sets.

In a study by the United Nations World Institute, it is mentioned that the government's push for the deployment of any successful renewable energy technology is also dependent on geographical and technological factors. For the widespread deployment of any technology, customer's confidence, trust, and acceptance also play a crucial role. [12] Apart from policymakers and financial institutions, stakeholders such as farmers and other consumers must be aware of the solar pump-sets by demonstrating the technology and application in fields. It shall also be made sure that the stakeholders have confidence in the technology and quality as well.

In a previous study done for the Rajasthan region, 18 out of 107 farmers complained about faulty solar pump-sets connections. The study also mentioned that having confidence in the product is an essential factor with being aware of it. One of the possible ways to build consumer's trust over time is by consistently maintaining the quality standards and focusing on providing reliable service after installation.

Attribute 5: The government's grants and subsidies are important for driving the deployment of solar pumps in India.

Raymond and Abhishek Jain have mentioned that solar pumps are an alternate solution to conventional diesel pump sets. They have also mentioned that supporting standalone pumps are more economically feasible when compared to supporting grid-connected solar pumps because electricity given to farmers is heavily subsidized rather than cross-subsidized. A farmer with a grid connection is unlikely to invest in a solar pump despite benefiting from heavily subsidized solar pump sets.[13] Recently the government has also planned to solarize the existing feeders to reduce the burden of subsidy on solar pump-sets for the state; however, stand-alone solar

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pump-sets would remain feasible for the area without stable electricity because buying a subsidized solar pump is more cost-effective than buying water for irrigation or to rent the conventional diesel pumps for irrigation.

The cost of subsidy on electricity for agriculture purposes is boring both by the distribution company and commercial/industrial consumers in the form of cross-subsidy. To minimize this problem, the government of India had come up with Pradhan Mantri Kisan Urja Suraksha UtthanMahabhiyan (PM KUSUM). It is a flagship program in which the central government gives 30% cost of the pump-set as CFA (Central Financial Assistance), 30% cost of the pump-set is provided by the state government as a subsidy. The remaining 30% of the funds are to be financed by banks, and the upfront money which the farmer has to pay is 10% of the actual cost of solar pumps. These subsidy helps to reduce the initial investment cost for the farmer and plays an important role in the deployment of solar pump-sets.

Attribute 6:Transparency of nodal agency in the bidding process and in releasing funds.

In the previous study, it has been seen that not having a standardized bidding system or having a bureaucratic bidding process leads to a problem in renewable energy adoption.[14] More often than not, complex bidding procedures cause a delay in projects. Hence, it is very important to have an open and transparent bidding system or framework to enable ease of doing business.

Attribute 7: Government's commitment to achieving 40% installation capacity from non-fossil fuel sources by 2030.

Many states have set renewable purchase obligation targets, yet due to ineffective implementation and insufficient penalties and dues, only a few distribution companies comply with them.[15] To fulfill the Intended Nationally Determined Contribution, each distribution company must comply with RPO targets. We think this is one of the factors why the central government has come up with the KUSUM scheme to upscale the installation of renewable energy.

In the previous study, it has been shown that water and energy consumption are interrelated, and irrigation accounts for the highest consumption of energy in the agricultural sector. A major part of this energy consumption is from conventional energy sources. [16] Hence, by replacing the conventional pump-sets with solar-powered irrigation pump-sets, a portion of the RPO can be fulfilled and can also aid in achieving 40% of the installed renewable energy capacity by 2022.

It has also been claimed in a report published by the Ministry of Environment Forest and Climate Change that the groundwater is depleting, leading to depleted ground-water levels. So, more energy is required while pumping the water from a more deep water table. It is also found that 2-7% of carbon dioxide emissions result from groundwater irrigation. India is also determined to cut down its greenhouse gas (GHG) emissions.

Although renewable energy has higher capital costs, it has significant potential to reduce GHG emissions during the operation phase. Previously done studies also indicate that the key drivers of using renewable energy in the water industry include policy supporting the mandatory reduction of greenhouse gas emissions. Hence, these policies and targets also become an important factor for accelerating the deployment of solar pump-sets.

