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Green Energy Transition in Rajasthan: Opportunities and Challenges in Installing Solar Panels in Low-income Households

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ABSTRACT

In this paper, we study the opportunities and challenges with respect to rooftop installation of solar panels in urban low-income households in the State of Rajasthan. Based on interviews with several participants, we found that there is a lot of enthusiasm for the adoption of this technology in people from these households. However, factors such as lack of adequate financial support for covering initial installations charges, severe space constraints in these households, and cultural/social issues act as an impediment in making a successful transition towards installing the panels. We conclude with a set of policy recommendations that may help in mitigating some of these challenges.

KEYWORDS:Climate change, decarbonization, global warming, green energy transition, low-income households, renewable energy, solar panels.

1. INTRODUCTION

As a response to 2015 Paris Agreement, several countries including India has committed to reduction in carbon emissions such that the country can mitigate the effects of climate change and attain a more sustainable development trajectory. In this context, the State of Rajasthan offers tremendous potential for attaining green energy transition and decarbonization, especially in generation of renewable energy and solarization of farming, industry, and household electricity consumption [1]. For sure, the state is attracting tremendous interest in terms of big-ticket investments in large solar parks and electricity generation facilities via solar panels. In addition, government has also taken initiatives towards promoting installation of rooftop solar panels in households for the purposes of domestic energy consumption. In this respect, the Government of India has come up with a subsidy scheme to encourage households to install solar panels on their rooftops (or other convenient locations within residential properties) such that at least a part of their electricity consumption can be taken care of by clean and renewable energy [2]. But from the authors' personal experience, it appears that the offtake of these incentives and subsidies is more popular among relatively higher-income households. In this paper, we, therefore, focus on how even

lower-income households can be encouraged to put solar panels on their rooftops. To this end, we interview several participants from low-income households using a semi-structured interview protocol. Based on these interviews, our results indicate that there is a great enthusiasm for the new technology. However, the participants suggest that they lack adequate financial support, face severe space constraints, and indicate certain cultural/social issues that are impeding adoption of the technology. Keeping these challenges in mind, our discussions with key stakeholders in the field lead to certain policy recommendations.

Aims and Objectives

- To study what is Green EnergyTransition and Decarbonization in the context of the State of Rajasthan
- To identify key opportunities and challenges for installing rooftop solar panels in low-income household in Rajasthan
- To propose policy recommendations to mitigate the challenges

Definitions

Green *energy transition.* Green energy transition can be simply defined as a process of shifting from non-renewable energy (e.g., fossil fuels) to renewable energy sources (e.g., solar, wind, etc.) [3]. Scholars have looked at green energy transition from four main perspectives: "the role of the government, of the market, of the public and of technological advancements" [3]. Although all these perspectives are interconnected and interrelated, the difference is in the focus. While the government perspective examines the impact of law, regulation, and government policies in a shift towards a greater mix of renewable energy in the total energy utilization [4, 5], the market perspective emphasizes the role of subsidies, taxes, production prices, and income level [5, 6]. Similarly, the public perspective is about education, awareness, and consumer behavior in terms of a readiness towards a more sustainable energy consumption [6]. Finally, technological perspective is interested in issues such as energy efficiency, stability of renewable energy production and storage, and developing correct infrastructure [7]. Beyond these various perspectives about what green transition entails, the principal underlying debate is whether energy transition is merely about technological shifts, i.e., development and adoption of newer technologies or it relates to how it might also involve fundamental changes in patterns of human consumption and wider societal push towards sustainability [3]. In this study, our stance is that a meaningful energy transition cannot take place without social involvement and changes that includes prioritizing energy transition among lower income population.

Decarbonization. Decarbonization involves reduction of emissions of greenhouse gases from burning of fossil fuels and other human activities [8]. Since gases like carbon dioxide, methane, nitrous oxide, and fluorinated gases contribute to warming of the planet by trapping heat that would have otherwise escaped to space, it is critically important to attain net zero emissions – i.e., no addition to existing stock of greenhouse gases in the atmosphere globally – by 2050, and in the process keep the increase in temperatures below 1.5 °C from that of pre-industrial levels. However, scholars estimate that merely keeping emissions down may not help in reaching the climate change goals. Therefore, decarbonization may also involve a second line of attack, whereby, technological advancements may help in reabsorbing or capturing carbon from the atmosphere via forests/agricultural lands or other technologies [8-10].

