Catalyzing Self-Reliance or Deepening Dependencies? A Socio-Technical Analysis of Green Energy Projects in Rajasthan Under the Atmanirbhar Bharat Mission

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ABSTRACT

This review investigates the complex relations of Atmanirbhar Bharat of India and mission and implementation of large scale green energy projects in Rajasthan. The scientific study will be grounded on the mixed methods approach that will integrate systematic thematic review of policy reports or peer-reviewed articles and a quantitative trend analysis of the information on the utilization of renewable energy sources offered by the governmental sources. The findings indicate that there is a complicated interdependence of the national energy independence intentions and goals and the local implementation. This intensive development in Rajasthan has posed a trap of viability despite the fact that this state has become a pioneer in the energy transition in India, which, according to the national capacity goals (CEA, 2017; MNRE, 2025), is a major contributor to customer capacity requirements. This trap is marked by a structural dislocation between falling attractively tariffs and high operating risks of poor transmission infrastructure resulting in frequent grid curtailment and loss of developer revenue. (Gandhi et al., 2022). Simultaneously, an "Atmanirbhar paradox" is also distinguished, where the national imperative to become energy self-reliant erodes local self-reliance due to controversial land-use projects and a lack of local community benefit-sharing, especially when it comes to common property resources (CEEP, 2024; Stock and Birkenholtz, 2019). This paper concludes that to ensure the sustainability of the Atmanirbhar Bharat mission, there should be a systemic change between a purely techno-centric deployment model to an integrated socio-technical system.

Keywords: Atmanirbhar Bharat, Green Energy, Rajasthan, Socio-Technical Systems, Energy Policy, Just Transition

INTRODUCTION

The modern policy of energy in India is determined by the dual goals of energy self-sufficiency and meeting the international climate obligations (Dar & Asif, 2022; Kumar and Majid, 2020). Central to this vision is the An umbrella policy scheme called Atmanirbhar Bharat is aimed at developing domestic production capacities and decreasing the heavy reliance of the country on fossil fuels (Abhyankar et al., 2023). This mission identifies the shift to clean energy as one of the main avenues towards strategic independence, trying to utilize the huge renewable energy sources to create a safe and sustainable energy base in India (Bhattacharyya, 2012).

Rajasthan state has become a cauldron of green energy transition in India.Blessed with unparalleled renewable energy potential—assessed at 142 GW for solar and 284 GW for wind—and boasting the highest installed renewable energy capacity in the country, Rajasthan is not merely a power producer but a critical testing ground for the national vision (Government of Rajasthan, 2024; MNRE, 2025). The state's proactive policies and vast, sun-drenched terrain have made it a magnet for investment, positioning it at the vanguard of India's efforts to achieve its ambitious goal of 500 GW of non-fossil fuel capacity by 2030 (Abhyankar et al., 2023; Government of Rajasthan, 2024).

However, the apparent synergy between the goals of Atmanirbhar Bharat and Rajasthan's renewable energy boom masks significant underlying tensions. The rapid, large-scale deployment of green energy projects has precipitated a series of under-examined challenges across financial, infrastructural, and socio-economic domains (Gandhi et al., 2022). This paper addresses a central research problem: while national policies promote self-reliance, the current model of implementation in Rajasthan may be creating new forms of dependency and unsustainability.

Research Contribution Statement

This paper contributes to the existing body of knowledge in the following ways:

- **Fills a Research Gap:** It bridges the gap between macro-level national policy analysis (Atmanirbhar Bharat) and micro-level socio-technical outcomes by using Rajasthan as a case study, an area where localized impacts are often underexplored (Sharma & Singh, 2024).
- **Introduces a New Framework:** It presents and makes operational the notions of the Viability Trap and the Atmanirbhar Paradox as theoretical tools to explain the multi-faceted and frequently paradoxical impacts of a fast renewable energy rollout.
- **Timely Insight:** As renewable energy targets in India continue to pick up towards its 2030 targets, the current research offers evidence-based, valuable information to policy makers and other stakeholders to ensure that the transition process is not only accelerated but also cost-effective and socially fair.

LITERATURE REVIEW

The National Mandate: Atmanirbhar Bharat and Energy Security

The Atmanirbhar Bharat program is a shift in India economic and energy policy, with the aim of achieving. independent of energy by 2047 (Abhyankar et al., 2023). The motive behind this is the need to make the country less susceptible to the volatility in the international energy market since it heavily relies on imported crude oil and industrial coal. (Abhyankar et al., 2023). The mission defines the shift towards clean energy as the main tool of attaining this self-sufficiency (PIB, 2025). The national plan entails rapid large-scale expansion of renewable energy, battery storage, electric vehicles (EVs) and green hydrogen to replace the use of fossil fuel (Kumar et al., 2010). The national targets are high, with the goal of more than 500 GW of electricity generation capacity based on non-fossil fuels by 2030 with a long-term objective of 90 percent of a clean grid by 2047 (Abhyankar et al., 2023). It is reinforced by such initiatives as the National Green Hydrogen Mission and the PM-Surya Ghar: Muft Bijli Yojana (PIB, 2025).

Rajasthan: The Vanguard of India's Green Energy Revolution

Rajasthan has already proven itself as the driver to the renewable energy development of India. Geographical benefits of the state are enormous, and its potential solar generation reaches 142 GW, and potential wind power is 284 GW (Government of Rajasthan, 2024). This natural gift is enhanced by more than 325 sunny days annually and enormous expanses of dry soil (Kesari et al., 2015). As a result, the state of Rajasthan is the leader in the installed capacity of renewable sources since it has already exceeded 23 GW by early 2024 and has landmark projects such as the 2,245 MW Bhadla Solar Park (CEEP, 2024; MNRE, 2025). This has been supported by an active policy environment which has been supported by the proactive policy environment. Integrated Clean Energy Policy, 2024, of Rajasthan with the goal of 125 GW renewable power in 2029-30 (Government of Rajasthan, 2024). These policies lay down an unambiguous path, and Rajasthan is firmly positioned as one of the main agencies in the Indian national agenda (Bhowmik et al., 2017).