RESEARCH DESIGN

A research design is the foundation of research. A careful study design can help reduce the possibility of measurement errors. A research design provides a framework of how the research should be further conducted. [17] In this study, it was divided into three stages, where the first stage included understanding the scenario of solar pump market in India by carrying document reviews, attending webinar related to solar pump market, interviewing the director of the company working in solar pump domain, understanding the perspective of project lead working in the nodal agency by writing emails.

The second stage consisted of developing questions, selecting, and connecting to experts with relevant experience in the sector. [18] The questionnaire was reviewed by an industry expert before floating to the selected audience for the survey and was floated online through various mediums. The third stage included eliminating unnecessary responses from those not having relevant work experience in the domain.

The third stage included analyzing the responses using descriptive statistics to support the drafted attributes. Further, a correlation between the considered attributes was developed using Pearson's bivariate correlation analysis. These variables were drawn into three factors using factor through factor analysis in IBM SPSS software. In the factor analysis, various dependent or correlated variables are drawn into groups of relatively similar attributes.

DATA COLLECTION

Survey Instrument:

A questionnaire was used to collect the responses consisting of ten questions. A brief understanding of why the survey is conducted was mentioned at the beginning of the questionnaire. Respondents were then asked questions that included their name, e-mail, and company address before proceeding to the next set of questions.[19] The next set of questions included work experience, area of expertise to understand whether the respondent is experienced in the solar pump domain or not.

Further, the drawn attributes were asked to be rated on a Likert scale of 1 to 5(Hartley, 2014), where 1= "strongly disagree" and 5= "strongly agree."

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Characteristics of data

During data collection, contact details of top management, managers, and chief engineers of the companies working or having experience in solar pump and panel services, government organizations including Chhattisgarh Renewable Energy Development Authority (CREDA), Chhattisgarh State Power Distribution Co. Ltd. (CSPDCL), Power Grid limited, non-profit organisation; Council of Energy Environment and Water (CEEW), Solar Energy Society of India (Indian section of the International Solar Energy Society), academicians and research associates having expertise in the domain were gathered. [20] A database was developed before distributing the survey, and they were contacted through different online platforms. The total number of responses collected from the survey was 101. However, 17 responses were eliminated,. The sample size was reduced to 84 because the participants did not fully complete the survey or did not have work experience in the required domain.

Response Analysis

Descriptive Analysis of Responses:

In the questionnaire, the Likert scale was used. Hence the responses were not normal in nature as well as they were not continuous. Usually, mode and median should be used to compare the responses while using the Likert scale because the mode and median signify the central tendencies, and the points in a Likert scale are considered ordinal. However, in this particular case, the median and mode of each attribute are the same.So, to gain more clarity for the comparison, it is assumed that the interval between each point in the scale is considered the same by the respondents. It has been seen that in a five-point Likert scale, participants avoid using extremities, so the last row in Table 1 has been added tohighlightthefactor for which the highest number of respondents chose neutral opinion. Hence, the last row here signifies that the highest number of respondents chose neutral opinion indicating that they are unsure or unsatisfied with that particular attribute.

Measurements		A1	A2	A3	A4	A5	A6	A7
N	Valid	84	84	84	84	84	84	84
	Missing	0	0	0	0	0	0	0
Mean		4.10	4.01	3.89	3.96	3.96	3.88	3.62
Median		4.00	4.00	4.00	4.00	4.00	4.00	4.00
Mode		4	4	4	4	4	4	4
Std. Deviation		.887	.885	1.006	1.113	.950	.962	1.005
Number of participating with neutral choice		8	8	14	25	28	26	30

Table 1: Descriptive Statistics

RESULTS AND DISCUSSION

Seven attributes that drive the deployment of solar pumps have been derived by reviewing the literature. When considering the mean in Table 1: Descriptive Analysis, the data suggests the factor that experts think drives the deployment of solar irrigation pumps most"the state government's initiative in promoting and deploying the solar pump-sets." It is followed by "support from financial institutions provided to manufactures and service providers of solar pumps."However, the attribute"Government's commitment to achieving 40% installation capacity from non-fossil fuel sources by 2030" was rated as the least important factor by the highest number of respondents compared to other attributes.

