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ROOFTOP SOLAR ADOPTION IN INDIAN HOUSEHOLDS: A CASE STUDY OF URBAN BIHAR

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ABSTRACT

This research aims to explore the uptake of rooftop solar photovoltaic (PV) systems in urban Bihar and the associated behavioral, economic, infrastructural, and policy dimensions that impact urban, residential decisions. Given the high solar potential and central government initiatives such as Pradhan Mantri Surya Ghar Yojana, rooftop solar PV systems are underrepresented in cities such as Patna, Gaya, and Bhagalpur. Using mixed methods (household survey, focus group discussions and stakeholder interviews) the research shows that, although participants' awareness of rooftop solar and perceptions were not negative, the most significant deterrents to uptake were associated with the upfront costs of the solar PV system, subsidy disbursement delays, poor coordination of agencies implementing the subsidy, and limited trust in service providers. The comparative data from states with better uptake of rooftop solar systems provide important insights about streamlined processes, flexible financing approaches, and localized outreach. The study offers three state-specific policies to close the gap between potential and uptake of rooftop solar, and thereby assist in pursuing an equitable and environmentally sustainable energy transition in urban Bihar.

Keywords: Rooftop solar, urban Bihar, energy adoption, renewable policy, socio-economic factors, sustainable energy.

INTRODUCTION

India's rapid urbanization has sparked unprecedented demand for energy, especially in cities with congested populations where energy supply often does not keep up with demand. In this landscape rooftop solar photovoltaic (PV) systems are providing a favorable decentralized alternative to traditional electricity supply in cities. Rooftop PV systems also deliver not only environmental

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benefits but they have potential economic benefits for urban households as they lessen the reliance on grid electricity, which continues to increase in prices.

In support of solar adoption, the Government of India initiated the National Solar Mission under the National Action Plan on Climate Change with a goal to install 100 GW of solar capacity of which 40 GW comprised rooftop capacity. Despite the aggressive target and with subsidies and net metering policies in place, the residential uptake of rooftop systems, or systems of any size, has been varied across states. Some urban areas, like Maharashtra, Karnataka and Delhi provide substantial evidence of progress, whereas others like Bihar, remain hesitant to move forward.

Urban areas in Bihar such as Patna, Gaya and Muzaffarpur are examples of the gap that exists. There is a constant feature of unreliable electricity supply, blackouts and increasing costs for consumers, yet they seem like perfect candidates for solar. However, limited uptake is due to several factors, including lack of awareness of solar technology, infrastructural or technical limitations, a low trust in the vendors, and financial barriers (e.g., high up-front costs and lack of credit access).

This study will try to explore these factors as contextually and empirically informed study. It will focus on highlighting the socioeconomic, behavioral, policy, and infrastructural factors affecting rooftop solar adoption among urban households in Bihar. The research will look at adopters and non-adopters in different income brackets with evidence-based study - facilitating better policy development and encouraging more localized solar uptake strategy.

Ultimately, understanding the unique dynamics of rooftop solar adoption in Bihar is important not only to help overcome regional disparities, but also to help play India's part in its wider clean energy Transition. By implementing targeted interventions that consider the realities on the ground, and leveraging its current resources, states like Bihar can make meaningful contributions to national sustainability aims.

1. OBJECTIVES

- To evaluate the factors influencing the adoption (or non-adoption) of rooftop solar systems among urban households in Bihar.
- To assess the level of awareness and perceptions regarding rooftop solar technology among urban residents.
- To analyze economic, policy, and infrastructural barriers and enablers for rooftop solar adoption in urban Bihar.
- To identify household-level demographic and behavioral factors (such as income, education, homeownership) associated with adoption decisions.
- To suggest practical policy recommendations to accelerate rooftop solar adoption in the state, based on empirical findings.
- To evaluate the effectiveness of government incentives and outreach programs in encouraging household-level solar installation.

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2. METHODOLOGY

A mixed-method research design was used to explore urban Bihar's rooftop solar adoption factors. The quantitative measure collected data from 600 urban households via a structured questionnaire in three cities: Patna, Gaya, and Bhagalpur. The study used stratified random sampling based on various socio-economic strata that include low-, middle-, and high-income groups. The questionnaire was designed to include key variables such as demographics, levels of awareness, perceptions, socio-economic status, and adoption behavior toward rooftop solar technology. The structured questionnaire was an effective way to collect significant data for statistical analysis that show patterns, and correlations on solar adoption.

To provide additional context and richness to the survey results, the research used qualitative methods in conjunction with survey methods. The qualitative methods consist of six focus group discussions (FGDs) and 15 in-depth interviews with a varied group of stakeholders, which included urban residents (with and without rooftop solar), officials from government institutions, solar vendors, and NGOs that focus on energy. The qualitative data enabled the research to shine light on complicated behavioral, cultural, and policy factors that are not always interpreted through the quantitative responses. The quantitative data was analyzed using SPSS software, while the qualitative data was thematically coded with NVivo, allowing for robust triangulation of findings and a comprehensive understanding of the rooftop solar adoption in the urban context of Bihar.

3. DATA ANALYSIS AND FINDINGS

3.1. Socio-Demographic Characteristics

Majority of participants in the study were middle-income households, structured around monthly income levels from INR 20,000 to 50,000, which is consistent with the socio-economic profile of emerging urban middle classes in Bihar. There existed a predominance of male head of household (68%) which conforms to existing patterns of household decision-making, especially with regard to financial and infrastructural investments. The educational attainment for the participants was moderately educated when disaggregated, where, 42% carried secondary education, and 35% had an undergraduate education. Household structure also indicates that 70% of households lived in independent homes, with roofs that could be accessed. Access to rooftops and private solar rooftops was strongly associated with household solar adoption, compared to those households that lived in apartments or shared housing.