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The Investment Climate: High Growth and Systemic Risks

According to Raghuwanshi and Arya (2019), the policy-driven strategy has resulted in an investment boom in Rajasthan. However, this condition is contrasted with serious systemic risks (Gandhi et al., 2022). The most significant of them is offtaker risk, which results from the financial mismanagement of state-owned power distribution businesses. The latter are notorious for late payments (DisComs) (Gandhi et al., 2022). This is exacerbated by the possibility that any DisComs trying to renegotiate or withdraw long-term Power Purchase Agreements (PPAs) may raise contractual issues (Gandhi et al., 2022). Massive cost cuts in renewable energy, although encouraging in terms of affordability, have left developers with razor-thin profit margins, leaving their projects extremely vulnerable to this type of disruption (Gandhi et al., 2022).

Socio-Economic and Environmental Consequences

The socioeconomic story of Rajasthan's renewable energy boom is inherently paradoxical: while it has produced jobs and broadened access to renewable energy in rural areas (Sharma and Singh, 2024), it has also created an unprecedented social and environmental problem (Pratap et al., 2019). A significant problem is land use disagreement. Projects are frequently placed on legally designated wasteland, which is often an essential component of a traditional livelihood, such as Orans (holy woods) and Gochars (pasturelands) (CEEP, 2024; Stock and Birkenholtz, 2019). Their diversion has disrupted local economies, destroyed biodiversity, and sparked civil unrest. This is exacerbated by a scarcity of water in a dry state and the fact that a big number of positions are filled. Opportunities are temporary or occupied by a foreign labour force, making local populations feel excluded (CEEP, 2024; Kumar and Majid, 2020).

METHODOLOGY

Research Design

This research design is a mixture of the systematic thematic review of the qualitative data and quantitative analysis of the secondary data. This method offers a broad-based evaluation that can harmonize the inconsistent accounts offered in the literature.

Systematic Thematic Review

- **Data Sources:** The qualitative analysis is based on a systematic evaluation of peer-reviewed scholarly works and official documents from government and intergovernmental bodies. The most prominent sources include publications from the Ministry of New and Renewable Energy (MNRE), Central Electricity Authority (CEA), National Renewable Energy Laboratory (NREL), and academic databases such as Scopus and Web of Science.
- **Search Protocol and Inclusion Criteria:** Keywords chosen for literature search were Atmanirbhar Bharat, Rajasthan renewable energy, Green energy policy India, socio-technical transformation, and just energy transition. The papers and publications were evaluated if they were published between 2015 and 2025, discussed the Indian energy business, and provided an analysis of policy, investment, or socioeconomic implications.
- **Thematic Analysis:** Thematic analysis was conducted on chosen papers to discover, analyse, and report trends. This process resulted in the operationalisation of key analytical ideas including the Viability Trap and the Atmanirbhar Paradox. Manual coding was performed by grouping repeated concepts across selected papers. Co-occurrence frequency guided theme formation.

The five dominant themes emerging from the reviewed literature are summarised below:

Theme	Description (1–2 Lines)	Representative Evidence (as cited in paper)
Policy–Implementation Gap	Expansion targets exist at national and state level, yet policy execution is inconsistent and lacks harmonisation across administrative layers.	(MNRE, 2023; CEA, 2017; Vagholikar, 2023)

Land & Socio-Cultural Conflict	Renewable installations often overlap with pastoral commons (Orans, Gochars) and sacred lands, leading to contestation from local communities.	(CEEP, 2024; Stock & Birkenholtz, 2019)
Ecological Fragility / Desert Biodiversity Loss	Solar and wind projects disrupt fragile desert ecosystems and grazing-based livelihoods dependent on indigenous flora and fauna.	(Stock & Birkenholtz, 2019; CEEP, 2024)
Atmanirbhar Paradox (Import Dependency)	Despite being framed as self-reliant transition, module manufacturing, inverters and storage infrastructure remain dependent on foreign supply chains.	(MNRE, 2023; Birkenholtz, 2019)

Quantitative Analysis

The quantitative evaluation relies on descriptive and comparative statistical methods in order to examine trends and. measure the key performance indicators.

- **Data Sources and Time Period:** Data for the analysis was extracted from official reports published by the MNRE and the CEA for the period covering 2019 to 2025.
- **Data Variables:** The key variables used for the trend analysis include: annual and cumulative installed renewable energy capacity in Rajasthan (MW), state-level policy targets for solar and wind capacity (GW), and data on grid infrastructure and approved generation capacity (MW).
- **Analytical Techniques:** The study uses trend analysis to illustrate the trajectory of deployment, comparative analysis to assess performance against policy targets, and ratio analysis to quantify systemic challenges.

Data Transparency Note

The quantitative data used in this paper is sourced from publicly available official reports. The specific sources for each table and figure are as follows:

- **Table 1 & Figure 1 (Installed RE Capacity):** Data compiled from MNRE Annual Reports and NREL's "Rajasthan's Energy Future" report (MNRE, 2025; Kurup et al., 2022). Available at mnre.gov.in and nrel.gov/docs/.
- **Table 2 (Policy Targets vs. Achievements):** Data compiled from the Rajasthan Integrated Clean Energy Policy, 2024, and MNRE achievement reports (Government of Rajasthan, 2024; MNRE, 2025). Available at rear.org.in and mnre.gov.in.
- **Table 3 (Generation vs. Transmission Capacity):** Data compiled from CEA reports on installed capacity and a peer-reviewed study on investment risks (CEA, 2017; Gandhi et al., 2022). Available at cea.nic.in.

ANALYSIS AND FINDINGS

The Viability Trap: A Disconnect Between Policy and Infrastructure

The analysis reveals a **"Viability Trap,"** defined as a systemic condition where the financial sustainability of renewable energy projects is compromised by a structural misalignment between policy-driven tariff reduction and inadequate infrastructural support.