CORRELATION ANALYSIS

The attributes considered above are not independent, so to understand the relation between them, co-relation analysis has been performed using IBM SPSS.

		A1	A2	A3	A4	A5	A6	A7
A1	Various state government initiatives in promoting and deploying solar pump-sets.	1						
A2	Support from the financial institution for providing loans for Solar pump/panel manufacturers or service providers.	.352**	1					
A3	Distribution company's and state nodal agency's initiative in deploying and promoting solar	.282**	.191	1				

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	pump-sets.							
A4	Awareness and confidence among the farmers and other beneficiaries for solar pump-sets.	.199	.013	.190	1			
A5	The government provides grants and subsidies.	.262*	.173	.248*	.363**	1		
A6	Transparency of nodal agency in the bidding process and in releasing funds.	.141	.228*	.348**	.142	.312**	1	
A7	Government's commitment to achieving 40% installation capacity from non-fossil fuel sources by 2030.	-.094	.195	-.041	.235*	.188	.227*	1

Table 2: Output of correlation analysis

Attribute one and Attribute 2: It can be observed that the "Government's initiative in promoting and deploying solar pump-sets" and "support from the financial institution for the provision of loans solar pump/panel manufacturers or service providers" are highly correlated in 99% confidence level (0.01 significance). Table 2 shows the Output of correlation analysis. It can be understood that support from the financial institution for any sector is highly dependent on the policy and initiatives taken by the government to promote a particular sector.

Attribute 1 and Attribute 3: The distribution company's initiative to promote a particular technology depends upon the support provided by the government. It can be best explained by considering the example of the PM-KUSUM(Pradhan Mantri Kisan Urja SurakshaUtthanMahabhiyan) scheme where the state government is providing financial support for 30% cost of solar pump-sets to the nodal agencies in some states or distribution companies in other states like Maharashtra. Hence, both the state governments and nodal agency play a significant role in successfully deploying solar pump-sets.

Attribute four and Attribute 5: A high correlation is also found between grants and subsidies provided by the government (attribute 5), and awareness and confidence among the farmers and other beneficiaries for solar pump-sets are important for driving the deployment of solar pumps in India (attribute 4). A farmer will agree to spend on machinery having high initial expenditure if substantial financial support is given in terms of subsidy, provided he/she must believe that the particular technology will be beneficial in fora long run.

Attribute six and Attribute 3: The correlation between distribution company/state nodal agency's initiative in deploying and promoting solar pump-sets(attribute 3) and Transparency of nodal agency in the bidding process and in releasing funds (attribute 6) can be justified because a successful deployment through the tender is possible only when the bidding process is smooth, open and transparent. Timely payment of funds by nodal agencies to the bidders also improves bidders' confidence for investing in the sector. Most of the bidding process is carried out in the solar pump sector by implementing agencies like nodal agencies or distribution companies. Their initiatives in this direction make the process transparent, attracting more participants to register for the tender and reducing the risk of under-subscribed tenders.

Attribute 6-Attribute 5: A high correlation between "transparency in the bidding process" and "grants and subsidy provided to farmers by the government" is observed. The subsidies increase the demand for the product and create more employment whereas, transparent bidding attracts more participants in the tender. A competitive bidding process help in catering to the increasing demand. Therefore a balance between them helps to promote the deployment of solar irrigation pump-sets.

Factor Analysis

Factor analysis is used to group the dependent variables and effectively extract the relationship between them. The seven attributes considered above in Pearson's co-relation analysis are highly correlated. Hence an exploratory factor analysis has been considered to further group them into factors.

The result (KMO value=0.611) of the Kaiser-Meyer-Olkin (KMO) test indicated that the sample was adequate for running factor analysis. Generally, a value greater than 0.5 is acceptable. Bartlett's test of sphericity was then run to check the redundancy between the variables before summarising them into factors. The output (df=21), at significance, 0.00suggested that the data was fit to conduct the factor analysis. Usually, the significance value of less than 0.05 is considered to be fit to conduct factor analysis.