3.2. Awareness and Perceptions of Rooftop Solar

The level of awareness of rooftop solar systems was quite significant, as 78% of participants affirmed that they heard about the technology. Sources of information included the internet, television, and recommendations from family and friends. Though participants had a limited frame of reference when it came to hands-on experience with rooftop solar, 65% of participants expressed a positive attitude towards rooftop solar. Many participants acknowledged the benefits of reducing electricity bills, increasing energy independence, and promoting environmental benefits. However, positive attitudes did not always lead to adoption as multiple financial and logistical concerns act as deterrent factors.

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3.3. Barriers to Adoption

Several challenges were identified that hinder rooftop solar adoption among urban households in Bihar.

a) **Financial Barriers:** The costs of installing a 1–3 kW system were frequently mentioned because the upfront cost can be daunting, ranging from INR 50,000 to INR 2,00,000, particularly for lower-middle-income households. Also discouraging for many potential adopters was the cash flow constraint arising from delayed disbursement of subsidies, preventing them from paying the upfront cost out of pocket.
b) **Technical Barriers:** Households confronted technical hurdles such as the lack of solar technicians, the lack of reliable service providers (resulting in poor installations and pre-installation worries), and poorly positioned rooftops (small and with shading) to adopt solar energy.
c) **Institutional Barriers:** Respondents described long bureaucratic processes for approvals and access to government incentives. Additionally, a large number of people were unaware of net metering, or the rules were too dense for them to work through.

3.4. Effectiveness of Government Schemes

While respondents identified relevant schemes, there was limited conversion from awareness to adoption. Even still, while 55% of respondents were aware of central and state government programs, such as the Pradhan Mantri Surya Ghar Muft Bijli Yojana, only 65% of adopters managed to access government benefits after their applications were potentially delayed, and dependent on local bureaucratic processes. Particularly, respondents expressed concern over the application process itself, public outreach, and local implementation in order to improve accessibility and outcomes.

3.5. Comparative Trends and Regional Insights

When compared to well-performing states like Delhi and Bengaluru, urban Bihar had a very low rooftop solar uptake rate of 22%. These results were largely due to weaker institutional capacity; insufficient technical infrastructure; and unsophisticated vendor ecosystems, whereas in the better-performing locations, net metering was easier, vendors were more trusted and greater peer influence, community-level uptake reflected the uptake of others. Such comparisons highlight the need for localized strategies for Bihar that work given its specific socio-economic and infrastructural situation.

4. DISCUSSION

4.1. Economic and Behavioral Drivers

The decision to adopt rooftop solar technology in urban Bihar involves not just economic capacity but also behavioral attitudes and social learning. The households with higher and stable incomes were able to adopt rooftop solar because they could manage the upfront investment and access credit. Furthermore, respondents that realized the long-term cost savings of reduced electricity bills were significantly more likely to adopt solar, but this reason was not sufficient on its own.

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Behavioral factors such as risk aversion and trust in service providers were also prominent factors. Many households expressed doubts about how reliable the technology was, concerns about the possibility of being misled by unverified vendors, and misconceptions about the maintenance of the product. Many residents developed a "wait-and-see" strategy that resulted in deferring adoption until they saw successful installations happening with their neighbors. It is evident that peer effects and visibility to successes are important in determining technology adoption at a community level.

4.2. Policy Gaps

While there are central and state policies to promote rooftop solar systems, there have been significant implementation gaps. Many respondents highlighted concerns about inefficiencies with accessing subsidies—from excessive documentation to long delays for disbursement. These process frustrations have dissuaded many willing houses to pursue installations despite policy drivers.

In addition, there is a broader lack of agents for implementing organizations, such as local municipal bodies and electricity boards or renewable energy departments. This leads to unclear delineation of responsibilities and incoherent messaging for end users. Furthermore, the lack of trained solar professionals, as well as certified installers, leads to low system quality and diminished trust in the sector. If there are not directed investments in technical training and capacity building, the state will likely especially struggle to realize its solar adoption and rooftop potential.

4.3. Lessons from Other Regions

Bihar can draw on various exemplary policy and implementation examples from several Indian States. For instance, Tamil Nadu and Kerala have both created one-window clearance systems to allow households to obtain approvals and subsidies for adopting suitable solar solutions in a more streamlined manner without going through bureaucratic channels. States have supported developing state-backed service networks, which include firms that install solar systems for consumers, thereby creating more consumer trust and ensure installations are trustworthy.

Innovative financing models, like solar leasing and third-party ownership in Maharashtra, allow consumers to remove the burden of upfront capital costs. Moreover, such models ensure households can obtain the benefits of solar energy without having to own the solar system. This increases access for disadvantaged lower income segments who otherwise may not be able to afford solar solutions. While Bihar does not have solar leasing or third-party ownership systems, the state could benefit from these approaches, by localizing to its own socio-economics challenges and drawing from community organizations, representatives at microfinance institutions, and urban local bodies to expedite delivery and outreach.

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CONCLUSION

Urban Bihar has significant unrealized potential for the uptake of rooftop solar, but progress is hampered by a confluence of financial accessibility, awareness, institutional inefficiency, and behavioral reluctance. This work emphasizes that addressing the divide between policy intent and on-the-ground implementation is vital. Greater efficiency in government subsidy schemes, creating innovative and accessible financing options, investing in the training of a technical workforce, and facilitating meaningful community-level engagement will all contribute to increased uptake. Taking the needs of a diverse group of stakeholders into account, as well as the need to confront systemic barriers with localized and inclusive policies, rooftop solar has the potential to be an available and sustainable option to meet the increasing energy demand of urban households in Bihar.

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