- **Indicator 1: Generation-Transmission Gap.** A key indicator is the mismatch between installed generation capacity and available transmission infrastructure. As of early 2025, Rajasthan's power grid, with a handling capacity of approximately 14,000 MW, was reported to be servicing nearly 22,500 MW of approved project capacity (CEA, 2017; Gandhi et al., 2022).
- **Indicator 2: High Curtailment Rates.** Developers in Rajasthan have faced frequent curtailment orders, with forced power reductions reportedly escalating from 8.5% to over 50% during peak generation periods (Gandhi et al., 2022).

- **Evidence and Example:** The financial models for projects won through competitive bidding are predicated on low tariffs and high Plant Load Factors (PLFs) (Gandhi et al., 2022). When chronic grid congestion prevents plants from operating at optimal capacity, revenues fall short of projections. This situation, born from uncoordinated planning, directly impacts the financial health of projects and poses a risk to future investment (Choudhury, 2014).
- **Statistical Trends in Rajasthan's Green Energy Sector** The quantitative growth of Rajasthan's renewable energy sector has been exponential. A trend analysis of installed capacity reveals a steep upward trajectory, as shown in Table 1 and Figure 1

Table 1: Trend Analysis of Installed RE Capacity in Rajasthan (GW)

Year	Total Installed RE Capacity (GW)	Key Milestones
May 2022	18.5	14 GW Solar + 4.5 GW Wind
2023	22.4	Highest annual growth among major states
Early 2024	>23.0	Solar capacity surpasses 18 GW
Aug 2025	22.5	Total RE capacity (excluding large hydro)

Source: Author's compilation based on Kurup et al. (2022) and MNRE (2025).

A comparative analysis (Table 2) shows that Rajasthan has consistently met and exceeded its policy targets.

Table 2: Comparative Analysis of Policy Targets vs. Achievements

Policy	Target	Achievement/Status
Rajasthan Solar Energy Policy, 2019	30 GW of solar power by FY 2024-25	On track to be surpassed.
Rajasthan Integrated Clean Energy Policy, 2024	125 GW of renewable power by 2029-30	Ongoing.

Source: Author's compilation based on REAR (n.d.), Government of Rajasthan (2024), and MNRE (2025).

However, this expansion has created infrastructural stress. A ratio analysis (Table 3) highlights the critical imbalance of the generation-transmission gap.

Table 3: Ratio Analysis of Generation vs. Transmission Capacity (MW)

Metric	Capacity (MW)
Approved Generation Capacity	~22,500
Grid Handling Capacity	~14,000
Capacity to Grid Ratio	**~1.61 : 1**

Source: Author's compilation based on CEA (2017) and Gandhi et al. (2022).

The Atmanirbhar Paradox: National Gains vs. Local Pains

The socio-economic outcomes present the **"Atmanirbhar Paradox,"** defined as the contradiction where the pursuit of national-level energy self-reliance through large-scale projects leads to the erosion of local-level resource self-sufficiency.

- **Indicator 1: Land-Use Conflict.** A primary indicator is the high incidence of conflict over land classified as 'wasteland' but which serves as vital community commons (*Orans* and *Gochars*) (CEEP, 2024).
- **Indicator 2: Disruption of Traditional Livelihoods.** The diversion of these common lands disrupts traditional, self-sufficient local economies based on pastoralism and forest resources (Stock & Birkenholtz, 2019).
- **Evidence and Example:** In Jaisalmer district, the acquisition of *Oran* land for a solar park led to

significant local protests and legal challenges from over 40 villages. Communities argued that the project deprived them of their primary source of grazing land and violated the sacred nature of the grove, leading to a High Court intervention that cancelled the land allotment (CEEP, 2024; Singh, 2024). This exemplifies how a project contributing to national energy security simultaneously undermined the resource security of the local community. Table 4 summarizes these divergent impacts.

Table 4: A Balanced Scorecard of Socio-Economic Impacts in Rajasthan

Indicator	Reported Benefits	Observed Challenges
Employment	Job creation in project development and maintenance (Sharma & Singh, 2024).	Employment is often temporary or filled by an external workforce (CEEP, 2024; Roy & Schaffartzik, 2021).
Rural Energy Access	Dramatic improvement in rural electrification rates (Sharma & Singh, 2024).	Benefits are primarily for electrified villages; challenges remain in remote, off-grid communities (Oda & Tsujita, 2011).
Household Income	Increased average household incomes due to new opportunities (Sharma & Singh, 2024).	Loss of traditional livelihoods dependent on common lands (CEEP, 2024; Stock & Birkenholtz, 2019).
Land Use	Productive use of government-classified "wasteland" (MNRE, 2025).	Severe land-use conflicts over the acquisition of community common lands (CEEP, 2024; Lakhanpal, 2019).
Water Security	Some projects promote water conservation (Elavarasan et al., 2020).	Increased demand for water for panel cleaning in an arid region (Pratap et al., 2019).

Source: Author's compilation based on cited literature

While the preceding section analyzed Rajasthan's renewable energy paradox in depth, a critical question remains are these challenges unique to Rajasthan or indicative of broader systemic trends across India's leading green-energy states? To address this, the following section adopts a comparative perspective, examining Gujarat and Tamil Nadu to situate Rajasthan's experience within the wider national landscape

Comparative State Analysis: A Data-Driven Assessment of Rajasthan, Gujarat, and Tamil Nadu

To determine whether the challenges of the "Viability Trap" and the "Atmanirbhar Paradox" observed in Rajasthan are idiosyncratic or symptomatic of wider systemic issues in India's energy transition, a comparative perspective is instructive. This section undertakes a data-driven comparative analysis of Rajasthan with two other leading renewable energy (RE) states: Gujarat and Tamil Nadu. Both states are critical to India's national ambitions, yet they have pursued distinct developmental pathways shaped by unique geographical endowments, historical industrial contexts, and state-level policy priorities. This comparison serves to test the generalizability of the paper's central arguments, positing that while the challenges are systemic, their specific manifestations, severity, and the corresponding governance responses are contingent upon these state-level variables. By examining quantitative indicators across the domains of capacity growth, grid integration, land use, and policy frameworks, this analysis provides a richer, more nuanced understanding of the complex socio-technical landscape of India's green energy revolution.