In factor analysis, principal component extraction (PCA) was used to reduce the complexity of data and to summarise them into few dimensions.

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Factor rotation was performed while considering principal component extraction, and varimax rotation was performed, an orthogonal method used to minimize the number of variables with high loading on a factor. Table 3 attached below provides the output of the test:

Rotated Component Matrix			
	Component		
	1	2	3
Various state government initiatives in promoting and deploying solar pump-sets.	.773		
Support from the financial institution for providing loans for Solar pump/panel manufacturers or service providers.			.729
Distribution company's and state nodal agency's initiative in deploying and promoting solar pump-sets.	.647		
Awareness and confidence among the farmers and other beneficiaries for solar pump-sets.		.845	
The government provides grants and subsidies.		.659	
Transparency of nodal agency in the bidding process and in releasing funds.			.567
Government's commitment to achieving 40% installation capacity from non-fossil fuel sources by 2030.			.712
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			

Table 3: Rotated Component Matrix

The rotated component matrix divided the attributes into three factors that drive the deployment of solar pumps and can be best described as:
Factor 1: Initiatives taken by the government and nodal agency.
Factor 2: Farmer's perception about the product and associated subsidy on the product.
Factor 3: Collaborated efforts of government, nodal agencies, and financial institutions to achieving a target of 40% installation capacity from non-fossil fuel sources by 2030.

CONCLUSION

In the preliminary phase of the research, seven attributes were drawn while reviewing the literature, which defined the reasons for the deployment of solar pumps.

1. Various state government initiatives in promoting and deploying solar pump-sets.
2. Support from the financial institution for providing loans for Solar pump/panel manufacturers or service providers.
3. Distribution company's and state nodal agency's initiative in deploying and promoting solar pump-sets.
4. Awareness and confidence among the farmers and other beneficiaries for solar pump-sets.
5. The government provides grants and subsidies.
6. Transparency of nodal agency bidding in the process and in releasing funds.
7. Government's commitment to achieving 40% installation capacity from non-fossil fuel sources by 2030.

The descriptive analysis suggested that the central tendency(median and mode) were the same. After considering the mean, the research suggested that various state government's initiative in promoting and deploying solar pump-sets is relatively the most important driver in the deployment of solar pumps. The attributes considered above are highly dependent on each other, so it is not valid to find the relative importance. Hence, the correlation between the attributes was drawn using correlation analysis followed by exploratory factor analysis.

To summarise, this study contributes to developing an empirical model to understand the factors that drive solar pump-sets deployment and their co-relation with each other. The derived factors from the factor analysis that drive the deployment of solar pump-sets are:
Factor 1: Initiatives taken by the government and nodal agency to promote and deploy solar pumps.
Factor 2: Farmer's perception about the product and associated subsidy the product.
Factor 3: Collaborated efforts of government, nodal agencies, and financial institutions to deploy the solar irrigation pump-sets parallelly to achieve a 40% installation capacity from non-fossil fuel sources by 2030.

The first factor highlights the importance of various government initiatives and nodal agencies ' initiative in large-scale deployments of solar pumps. The second factor shows the reason for large-scalethe large-scale acceptance of solar pump-sets by farmers, including subsidy provided by the government, their awareness about the technology, and confidence in it. The third factor describes that apart from the initiatives from government and benefits of subsidy to the farmers, another reason that is driving the deployment of solar water irrigation

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pump-sets is joint efforts from the financial institution to support renewable industry and efforts taken by state nodal agencies assigned for the tendering process of solar irrigation pump-sets while parallelly achieving a target of 40% renewable energy target by 2030.

LIMITATION AND FUTURE SCOPE

The scope of this study limits to finding the drivers of solar pump-sets. However, future researchers can also determine challenges and barriers in the same. This study is generalized for India, but future researchers can also determine the barriers and challenges faced in deploying solar pump-sets in a particular state of India. Researchers can also draw the relative significance of each factor concluded in the study.

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