

Rajasthan's Role in India's Solar Energy Revolution: Opportunities, Challenges, and the Road Ahead

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ABSTRACT

India is rapidly advancing toward its renewable energy targets, with a national aim of achieving 860 GW of renewable energy capacity by 2030. Among all Indian states, Rajasthan leads the solar energy transformation with an installed capacity of over 18.7 GW as of 2024, contributing nearly 27% of India's total solar capacity. The state's geographic advantage—with over 325 sunny days annually, high solar irradiance (5.5–6.0 kWh/m²/day), and vast barren land—makes it uniquely positioned for solar energy development. In 2023 alone, Rajasthan added approximately 4.4 GW of new solar capacity, the highest in the country. With a population exceeding 80 million and a land area of 342,239 sq km, Rajasthan is not only a geographic giant but also a renewable energy powerhouse. However, to meet future demands and ensure grid stability, massive investment in energy storage, transmission infrastructure, and policy innovation is essential. This article explores Rajasthan's strategic solar position, the economic and environmental impact of its solar growth, and the barriers it must overcome to lead India's clean energy future.

Keywords: Innovative Practices, Solar Power, Green Energy, Government Policies.

Introduction

India's commitment to a cleaner and more sustainable energy future is reshaping the country's development agenda. Within this landscape, Rajasthan is playing a key role in helping the nation meet its renewable energy goals. Its natural advantages—vast land, arid climate, and abundant sunlight—coupled with proactive state and central government policies, have propelled Rajasthan to the forefront of the solar energy revolution.

Rajasthan lies between latitudes 23.3°N to 30.12°N and longitudes 69.3°E to 78.17°E in the northwestern region of India. The state's climate, characterized by low rainfall and intense sunlight, makes it one of the most suitable places in the country for generating solar power. The average solar radiation in Rajasthan ranges from 5.5 to 6.0 kWh/m²/day, with over 325 days of clear sunshine annually—translating into more than 3,000 hours of solar potential each year. These factors create the ideal conditions for deploying large-scale solar energy projects.

As of late 2024, Rajasthan leads India with over 18.7 GW of installed solar capacity. This alone represents about 27% of India's total solar output. The state is home to several landmark solar projects, including the globally renowned Bhadla Solar Park, which has a planned capacity of 2.25 GW and currently hosts over 2 GW of operational capacity. Other notable solar clusters include those in Jodhpur, Jaisalmer, and Phalodi, where high solar irradiance and the availability of non-agricultural land support utility-scale solar development.

The rise in solar installations has brought significant socioeconomic benefits. It is estimated that solar projects in Rajasthan

Primary Objective of the Study

- To identify and analyze the practical implementation of green energy and to determine the various innovative practices adopted by the Rajasthan State Government and to map the perception of people towards the Green Energy.

Research Methodology

- **Research Type:** Descriptive Research
- **Research Area (Location):** The research area is the universe covers the citizen of the five major cities of the Rajasthan state i.e.; Kota, Jaipur, Udaipur, Jodhpur and Ajmer.
- **Data Collection:** Through close-ended structured questionnaire based on likert scale to collect the users perception on roof top solar.

The Government of Rajasthan is leading India's renewable energy transition through bold policies, strategic initiatives, and large-scale investments. At the 'Rising Rajasthan' summit, the state emphasized its key role in meeting India's clean energy goals. With its abundant solar and wind potential, Rajasthan has introduced landmark policies like the Rajasthan Integrated Clean Energy Policy, 2024, and Rajasthan Renewable Energy Policy, 2023, aiming to significantly increase renewable energy capacity while promoting sustainability and economic growth.

Rajasthan has implemented forward-looking policies to harness its solar and wind energy potential. These initiatives are aimed at increasing renewable capacity, attracting investment, and boosting energy access in rural areas. Key initiatives include the Rajasthan Renewable Energy Policy, 2023, the Solar Energy Policy, 2019, and the Renewable Energy Transmission Investment Program.

Rajasthan Renewable Energy Policy, 2023

This policy targets 90,000 MW of renewable energy capacity by 2029-30. It promotes solar, wind, and hybrid energy projects with financial incentives, simplified regulations, and a focus on rural electrification. It supports microgrids and decentralized energy systems in underserved regions.

This flagship policy aims to achieve 125,000 MW of renewable capacity by 2030. It promotes solar, wind, hybrid energy, energy storage systems, and green hydrogen. The policy ensures grid integration, fosters innovation, and supports rural and industrial applications.