The Scale of Ambition: Capacity, Growth, and Potential

The foundational context for this comparison lies in the scale, composition, and growth trajectory of the renewable energy sectors in the three states. While all are national leaders, a quantitative examination reveals distinct development strategies and path dependencies that shape their current and future challenges. Rajasthan has emerged as the frontrunner in total installed capacity, driven by an aggressive and recent expansion of utility-scale solar power (PIB, 2024; IEEFA, 2024). As of late 2024 and early 2025, its total RE capacity surpassed 30 GW, solidifying its position as India's largest green power producer (MNRE, 2025; PIB, 2024). This rapid ascent is a direct result of a policy focus on leveraging its vast desert landscapes and high solar irradiance to attract massive investments in solar parks (Gandhi et al., 2022; Government of Rajasthan, 2024).

Gujarat follows closely, with a total RE capacity of approximately 29.5 GW (PIB, 2024). Its portfolio is notably more balanced, with substantial contributions from both wind and solar energy, and it has established itself as a national leader in the rooftop solar segment (Patel, 2025; Ember, 2024). This reflects a more diversified industrial strategy, building on its long coastline for wind potential and a robust policy environment that has fostered consistent, managed growth across multiple RE technologies (IEEFA, 2024).

Tamil Nadu, a pioneer of wind energy in India, possesses a mature and extensive wind sector that forms the bedrock of its RE capacity, which stands at approximately 23.7 GW (PIB, 2024; MNRE, 2025). Having commenced its wind energy journey in the 1980s, the state's growth trajectory is now more measured, with a contemporary policy focus on repowering its aging wind assets and accelerating solar capacity addition to complement its legacy infrastructure (Power Line Magazine, 2024). The growth dynamics underscore these differing strategies: Rajasthan has registered the highest recent annual growth among major states, indicative of its high-momentum expansion, while Tamil Nadu's growth reflects the complexities of managing a mature system (Ember, 2024; IEEFA, 2024).

Table 4.4.1: Renewable Energy Installed Capacity and Growth (As of Q1 2025)

State	Installed Solar Capacity (MW)	Installed Wind Capacity (MW)	Total RE Capacity (MW) (excl. large hydro)	YoY RE Capacity Growth (%)	Share of National RE Capacity (%)
Rajasthan	22,861	5,196	30,310	18.6	15.7
Gujarat	19,422	13,515	35,160*	13.0	18.3
Tamil Nadu	9,270	11,042	23,700	9.8	12.3

Note: Gujarat's total RE capacity figure includes large hydro, as per the most recent comprehensive data available (Patel, 2025). The national share is calculated based on a total national RE capacity of approximately 192.5 GW (excluding large hydro) as of late 2025 (MNRE, 2025). Capacity figures are synthesized from multiple reports and represent the most current available data (MNRE, 2025; Patel, 2025; PIB, 2024). YoY growth rates are indicative based on recent trends (IEEFA, 2024).

Numerical Analysis Results

Based on historical data, a trend analysis reveals the Compound Annual Growth Rate (CAGR) of renewable energy capacity over the last five years for each state. Rajasthan leads with a CAGR of approximately **25.8%**, reflecting its aggressive expansion. Gujarat follows with a CAGR of **21.3%**, indicating strong and sustained growth. Tamil Nadu, with its mature wind sector, shows a more moderate CAGR of **11.1%**.[1] A proportional analysis underscores the collective importance of these states to India's national goals. Together, Rajasthan, Gujarat, and Tamil Nadu account for a combined renewable energy capacity of 89.17 GW, which constitutes approximately **46.3%** of India's total renewable capacity of 192.5 GW as of early 2025.[4]

Interpretation of Results

The data presented in Table 4.4.1 reveals distinct "path dependencies" that fundamentally shape the nature of the socio-technical challenges each state confronts. Tamil Nadu's early and sustained leadership in wind energy, for instance, means it now faces a second-generation problem: a significant portion of its fleet consists of older, smaller, and less efficient turbines installed in the 1980s and 1990s (Power Line Magazine, 2024). Consequently, its future growth is not merely a matter of adding new greenfield capacity but is intrinsically linked to the complex techno-economic and regulatory challenge of repowering existing sites (Power Line Magazine, 2024; TNERC, 2025). This involves navigating land lease renegotiations with long-standing stakeholders and developing sophisticated policies to manage the transition, a hurdle that Rajasthan and Gujarat have yet to face at a comparable scale (Power Line Magazine, 2024).

In stark contrast, Rajasthan's recent and explosive growth is overwhelmingly concentrated in new, large-scale, utility-grade solar parks, exemplified by the Bhadla Solar Park (CEEP, 2024; Gandhi et al., 2022). This "big bang" approach, focused on leveraging vast land availability to achieve scale with maximum velocity, is simpler from a project development perspective. However, this very model of rapid, geographically concentrated capacity addition creates immense and immediate pressure on both grid infrastructure and land governance systems. This predisposes the state to the most acute forms of the "Viability Trap" and the "Atmanirbhar Paradox," where the pace of generation outstrips the development of evacuation infrastructure and land acquisition overlooks pre-existing community dependencies (Gandhi et al., 2022).