2. GREEN ENERGY TRANSITION IN INDIA AND RAJASTHAN

India's Long-term Low-carbon Development Strategy

India, and other developing countries across Asia, Africa, and Latin America, have historically contributed comparatively little to global warming. For instance, India's per capita annual emissions are about a third of the global average. Similarly, an Intergovernmental Panel on Climate Change (IPCC) report notes that the share of Southern Asian region is ~4% of cumulative emissions between 1850 and 2019 [11]. In comparison, North America and Europe have contributed almost 10 times more to global cumulative emissions, despite supporting much lesser population numbers [11]. Therefore, from an equity perspective, India is justified in asking developed countries for greater investments such that they take the lead in achieving net zero targets earlier than the rest of the world, and provide support in terms of climate finance, technology transfer, and capacity building.

However, recognizing that climate change is a global problem, India is committed to the principle of common but differentiated responsibilities and respective capabilities (CBDR-RC) that operates within the United Nations Framework Convention on Climate Change [11]. In essence, this involves making policy choices that ensures economic development along low-carbon pathways with a target towards achieving net-zero by 2070. In this regard, India adopted a National Action Plan on Climate Change (NAPCC) in 2008 to put energy transition on a sustainable path, providing adequate access to household energy, energy security, and energy for the development of all sectors of the economy even when the need for controlling carbon emissions remains paramount [12]. In this respect, Government of India (GOI) has made several strategic investments to achieve these policy aims including development of low-carbon electricity system, low-carbon transport system, low-carbon urban design and buildings, and low-carbon industrial system. For details, please refer Appendix A.

Green Transition and Decarbonization in the State of Rajasthan

Rajasthan holds immense potential for green energy generation, especially solar power generation. The total area is approximately 342,239 square kilometers (~10.4% of India's total landmass) with high solar irradiance, wind speeds, and abundant barren land to deploy many solar and wind power projects. Rajasthan receives the highest solar radiation in the country (5.72 kWh/m2/day) and has the highest number of clear sunny days (>325) in a year. The State of Rajasthan has taken various initiatives to create a conducive policy environment including simplification of the approval process, tax breaks, easing land acquisition norms, promotion of rooftop and decentralized solar projects, and setting up big ticket solar parks in Bhadla, Phalodi – Pokhran, and Nokh. Covering more than 14,000 acres, Bhadla Solar Park in Rajasthan (capacity 2,245 MW) is to date the largest solar energy generation facility in the world. As of September 2022, Rajasthan had an installed capacity of 20.0 GW of renewable capacity (16.9% of India's total RE capacity), out of which 15.2 GW belongs to solar (76.0 percent; 25.1% of India's total Solar capacity) and 4.5 GW to wind capacity (22.5 percent), and 0.3 GW to hydro or biomass generation capacity (1.5 percent) [17].

Another area for green transition is installation of rooftop solar panels. Rooftop solar panels offer several advantages to the end-users. Most importantly, since the panel is using what is essentially a free fuel, the costs for electricity production are quite minimal. Moreover, once installed, solar panels do not require much maintenance. However, there is a large upfront cost to installing a solar panel, which includes the cost of the panel itself and other miscellaneous costs including installation charges. On average, for rooftop panels, it costs about Rs. 60,000 per kW capacity across India. For most urban Indian households, this cost is extremely high. Therefore, to encourage installation of rooftop solar panels, Government of India is offering a subsidy scheme that has been adopted by the Government of Rajasthan. In particular, the government is offering 40% subsidy for panels up to 3kW capacity for homes and group housing such as apartment buildings [2]. For panels between 3kW and 10 kW, consumers will get a subsidy of 40% for first 3kW and 20% for the rest. There is no subsidy beyond 10kW. In addition, there are also certain income tax benefits because of accelerated depreciation. The subsidy is available only under certain conditions: a government-authorized vendor must carry out the installation and the panel must be connected to the grid [2]. Accordingly, it has set an ambitious target of 1000 MW installed capacity as rooftop solar panels by 2024-25 with 33 district headquarters designated as 'Green Energy Cities' (target: 300 MW) [1].

One of the stated goals of the policy is to encourage green transition in Rajasthan, even at the lower-income levels. At the same time, the government hopes to generate employment opportunities in the sector and tackle the issues of frequent power cuts and disruption in electricity supply. An interesting feature of this policy is that it is available to all residential households including large apartment buildings, housing societies, and educational institutions. So, anecdotally, we realized that the scheme is quite popular among relatively higher-income households, but the uptake is quite limited in poorer households. Therefore, the goal

of this study is to examine the challenges in adoption of rooftop solar panels in lower-income households.