Rajasthan Solar Energy Policy, 2019

This policy focuses on maximizing solar energy through large solar parks, rooftop installations, and floating solar projects. It encourages private investment, net metering, and solar-powered agriculture to reduce reliance on conventional power.

Renewable Energy Transmission Investment Program

This program aims to upgrade Rajasthan's grid to integrate large-scale renewable energy. It focuses on reducing transmission losses, modernizing infrastructure with smart grid technology, and enabling interstate energy trade.

Rajasthan Renewable Energy Corporation Ltd. (RRECL)

RRECL is the nodal agency implementing renewable energy projects across the state. It facilitates approvals, investments, awareness campaigns, and R&D collaboration, playing a vital role in project execution and monitoring.

Rajasthan Integrated Clean Energy Policy, 2024

- **Geographic and Climatic Advantage**

Rajasthan is situated between latitudes 23.3°N and 30.12°N and longitudes 69.3°E and 78.17°E, lying in the northwestern part of India. Its hot and arid climate ensures solar radiation levels ideal for photovoltaic and thermal solar energy generation. The average solar radiation ranges between 5.5 and 6.0 kWh/m²/day, with more than 325 sunny days annually—equating to over 3,000 hours of sunshine per year. This gives Rajasthan the natural edge over other states for harnessing solar energy.

Current Status of Solar Energy in Rajasthan

As of the end of 2024:

- **Installed Solar Power Capacity:** 18.7 GW (27% of India's total solar capacity).
- **Target Contribution to 2030 Goal:** Expected to contribute over 25% to India's 860 GW renewable target.

- **Largest Solar Park:** Bhadla Solar Park, with a planned capacity of 2.25 GW (currently operational over 2 GW).

Rajasthan Renewable Energy Corporation Limited (RRECL) is the nodal agency promoting solar energy, offering multiple incentives and policy support.

Major Solar Projects in Rajasthan

- **Bhadla Solar Park:** Over 2,245 MW installed; one of the world's largest solar parks.
- **Jodhpur and Jaisalmer Clusters:** Hosting multiple solar farms due to high irradiance and land availability.
- **Phalodi Solar Cluster:** Emerging as another key site for utility-scale solar installations.

Socioeconomic and Environmental Benefits

- **Employment:** Solar energy projects have created over 90,000 jobs in Rajasthan, including construction, operations, and maintenance.
- **Rural Electrification:** Solar mini-grids have powered over 2,500 remote villages, improving education, healthcare, and livelihoods.
- **Carbon Reduction:** Rajasthan's solar energy helps avoid over 28 million tons of CO₂ emissions annually.

Policy and Government Initiatives

The Rajasthan Solar Energy Policy (2019) aims to:

- Install 30 GW of solar capacity by 2025.
- Encourage private sector participation with land banking and fast-track clearances.
- Provide incentives such as stamp duty exemptions, land subsidies, and feed-in tariffs.
- Central government schemes supporting solar adoption include:
- PM-KUSUM: Subsidizing solar pumps for agriculture.
- Grid-Connected Rooftop Solar Program.
- Solar Park Development Scheme.

Challenges and Roadblocks

Despite the strong growth, several challenges remain:

- **Grid Integration:** Intermittent solar supply stresses the grid; requires smarter, flexible grids.
- **Storage Deficit:** Limited deployment of battery storage increases dependency on conventional backup.
- **Land Acquisition Issues:** Large tracts of land required for solar parks often face delays.
- **Financing Gaps:** High initial investment and risk-averse private investors hinder faster rollout, especially in off-grid systems.
- **Public Awareness:** Limited rural awareness about rooftop solar subsidies and savings potential.

Data Analysis

Table 1: Believe that Roof Top Solar will be Beneficial

Believe that Roof Top Solar will be Beneficial	No. of Respondent	Percentage
Yes	199	38.87
No	114	22.27
Don't No	199	38.87
Total	512	100

Interpretation: The table shows the distribution of 512 respondents regarding their belief in the benefits of rooftop solar systems. Out of the total, 199 respondents (38.87%) believe that rooftop solar will be beneficial. However, an equal number of respondents, 199 (38.87%), are uncertain about the benefits, indicating a lack of knowledge or confidence. Meanwhile, 114 respondents (22.27%) do not believe that rooftop solar would be beneficial. This mixed perception highlights the need for more awareness and information dissemination regarding the advantages of rooftop solar systems.