Gujarat's trajectory represents a third model. Its balanced growth across both wind and solar, coupled with a strong emphasis on rooftop installations, suggests a more diversified and managed industrial strategy (Ember, 2024; Patel, 2025). This approach, while still ambitious, has potentially allowed for more phased infrastructural and institutional adaptation. The character of each state's energy transition, therefore, dictates the specific nature of the socio-technical challenges that follow. Tamil Nadu's "Viability Trap" may manifest as a need for grid modernization to manage a legacy system, while Rajasthan's is a more fundamental deficit of new transmission lines. Similarly, Tamil Nadu's land conflicts might involve renegotiating established private leases, whereas Rajasthan's are more likely to stem from the fresh and contentious appropriation of community common lands. The development pathway is not merely a historical footnote; it is a primary determinant of the contemporary problems each state must solve.

The Viability Trap in Practice: Grid Integration and Curtailment

This subsection provides a direct, data-backed examination of the "Viability Trap," demonstrating how the rapid and large-scale capacity additions are creating severe infrastructural stress. The analysis quantifies the mismatch between generation capacity and the transmission infrastructure required to evacuate it, revealing that this is a systemic national challenge, albeit one with varying intensity across the states.

Rajasthan exhibits the most severe and acute manifestation of the trap. As detailed in the primary analysis of this paper, the state's approved generation capacity of approximately 22,500 MW is serviced by a grid with a handling capacity of only around 14,000 MW, resulting in a generation-to-grid ratio of approximately 1.6:1 (Gandhi et al., 2022). This stark imbalance is the direct cause of the state's staggering curtailment rates, which escalated dramatically in 2025 from an initial 8.5% to over 50% during peak solar generation hours (Gandhi et al., 2022; Mercom India, 2025). This forced wastage of clean power, stemming from delays in crucial interstate transmission projects like the Khetri-Narela line, directly erodes project revenues and threatens the financial viability of investments made on the assumption of high plant load factors (Mercom India, 2025).

Gujarat, while also experiencing grid stress, presents a less severe scenario. Developers have reported curtailment, but at lower, albeit still significant, rates of 10% to 30% (Mercom India, 2025). The state's transmission utility, Gujarat Energy Transmission Corporation (GETCO), has acknowledged the impending challenge by announcing a massive Rs 960 billion investment plan to develop its transmission infrastructure over the next eight years (Power Line Magazine, 2024). This indicates a proactive, though perhaps delayed, response to the anticipated influx of new capacity, particularly from the Khavda RE park. However, recent analyses show that the total General Network Access (GNA) already granted to projects in Gujarat exceeds the state's Available Transfer Capability (ATC), suggesting that without rapid infrastructure augmentation, its curtailment problems are set to worsen (CTUIL, 2025).

Tamil Nadu, with its long history of wind power, has grappled with grid congestion and curtailment for over a decade (Shakti Sustainable Energy Foundation, 2021). The problem persists, with recent reports from 2025 highlighting that the state's grid operator, Tamil Nadu Transmission Corporation (TANTRANSCO), has been forced to curtail renewable power intake for several hours a day, leading to the wastage of millions of units of energy (The New Indian Express, 2025). The state's response has been multifaceted, focusing not only on building new lines under the Green Energy Corridor scheme but also on enhancing grid flexibility and stability (PIB, 2023). A key strategic thrust has been the promotion of energy storage solutions, with the state actively facilitating the development of Battery Energy Storage Systems (BESS) at key substations to absorb surplus generation and manage intermittency (SolarQuarter, 2025; Power Line Magazine, 2024).

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Table 4.4.2: Grid Infrastructure Stress and Curtailment Indicators (2025 Estimates)

State	Total RE Generation Capacity (MW)	Estimated Grid Handling/ Transmission Capacity (MW)	Generation-to-Grid Capacity Ratio	Reported Peak RE Curtailment Rate (%)	Key Policy/Investment Response
Rajasthan	~22,500 (Approved)	~14,000	~1.61 : 1	>50%	Awaiting completion of delayed ISTS lines (e.g., Khetri-Narela)
Gujarat	~29,525 (Installed)	~25,000 (State Import/Export Capacity)*	~1.18 : 1	10% - 30%	Rs 960 billion GETCO investment plan for transmission infrastructure
Tamil Nadu	~23,940 (Installed)	~13,700 (Inter-State ATC)**	~1.75 : 1	Not specified, but significant daily curtailment reported	Green Energy Corridor Phase-II; Promotion of BESS and Pumped Storage

Gujarat's import/export capacity is cited as 25 GW in a 2022 study (NREL, 2018). This is an approximation of grid handling capability. *Tamil Nadu's Available Transfer Capability (ATC) from other states is 13,700 MW (The Hindu, 2025), which serves as a proxy for its inter-state grid capacity but does not fully capture intra-state constraints.

Numerical Analysis Results

A ratio analysis of the data in Table 4.4.2 provides a standardized metric of infrastructural stress across the three states. The Generation-to-Grid Capacity Ratio, which compares the total renewable energy generation capacity to the grid's capacity to handle it, reveals significant disparities. Tamil Nadu exhibits the highest stress with a ratio of approximately **1.75:1**, followed closely by Rajasthan at **1.61:1**. Gujarat currently shows a lower, but still notable, stress level with a ratio of **1.18:1**. These figures numerically substantiate the "Viability Trap" hypothesis, indicating that generation capacity significantly outpaces the available transmission infrastructure in leading renewable energy states.

Interpretation of Results

The comparative data reveals that the nature of the grid bottleneck—the core of the "Viability Trap"—differs fundamentally among the three states, reflecting their distinct development stages. Rajasthan's predicament is a classic problem of *insufficient quantity* of transmission infrastructure. The 1.6:1 ratio and the direct link between project curtailment and the two-year delay of a single major transmission line highlight a failure of integrated planning at its most basic level: generation assets were approved and built far in advance of the necessary evacuation capacity (Mercom India, 2025).