3. METHOD

The study aims at understanding the key opportunities and challenges associated with green transition in the State of Rajasthan and the steps that can be taken to mitigate these challenges. Specifically, we focus on understanding the perspectives and views of people – from low-income households – concerning installing solar panels at their homes. As noted, one of the key initiatives of the government of Rajasthan has taken is towards generation of solar power. In this regard, in addition to establishment of solar plants, government is also promoting installation of solar panels in the houses. This would help the households to reduce their electricity bills, and hence, would lead to a reduction in their household expenses. Despite this advantage, a large majority of low-income households are not coming forward to install solar panels. As such, we aim to investigate why this may have been the case.

To this end, we interviewed 20 individuals who had household income below Rs. 15,000 per month in Jaipur, Rajasthan. In terms of our sample demographics, 60% were men. The participants worked as a peon, typist, watchmen, household help, driver, cook, etc. Next, we discussed our findings from these interviews with 5 experts from the government, private, and non-profit sector. This was done to understand their perspectives regarding policy implementation. In addition, we supplemented our data with secondary data sources including reports and policy documents.

Our interviews with individuals included questions on the benefits and challenges of installing solar panels, their preference regarding installation and why (or why not) would they do so and steps that could be taken to facilitate installation. We conducted the interviews in Hindi; these interviews were translated in English. At the beginning of the interview, the participants were assured that their responses will remain confidential and anonymized and only cumulative data will be presented. The duration of interviews was 20 to 30 minutes. They were either tape-recorded or when the participants did not feel comfortable with being recorded, responses were noted manually. Please see Appendix B for the interview protocol.

We analyzed the interview responses to identify key themes. While doing so, we also looked at existing reports and literature on these issues; this helped us in refining our understanding by providing a more comprehensive view of the issues. Both coauthors discussed the themes and their own observations regarding the issues to arrive at a framework of opportunities, challenges, and suggestions.

4. RESULTS AND DISCUSSION

Our analysis of interviews with individuals from low-income households revealed that government's initiative to install solar panels at homes has several opportunities and challenges. Specifically, the findings reveal two areas of opportunities: 1) Awareness of the technology and its benefits; 2) Excitement to adopt a new technology. However, despite these positive factors, none of the participants had installed the solar panels at their homes. We found that the factors that came in the way of installing solar panels include: 1) High initial investment and insufficient financial support; 2) Space constraints; and 3) Cultural and social issues. We first describe these opportunities and challenges and then reflect on policy recommendations.

Installing Solar Panels in Low-income Households: Potential Opportunities

Awareness of the technology and its benefits

To begin, most participants were aware of solar panels and that "it was a device to convert solar energy to electricity." They were aware that they could be installed at homes to convert solar energy to electricity. They had also seen solar panels installed in different houses. In fact, some participants were even cognizant of the industrial and public uses, e.g., use of solar streetlights. Further, participants were aware of the benefits of installing a panel at home and that it could potentially "make (their) life better." For instance, several of them mentioned that it can help them "reduce their electricity bills" and may even "make the monthly electricity bill negligible." Some of them also suggested that solar panels will "decrease environmental

pollution" and could be a good source of alternative energy.

Excitement to adopt a new technology

Next, the participants displayed excitement about the possibility of adopting new technology and interestingly, they did not seem apprehensive about it. Having seen the solar panel in many houses, they did not want to be left behind and would like to have one in their house too. For many of them, solar panels were almost something that had "magical qualities"; for instance, they found it surprising that solar panels could transform sunlight that is so readily available into electricity, for which they had to pay a bill every month.

Installing Solar Panels in Low-income Households: Perceived Challenges

High initial investment and insufficient financial support

Most participants found that the "initial cost of installation is high." This is understandable because of the following reasons. For one, their monthly wages ranged from Rs. 10,000 to Rs. 25,000. Even with the subsidy they receive from the government, the cost of installation was a big sum of money for them. Second, they did not see the rationale of making this investment. They did not own many electric gadgets; therefore, "their electricity usage, and hence the money they spent on it, was quite low". Moreover, as a few participants pointed out, the state government gives the initial 50 kWh per month of power free to all households, as such, a part of their electricity consumption was free anyways. Given these reasons, they found the investment for installing expensive solar panels too high compared to the savings it offered.