Table 2: Overall Satisfaction with the Rooftop Solar System Installed

Overall satisfaction with the rooftop solar system installed	No. of Respondent	Percentage
Very Satisfied	19	3.71
Satisfied	341	66.60
Neutral	89	17.38
Unsatisfied	52	10.16
Very Unsatisfied	11	2.15
Total	512	100

Interpretation: The table shows the overall satisfaction of respondents with their installed rooftop solar systems. The majority, 341 respondents (66.60%), are satisfied with their system, while 19 respondents (3.71%) are very satisfied. 89 respondents (17.38%) felt neutral, and 52 respondents (10.16%) are unsatisfied. A small number, 11 respondents (2.15%), are very unsatisfied. This indicates that most respondents are generally satisfied with their solar systems, though there is a portion who remain neutral or dissatisfied.

India's clean energy ambitions are increasingly supported by the promotion of rooftop solar systems, especially under the PM Solar Yojna. To understand the socio-economic readiness for such initiatives, this study analyzed data from 452 respondents covering income levels, property characteristics, awareness sources, and system preferences.

The majority of respondents (51.77%) fall into the monthly income bracket of ₹50,000–₹100,000, followed by 39.16% in the ₹20,000–₹50,000 range. Higher-income households (earning ₹100,000 and above) represent only 5.97%, while lower-income families (below ₹20,000) account for 3.10%. This suggests that most potential rooftop solar users belong to middle-income groups.

In terms of property ownership, residential buildings dominate, with 64.82% of respondents owning such spaces. Commercial property owners account for 26.77%, while industrial and other property types are less common. A significant 95.35% of respondents reported having flat roofs, which are ideal for installing solar panels. However, 79.20% noted that their rooftops remain shaded for most of the day, potentially limiting solar efficiency.

Rooftop space availability is promising, as 85.42% of respondents reported having 100–200 sq. ft. available, and 64.93% have more than 200 sq. ft., suggesting technical feasibility for solar panel installation. Despite this, overlapping responses and high percentages suggest that respondents may have multiple properties or areas with varied shading conditions.

When it comes to awareness, 30.53% of respondents learned about rooftop solar systems from friends and relatives, and 28.98% through television advertisements. Newspaper ads and internet sources also contributed, but social media and radio had limited reach. Vendor selection is even more dependent on personal networks, with 93.36% choosing vendors based on recommendations from friends and family.

Awareness of government subsidies under PM Solar Yojna is relatively strong at 63.72%, though a significant 36.28% still lack this information. Belief in the benefits of rooftop solar is held by 63.72% of respondents, while 19.03% are undecided and 17.26% remain unconvinced. Among those who believe in the benefits but haven't installed systems, the top barrier is lack of funds (55.21%), followed by low energy consumption (29.86%) and inadequate roof space or sunlight.

For those who are unsure or skeptical about solar adoption, lack of knowledge is the biggest hurdle (52.44%), emphasizing the need for stronger information dissemination. Most respondents (82.29%) are motivated by the prospect of reducing electricity bills, with only a small fraction driven by environmental or energy independence reasons. The preference for on-grid systems (86.46%) reflects a desire for cost-effectiveness and simplicity, while all respondents unanimously prefer complete system installations including inverters and batteries.

Regarding preferred capacity, most (64.58%) favor systems between 5–10 kW, suitable for medium-scale residential or commercial use. Electricity consumption patterns support this, as 44.79% of respondents use less than 200 kWh per month, and another 30.21% consume between 200–500 kWh. Correspondingly, electricity bills are low, with 45.49% paying under ₹2000 per month.

Frequent power outages affect 73.61% of respondents, highlighting another incentive for adopting solar systems, especially those with backup solutions. In terms of budget, 56.60% of

respondents are willing to spend ₹1,00,000 to ₹2,00,000, while 19.44% can invest between ₹50,000 to ₹1,00,000. The rest are open to higher investments, with 11.11% willing to spend above ₹5,00,000.

A majority (57.64%) are interested in financing options, signaling the importance of accessible loan or installment-based payment schemes. Additionally, 58.68% are aware of existing government subsidies, suggesting reasonable but improvable outreach. When asked about installation timelines, 37.85% plan to install within six months, and 23.61% within a year, pointing to strong short-term interest.