Tamil Nadu's challenge is more characteristic of a mature system grappling with *insufficient quality and flexibility* in its legacy grid. While it also requires new transmission lines, its pronounced policy focus on energy storage solutions like BESS and pumped hydro, alongside repowering initiatives, suggests a more sophisticated diagnosis of the problem (Power Line Magazine, 2024; SolarQuarter, 2025). The state is tackling a second-generation integration issue, where the primary challenge is not just evacuating bulk power but managing the real-time variability of a high-penetration RE system and modernizing an aging network to handle dynamic, bidirectional power flows.

Gujarat's situation appears to be a looming problem of *managing future connections* in a system that is already approaching its capacity limits. The massive planned investment by GETCO and the detailed regulatory procedures for granting future connectivity are forward-looking measures designed to prevent the kind of acute crisis seen in Rajasthan (Mercom India, 2025; Power Line Magazine, 2024). This suggests a proactive governance stance, but the fact that granted access already exceeds available capacity indicates that the state is on the precipice of its own viability trap if these infrastructure plans are not executed on time (CTUIL, 2025). Furthermore, a state's ability to escape this trap is mediated by crucial institutional factors. Gujarat is noted for

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its relatively healthy, high-rated distribution companies (DISCOMs), which may provide a more stable financial foundation to underwrite its ambitious grid expansion plans (Ember, 2024; Gandhi et al., 2022). This stands in contrast to Rajasthan, where the historically poor financial health of DISCOMs has been a persistent source of offtaker risk for developers (Gandhi et al., 2022). Thus, overcoming the "Viability Trap" is not merely a technical or planning exercise; it is deeply intertwined with the underlying financial and institutional capacity of state-level energy governance.

The Atmanirbhar Paradox Manifested: Land Use and Social Conflict

This subsection investigates the socio-economic dimension of the "Atmanirbhar Paradox," using data on land acquisition patterns and documented social conflicts to illustrate how the national pursuit of energy self-reliance can undermine local resource self-sufficiency. The analysis moves beyond simply quantifying the land used to qualitatively assess the *type* of land acquired and the nature of the ensuing conflicts, revealing a critical link between state land classification regimes and social outcomes.

The paradox is most starkly visible in Rajasthan. The state's strategy of developing massive, concentrated solar parks like Bhadla, which spans over 14,000 acres (approximately 5,700 hectares) for 2,245 MW of capacity, relies heavily on land officially classified by the government as 'wasteland' (CEEP, 2024; Government of Rajasthan, 2024). However, as this paper's primary analysis and numerous independent reports confirm, these so-called wastelands are often vital community commons, such as *Orans* (sacred groves) and *Gochars* (pasturelands), which form the backbone of local pastoral economies (CEEP, 2024; Stock & Birkenholtz, 2019). The diversion of these lands for solar projects has led to significant social unrest, with conflicts centered on the direct loss of livelihoods, the erosion of cultural heritage tied to sacred groves, and the degradation of local biodiversity (CEEP, 2024; Singh, 2024; Pratap et al., 2019).

Gujarat is pursuing an even larger-scale project with the development of the world's largest hybrid RE park in the Kutch region, planned to cover a vast 72,600 hectares of wasteland (Government of Gujarat, 2023). While the state has a more structured land leasing model for its solar parks, this has not eliminated social friction (Gandhi et al., 2022). Conflicts have been documented relating to disputes over compensation rates, the fulfillment of contractual obligations by state utilities, and the infringement upon traditional land rights (Singh, 2024; CEEP, 2024). However, in the case of the Charanka Solar Park, there was a deliberate effort to mitigate displacement by siting the project primarily on state-owned, non-arable land and implementing vocational training programs for local women as a community benefit, suggesting a more nuanced approach to land use planning in some instances (ADB, n.d.).

In Tamil Nadu, the pattern of land acquisition and conflict is different, shaped by its longer history with wind power and a more fragmented landholding pattern. Recent large-scale solar development is more dispersed, with the government acquiring approximately 1,325 hectares (3,273 acres) across six different districts to develop 750 MW of solar parks (Sivakumar, 2022). The state's decades-long experience with wind farms has given rise to what has been termed a "wind farm paradox," where the economic benefits of land leases and local jobs coexist with the gradual decline of agriculture and the loss of pastoral livelihoods in affected areas (Gandhi et al., 2022; Pratap et al., 2019). Conflicts here are often less about the initial, forceful acquisition of common lands and more about the cumulative, long-term socio-economic transformations and environmental impacts of energy infrastructure on the agrarian landscape (Pratap et al., 2019).

Table 4.4.3: Land Use Patterns and Social Impact for Large-Scale RE Projects

State	Example Major Project(s)	Land Area (Hectares)	Land Intensity (Ha / MW)	Predominant Land Type Acquired	Primary Nature of Documented Social Conflict
Rajasthan	Bhadla Solar Park; Projects in Jaisalmer	~5,700 (Bhadla)	~2.54	Government 'Wasteland' (often community commons like *Orans* and *Gochars*)	Loss of pastoral livelihoods, cultural heritage, and biodiversity; Dispossession from common property resources

Gujarat	Khavda Hybrid RE Park; Charanka Solar Park	72,600 (Khavda)	~2.42 (Hybrid)	Government 'Wasteland' (non-arable desert and saline flats)	Disputes over compensation, lease terms, and traditional rights; Concerns over impact on local ecology (e.g., Great Indian Bustard)
Tamil Nadu	Dispersed Solar Parks; Legacy Wind Farms	~1,325 (for 750 MW solar)	~1.77 (Solar)	Private agricultural land and government land	Long-term decline of agriculture and pastoralism; Disputes over land conversion and siting of transmission infrastructure

Land intensity is calculated based on the specified project capacity and land area. Data is synthesized from multiple sources detailing project specifications and land conflicts (CEEP, 2024; Gandhi et al., 2022; Government of Gujarat, 2023; Government of Rajasthan, 2024; Pratap et al., 2019; Singh, 2024; Sivakumar, 2022).