The participants not only found the solar panel to be an expensive investment, but also that the subsidy offered was insufficient. The lower income households would typically need a solar panel of up to 3 kW. The government provides a subsidy of 40% for up to 3 KW. The rest of the cost must be borne by the families who are installing the panel. For almost all participants the subsidy was not enough, and they would prefer "greater financial support" from the government. In addition, they lacked alternative sources of funding with low interest rates. For instance, banks provide loans to buy solar panels; however, the interest rate for such loans is comparable to other consumer loans such as car or motorcycle loans. Even if a low-income householder desires to install a solar panel a lack of easy financing opportunities acts as an impediment.

Space constraints

Installing solar panel requires open space that is exposed to sun and several participants suggested that they did not have that space in their houses. This was due to many reasons. First, almost as a rule their houses were small with several people in residing in "limited space." Solar panels are typically installed on roof tops, which are used for several purposes including sleeping at night during the summer. Next, people also live in shared space where the roof is shared between two or more households and there is a lack of clarity about the ownership of the roof. These issues make it difficult to put a solar panel. Additionally, in some cases, "roofs do not get direct sun light", which does not allow the solar panel to work at its optimal capacity. Finally, most people do not own their houses and move when they find a cheaper place to stay; this makes installing the solar panel complicated.

Cultural and social issues

Several participants, particularly women, had concerns about the feasibility of using electricity for cooking purposes. While they could visualize how solar power may help in running household gadgets like ceiling fans or televisions etc., they were hesitant about changing their traditional ways of cooking food to an electric stove. For instance, one of the staples in North-Indian households is the chapati (or wheat-based flat bread) and it was not clear how they can make these chapatis as easily on an electric stove. Relatedly, a couple of other participants also mentioned that they operate firewood-operated stove at home. It is the traditional way of cooking even if it is harmful from the standpoint of respiratory function. The concern was how they will migrate to the new way of cooking. Most of the participants that we interviewed lived in a joint-family setup, and they were not sure whether the elders in the family will agree.

Installing Solar Panels in Low-income Households: Suggestions

Many participants mentioned that they would install the panel if they were made more affordable for them. In this regard, they suggested that a much higher subsidy or discount may motivate people to install them. The solar panel could also be made available at a much cheaper rate. Additionally, another suggestion was that government could also educate people about its benefits such as decrease in environmental pollution and reduction in electricity bills.

Policy Recommendations from Stakeholders

Our discussions with the key stakeholders in the government, private, and non-profit sector led to the following policy recommendations. First, the government can supplement the subsidy scheme by offering low-interest loans to the households offsetting the monthly interest payments with the current electricity bills. Similarly, the government may also offer extra subsidies for solar panels up to 1- or 2-kW capacity. Second, to overcome the issue of space constraints, the stakeholders recommended setting up of communal solar panels or perhaps two or more households can apply jointly for an installation. Next, the stakeholders recommended that the government could run an awareness campaign with the support of a few non-profit organizations to demonstrate how electric cooking can supplement (and not entirely replace) traditional methods of cooking. Finally, government may encourage banks to introduce green financing options (e.g., green retail loans) which allow people to borrow money at a much lower rate, something that has started happening in several European countries.

5. CONCLUSION

The crisis of global warming and climate change is here and now. In this regard, solar energy is a key component of our combined efforts towards green energy transition and decarbonization. Our study identifies installation of rooftop solar panels as an exciting opportunity even from the standpoint of lower-income households. However, we also find that this opportunity comes with certain challenges including lack of financial support, space constraints, and certain cultural/social practices. We conclude with a set of policy recommendations that may help in faster adoption of the technology.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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APPENDIX A

Strategic Transitions in India

To achieve these policy aims, India has made strategic investments and made significant progress in the past two decades. Below, we discuss some of the key strategic transitions.

Development of low-carbon electricity system. India has one of the largest power systems in the world catering to a population of 1.3 billion. With a peak demand of about 206 GW, the total electricity generation for FY 2021-22 was under 1,500 TWh/BU. The industrial sector accounted for about 43% share of consumption, the residential sector 24% and the agriculture sector 18%. India has an installed generation capacity of 404 GW (July 2022), of which 168 GW (41.6%) is from non-fossil fuels including 22% from hydroelectricity. Renewables, especially wind and solar are growing at a fast pace (CAGR: 15.6%) with the generation capacity growing to 110 GW in 2022 from 39 GW in 2015 [15-17].

Development of low-carbon transport system. Overall, transport sector contributes to about 12.1% of India's energy-related CO2 emissions (MoEFCC, 2021) and 9.7% of the country's total Greenhouse Gas emissions. Emissions from the transportation sector are mainly from fossil fuel consumption in the road sector, though vehicle ownership in India is far below the world average. In 2018, the total vehicle penetration per 1000 people in India was 32, in contrast to 134 in China, 619 in Germany, and 804 in the USA (MoRTH, 2021). Initiatives for developing low-carbon transportation system include Bharat Stage VI emission standards, scrapping of old, polluting vehicles, fuel efficiency norms, use of biodiesel and other alternative fuels, and a push towards Hydrogen economy in a mission-mode [18-19].