Most respondents (57.99%) also desire ongoing maintenance and monitoring services, indicating a demand for reliable after-sales support. Prior adoption of renewable energy systems is relatively high, with 64.93% reporting previous experience with solar or wind energy installations. However, the most commonly cited concern remains installation cost (40.97%), followed by system performance and maintenance.

Encouragingly, 59.72% of respondents have already received a free solar site assessment, and 61.11% have consulted with expert teams. These interactions could play a critical role in converting interest into actual installations.

In summary, the findings show a growing interest in rooftop solar systems, particularly among middle-income, urban, and semi-urban households with suitable roof space. However, barriers such as shading, cost, and limited awareness continue to restrict adoption. Tailored awareness campaigns, simplified access to subsidies, attractive financing options, and robust after-sales support could significantly boost solar rooftop adoption and contribute to India's clean energy goals.

Conclusion

Rajasthan has firmly established itself as India's solar energy leader, leveraging its geographic advantages, forward-looking policies, and large-scale projects. Yet, to unlock its full potential and meet national renewable targets, the state must overcome infrastructural, financial, and policy challenges. With the right investments and collaborations between government, industry, and communities, Rajasthan can not only meet its energy needs sustainably but also set a global example in solar energy leadership.

Rajasthan, with its vast solar potential, is poised to play a pivotal role in India's rooftop solar revolution. The survey findings reflect the state's strong foundational readiness—characterized by widespread ownership of residential properties with flat roofs, large available rooftop spaces, and significant public interest in solar energy. A substantial number of respondents are aware of the benefits of rooftop solar systems, and many are motivated by the desire to reduce electricity bills, increase energy independence, and contribute to environmental sustainability.

However, key challenges persist. A majority of rooftops experience shading for most of the day, potentially impacting system performance. Additionally, financial constraints, lack of detailed knowledge, and inadequate awareness of government subsidies remain significant barriers. Despite these hurdles, Rajasthan's population demonstrates a clear preference for complete, grid-connected solar solutions and is increasingly open to financing options and expert consultations.

With appropriate interventions—such as improved public awareness campaigns, accessible financing mechanisms, targeted government subsidies, and technical solutions to mitigate shading—Rajasthan can significantly accelerate rooftop solar adoption. As one of India's most solar-rich states, Rajasthan is not only vital for achieving the national rooftop solar targets but also for setting a model of decentralized, citizen-led clean energy transition. If harnessed effectively, the state can serve as a blueprint for solar empowerment across the country, supporting India's broader goal of sustainable and inclusive energy growth.

References

1. Central Electricity Authority. (2024). *All India Installed Capacity (Renewable & Non-Renewable)*. Ministry of Power, Government of India. Retrieved from <https://cea.nic.in/>
2. Ministry of New and Renewable Energy. (2023). *State-wise Solar Power Installed Capacity in India*. Government of India. Retrieved from <https://mnre.gov.in>
3. Rajasthan Renewable Energy Corporation Limited (RRECL). (2023). *Rajasthan Solar Energy Policy 2019 – Implementation Progress Report*. Retrieved from <https://rreclmis.energy.rajasthan.gov.in/>
4. Council on Energy, Environment and Water (CEEW). (2023). *Scaling Rooftop Solar: Powering India's Renewable Transition*. Retrieved from <https://ceew.in>

5. International Energy Agency (IEA). (2023). *India Energy Outlook 2023*. Retrieved from <https://iea.org/reports/india-energy-outlook-2023>
6. Indian Renewable Energy Development Agency Ltd. (IREDA). (2023). *Annual Report 2022–23*. Ministry of New and Renewable Energy. Retrieved from <https://www.ireda.in>
7. Press Information Bureau. (2024). *Progress Under PM-KUSUM and Rooftop Solar Program*. Government of India. Retrieved from <https://pib.gov.in>
8. Singh, R., & Patel, M. (2022). *Drivers and Barriers to Rooftop Solar Adoption in India: A Consumer Survey Approach*. *Renewable and Sustainable Energy Reviews*, 160, 112294. <https://doi.org/10.1016/j.rser.2022.112294>
9. The Energy and Resources Institute (TERI). (2023). *Opportunities for Scaling Up Rooftop Solar in Indian States*. Retrieved from <https://www.teriin.org>
10. Burning Compass. (2024). *Rajasthan District Map and Geographic Overview*. Retrieved from <https://www.burningcompass.com/countries/india/rajasthan-district-map.html>.