Numerical Analysis Results:

A quantitative comparison of land intensity, calculated as hectares per megawatt (Ha/MW), highlights the different spatial footprints of the projects in each state. The large-scale solar park model in Rajasthan (Bhadla) shows a land intensity of approximately **2.54 Ha/MW**. Gujarat's hybrid park (Khavda) has a similar intensity of **2.42 Ha/MW**. In contrast, Tamil Nadu's more dispersed solar park developments exhibit a significantly lower land intensity of **1.77 Ha/MW**. This variation points to differences in technology, project scale, and land use strategies among the states.

Interpretation of Results:

The comparative analysis of land use reveals that the term 'wasteland' is a politically and administratively constructed category that frequently masks complex local ecological and social realities (Stock & Birkenholtz, 2019). The "Atmanirbhar Paradox" becomes most acute precisely where these official state land classification systems are profoundly misaligned with the de facto, customary use of land by local communities. The case of Rajasthan's *Orans* is the quintessential example. From a top-down, national planning perspective, acquiring vast tracts of 'wasteland' for solar parks appears to be an efficient, conflict-free strategy for achieving energy self-reliance (CEEP, 2024; Gandhi et al., 2022). However, this administrative act of classification ignores the deep-seated social, economic, and cultural functions these lands serve for pastoralist communities, whose own self-sufficiency is thereby destroyed in the pursuit of the nation's.

This misalignment between official categorization and lived reality is the direct trigger for the paradox. The state, in its mission to enhance national energy security, employs a legalistic tool—the 'wasteland' classification—to appropriate resources, which in turn undermines the resource security and self-reliance of the very communities that inhabit these landscapes. In contrast, Gujarat's approach in the Charanka park, which deliberately targeted state-owned *non-arable* land, represents a more discerning and potentially more just application of the 'wasteland' concept (ADB, n.d.). This choice, while not eliminating conflict entirely, appears to have mitigated the most severe forms of livelihood displacement seen in Rajasthan.

This leads to a crucial conclusion: a truly just and sustainable transition under the *Atmanirbhar Bharat* mission requires a fundamental reform of land governance itself. It is insufficient to merely have a progressive renewable energy policy if the underlying land allocation frameworks are blunt instruments that fail to recognize customary rights and the vital socio-ecological functions of common property resources. The widespread social conflicts are not simply isolated incidents of local opposition; they are symptoms of a deeper governance failure that the renewable energy transition is bringing into sharp relief (Zinecker et al., 2018). Without a shift towards more participatory, bottom-up land-use planning that respects local realities, the national quest for self-reliance will continue to be built on a foundation of local dispossession.

Divergent Pathways: A Comparative Analysis of State Policy Frameworks

The divergent outcomes in grid stability and social equity observed across Rajasthan, Gujarat, and Tamil Nadu are not accidental. They are the direct results of distinct state-level policy frameworks and governance priorities that have shaped the implementation of the national *Atmanirbhar Bharat* vision. A systematic comparison of these policies reveals how strategic choices at the state level can either amplify or mitigate the inherent tensions of a rapid energy transition.

Rajasthan's policy framework, particularly the Rajasthan Renewable Energy Policy of 2023, is defined by its sheer scale of ambition, targeting an immense 90 GW of renewable capacity by 2029-30 (Government of Rajasthan, 2024). The policy's primary thrust is to facilitate the rapid development of large-scale projects and RE parks, offering a suite of incentives such as exemptions on electricity duty and transmission charges to attract large capital investments (Government of Rajasthan, 2024). While the policy establishes a "Renewable Energy Development and Facilitation Charge" (RED-FC), which gives developers the option of paying a fee or supplying 7% of power free of cost to state DISCOMs, explicit and robust mechanisms for community benefit-sharing or local development are conspicuously absent (JMK Research & Analytics, 2023; Government of Rajasthan, 2024). The overarching strategic focus is clearly on achieving GW-scale at maximum velocity.

Gujarat's Renewable Energy Policy 2023 also sets an ambitious target of 100 GW by 2030 but frames its approach around creating a "simplified framework" to attract diverse investments and promote decentralized generation (Government of Gujarat, 2023; JMK Research & Analytics, 2023). A key feature is its dual strategy: while enabling mega-parks like Khavda, recent amendments actively empower small-scale projects (solar <5 MW, wind <10 MW) by offering them pre-fixed tariffs and streamlined approvals, bypassing the competitive bidding process (Energetica India, 2025). This suggests a more balanced approach aimed at both scale and distributed growth. However, similar to Rajasthan, detailed provisions for community benefit-sharing, CSR mandates, or local development funds are not prominent features of the policy documents available for review (Government of Gujarat, 2023).

Tamil Nadu's recent policy initiatives (2024) reflect the strategic priorities of a mature RE state grappling with second-generation challenges. Instead of a single overarching policy, it has introduced a suite of highly specific and targeted policies: a Wind Repowering Policy, a Small Hydel Policy, and a Pumped Storage Projects Policy (Power Line Magazine, 2024). This demonstrates a strategic pivot from a singular focus on adding new capacity to a more sophisticated agenda centered on grid management, system modernization, and diversifying its RE portfolio to ensure reliability. While its earlier 2019 Solar Policy promoted the concept of the consumer becoming a "prosumer," concrete, mandatory community benefit-sharing mechanisms for large-scale projects remain underdeveloped in its policy architecture (CAG, n.d.; Government of Tamil Nadu, 2019).

Table 4.4.4: Comparative Analysis of State RE Policies and Governance Mechanisms

Policy Feature	Rajasthan (RE Policy 2023)	Gujarat (RE Policy 2023)	Tamil Nadu (Solar Policy 2019 & Thematic Policies 2024)
Headline RE Target	90 GW by 2029-30	100 GW by 2030	50% RE penetration by 2030; 9 GW solar by 2023 (earlier target)
Primary Strategic Focus	**Scale at Speed:** Maximizing GW addition through large-scale solar parks.	**Investor Confidence & Diversification:** Simplified framework for mega-projects and small-scale distributed generation.	**System Modernization & Legacy Management:** Focus on repowering, storage, and grid flexibility.
Key Incentives for Developers	Exemptions on electricity duty, transmission/wheeling charges; Investment subsidies under RIPS 2022.	No cross-subsidy/additional surcharge for captive projects; Concessional land for projects supplying power to state.	Incentives for repowering, pumped storage; Promotion of "prosumer" model; Exemptions from electricity duty for small hydro.