Development of low-carbon urban design and buildings. According to Census 2011, approximately 377 million Indians comprising 31.1% of the country's population lived in urban areas. The country had 53 city agglomerations with over a million people, and six city agglomerations with over 10 million population. The urban population is projected to grow to about 600 million by 2030. Initiatives for developing a more sustainable urban environment include adoption of Building Codes and Bylaws, Energy Conservation Act and Development Control Regulations, and rating systems for buildings' energy efficiency [20-21].

Development of low-carbon industrial system.The industrial sector contributed about 25.9% to India's Gross Value Added(GVA) in 2020-21. Manufacturing alone,contributed 14.4% to GVA this year, with construction and energy and other supply utilities adding another 9.9%. The Government of India is focused on expanding the contribution of manufacturing to GDP as this is necessary in a developing country to generate employment, enhance incomes, and create infrastructure. Initiatives to improve energy efficiency in the industrial sector include National Mission on Enhanced Energy Efficiency – Perform, Achieve Trade (PAT) Scheme: This energy efficiency scheme for notified industries and industrial units is envisaged to widen its coverage to other energy intensive industries such as ports, chemicals, ceramics, sugar, and mines [21].

APPENDIX B
Interview Protocol

1.	What do you know about solar panel? From where did you learn about them?	सोलरपैनलकेबारेमेंआपक्याजानतेहैं? आपनेउनकेबारेमेंकहाँसेसीखा?
2.	What are some reasons of putting a solar panel at your home? According to you, what are some benefits of putting solar panel at home?	आपकेघरमेंसोलरपैनललगानेकेकुछकारणक्याहैं? आपकेअनुसारघरमेंसोलरपैनललगानेकेक्याफायदेहैं?
3.	What are some reasons because of which people do not put solar panel at home? did anyone you know did not put a panel because of these reasons?	ऐसेकौनसेकारणहैंजिनकीवजहसेलोगघरमेंसोलरपैनलनहींलगाते हैं? क्याआपकेकिसीजाननेवालेनेइनकारणोंसेपैनलनहींलगाया?
4.	What can be done to persuade you to put the solar panel at home?	आपकोघरपरसोलरपैनललगानेकेलिएराजीकरनेकेलिएक्याकिया जासकताहै?
5.	Do you think that solar panel will help you in making your life better? For example, by helping you make or save money? Do you know anyone whose life has improved after putting panels? How?	क्याआपकोलगताहैकिसौरपैनलआपकेजीवनकोबेहतरबनानेमेंआ पकीमददकरेगा? उदाहरणकेलिए, पैसाबनानेयाबचानेमेंआपकीमददकरके? क्याआपकिसीऐसेव्यक्तिकोजानतेहैंजिसकापैनललगानेकेबादजी वनबेहतरहुआहो? कैसे?
6.	For cooking, what kind of fuel do you use? With solar panel installed, people can use an electric stove. How do you feel about switching from a firewood/gas to electric stove? Does it mean a change in your cooking habits? Are you ready for that?	खानापकानेकेलिएआपकिसप्रकारकेईंधनकाउपयोगकरतेहैं? सोलरपैनललगानेसेलोगइलेक्ट्रिकस्टोवकाइस्तेमालकरसकतेहैं। जलाऊलकड़ी/गैससेइलेक्ट्रिकस्टोवपरस्विचकरनेकेबारेमेंआपके सामहसूसकरतेहैं? क्याइसकामतलबआपकेखानापकानेकीआदतोंमेंबदलावहै? क्याआपइसकेलिएतैयारहैं?
7.	In the future, government would like that people put solar panels. What can the government do ensure that people are motivated to put them? Can someone else also help in motivating people to put panels?	भविष्यमेंसरकारचाहेगीकिलोगसोलरपैनललगाएं।सरकारक्यासु निश्चितकरसकतीहैकिलोगउन्हेंलगानेकेलिएप्रेरितहों? क्याकोईऔरभीलोगोंकोपैनललगानेकेलिएप्रेरितकरनेमेंमददकर सकताहै?
8.	Details • Age • Male/Female • Household Income Levels • Profession	विवरण • आयु • पुरुष/ स्त्री • घरेलूआयस्तर • पेशा