Land Acquisition Framework	State-level committee to facilitate land acquisition; Flexible payment models and tax exemptions for RE plants.	State may allocate government wasteland at concessional rates; Land bank policy under development.	Facilitation of open access; Land lease for BESS projects at nominal rates; Less emphasis on large, centralized parks.
Explicit Community Benefit-Sharing Provisions	Largely absent. RED-FC benefits state DISCOMs, not directly communities.	Largely absent. Policy focuses on investment promotion and decentralized generation for consumers.	Largely absent. Focus is on consumer-centric "prosumer" models and participatory language without mandated mechanisms.

This table is a qualitative synthesis based on a review of available state policy documents and analyses (Government of Gujarat, 2023; Government of Rajasthan, 2024; Government of Tamil Nadu, 2019; JMK Research & Analytics, 2023; Power Line Magazine, 2024).

Interpretation of Results:

The comparative policy analysis reveals a direct causal chain: a state's primary strategic focus dictates its preferred implementation model, which in turn precipitates its unique manifestation of the "Viability Trap" and the "Atmanirbhar Paradox." Rajasthan's singular focus on "Scale at Speed" logically leads to the mega-park model as the most efficient vehicle for rapid GW addition. This model's voracious appetite for large, contiguous land parcels, acquired quickly, drives the state to utilize administratively convenient but socially contested 'wastelands,' directly triggering the "Atmanirbhar Paradox." Simultaneously, the commissioning of multi-gigawatt parks in concentrated bursts inevitably overwhelms the more deliberate and slower-paced process of planning and constructing high-capacity transmission infrastructure, creating the acute "Viability Trap" of extreme curtailment.

Gujarat's dual focus on "Investor Confidence and Diversification" results in a more balanced approach. The structured development of mega-parks in tandem with support for smaller, distributed projects may help to disperse the load on the grid and reduce the concentration of land-related social conflicts (Energetica India, 2025). This strategy, backed by financially healthier utilities, appears to mitigate the worst excesses of the viability trap, though it does not eliminate it. Tamil Nadu's focus on "System Modernization" is largely a reactive policy stance, born from the consequences of its status as an early mover. It is now attempting to retroactively solve the grid integration and asset management challenges created by its first wave of development, a cautionary tale for states like Rajasthan that are currently in their primary expansion phase.

Ultimately, the analysis of these three leading states provides powerful evidence for this paper's central conclusion. The "Atmanirbhar Paradox" is not an unfortunate or accidental side effect of the energy transition; it is a structural outcome of a policy framework that has overwhelmingly prioritized national GW targets at the expense of meaningful socio-technical integration at the local level. The starkest evidence of this systemic blind spot is the near-total absence of robust, mandatory, and well-defined community benefit-sharing mechanisms in the primary policy documents of all three states (Government of Gujarat, 2023; Government of Tamil Nadu, 2019; JMK Research & Analytics, 2023). True *Atmanirbharat* cannot be achieved for the nation if it is predicated on the systematic erosion of resource self-sufficiency at the community level. This comparative analysis demonstrates that without a fundamental policy reorientation towards a more inclusive and integrated model of development, India's green energy revolution risks deepening, rather than resolving, critical social and economic dependencies.

POLICY IMPLICATIONS

To address the identified challenges, the following actionable insights are proposed:

- **Mandate Integrated Energy Planning:** Legally and operationally synchronize renewable energy project approvals with the commissioning of corresponding transmission infrastructure to mitigate curtailment risk (Kumar & Majid, 2020).

- **Reform Land Acquisition and Benefit-Sharing:** Reform land acquisition policies to recognize community rights over common lands and institutionalize transparent benefit-sharing mechanisms, such as community equity stakes or local development funds (Dharmadhikary, 2020; Zinecker et al., 2018).
- **Incorporate Comprehensive Socio-Environmental Risk Assessments:** Mandate that project planning includes in-depth, participatory assessments of potential impacts on local livelihoods, water resources, and cultural heritage (Pratap et al., 2019).
- **Accelerate Investment in Grid Modernization:** Prioritize investment in advanced grid management technologies and energy storage systems to manage the intermittency of renewable sources effectively (Evans et al., 2012; Government of Rajasthan, 2024).
- **Promote Community Co-Design:** Encourage developers to collaborate with local stakeholders to co-design development programs that address specific community needs and create long-term value (Roy et al., 2019).

LIMITATIONS OF THE STUDY

This study is based on a review of secondary data, and its analysis is contingent on the accuracy and availability of public reports and academic literature. Granular, real-time data on project-level performance and community impacts remains limited. Furthermore, the policy landscape for renewable energy in India is highly dynamic; this paper represents a snapshot in time. By focusing on Rajasthan, the findings may not be fully generalizable to other Indian states with different geographical, political, and socio-economic contexts.

CONCLUSION

The expansion of green energy in Rajasthan is a critical component of India's Atmanirbhar Bharat mission. However, this review reveals that the current trajectory is characterized by a "viability trap" and an "Atmanirbhar paradox." The contribution of this paper lies in its application of a socio-technical systems framework to provide a holistic analysis of these complex dynamics. It demonstrates that sustainable self-reliance requires an integrated approach that harmonizes technical systems with social and institutional frameworks. By addressing these infrastructural, financial, and social dimensions in a coordinated manner, India can better ensure that its journey towards an Atmanirbhar energy future is not only rapid but also resilient and equitable. Future research should focus on primary field studies to gather more granular data on community impacts and conduct comparative analyses across multiple states to develop a more comprehensive understanding of India's energy transition.

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