CENTRAL GLOBAL UNIVERSITY

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STUDY ON IMPACT OF RENEWABLE ENERGY POLICIES IN BUILDING RENEWABLE ENERGY INFRASTRUCTURE IN INDIA

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of

Professional Doctorate in Renewable Energy & Sustainable Infrastructure

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ABSTRACT

Economic growth and Sustainable infrastructure development are the important parameters for any country to grow and excel in the global market. Renewable energy is playing a very important in achieving sustainable objectives of any country. Every investment made in creating Renewable energy infrastructure development is considered to be the effective means of growing sustainability in the country. India is continuously emerging as key player in building sustainable infrastructure and competing globally. It is also attracting lot of investments from outside. The government of India is implementing several policies in creating renewable energy infrastructure in India. This paper discusses the relation between renewable energy policies, renewable energy infrastructure and its investments in India. The objective of this paper is to emphasize on how the renewable energy policies are supporting in creating renewable energy infrastructure in India. This paper outlines a conceptual frame work and qualitative analysis to understand the factors affecting in creation of renewable energy infrastructure in the country linking with regulatory frame work in India. The results suggests that the policies increases the growth and deployment of renewable energy projects in India thereby supporting sustainable infrastructure development in India.

Keywords: Renewable energy policy, Investment, Renewable energy, Infrastructure development

1. INTRODUCTION

The Government of India is taking several steps in creating energy security and reducing the dependency on fossil fuel based conventional energy sources. Renewable Energy is becoming key to address this requirement to meet the future energy demand by minimizing the carbon foot print and dependency on the convention way of electricity supply. The government of India has set an ambitious target of 500GW of non-fossil fuel capacity by 2030. To meet this target and to meet the demand supply gap in the country, the government has come up with several renewable energy policies, as the Renewable energy sector requires heavy upfront investments which the government alone cannot be borne. Successful deployment of Renewable energy projects can happen only with joint investment from public and private sector entities. Hence it requires effective and investor friendly policies to deploy renewable energy projects at a large scale in the country.

In recent years, the Indian government has introduced a series of emerging policy instruments intended to catalyze growth in the renewable energy (RE) sector. These include initiatives such as the National Green Hydrogen Mission, Energy Storage Policy, Open Access reforms, and the PM-KUSUM scheme for agricultural solarization. These policies go beyond conventional solar and wind programs, encompassing innovative solutions that aim to decarbonize hard-to-abate sectors, improve grid reliability, and expand energy access to underserved communities.

As of late 2025, India's total installed power generation capacity stands at approximately 509 GW, comprising both renewable and non-renewable sources. The renewable energy capacity has reached about 253 GW, accounting for nearly 50% of the total capacity. The breakdown within the renewable segment is shown below:

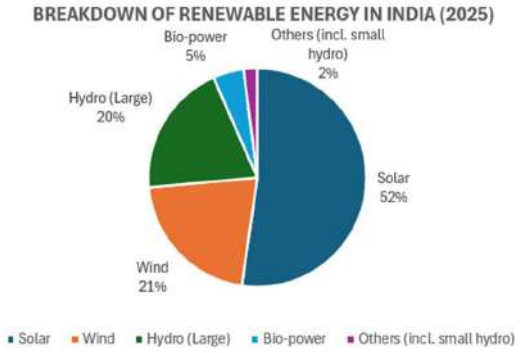

Fig 1. Breakdown of Renewable Energy in INDIA

2. LITERATURE REVIEW

The renewable energy (RE) sector in India has been a focus of significant policy innovation and academic inquiry over the past two decades. The country's energy transformation has moved from subsidy-based support for traditional renewables to more sophisticated mechanisms involving competitive markets, emerging technologies like green hydrogen and energy storage, and decentralized models of power generation. The key literature on India's renewable energy policy evolution, sector-specific initiatives, and emerging themes, at a glance have been presented here.

- **National Green Hydrogen Mission:** The launch of the National Green Hydrogen Mission in 2023 marked a turning point in India's clean energy ambitions. As Kumar et al. (2023) suggest, hydrogen has the potential to decarbonize hard-to-abate sectors such as steel, cement, and long-haul transport. However, its widespread deployment is contingent upon policy-driven cost reductions, infrastructure readiness, and large-scale R&D investments. The Government of India is supporting this sector by deploying ₹600 crore allocation for FY 2026-27, the mission approved 8,62,000 TPA of Green hydrogen production and 3,000 MW/year electrolyzer manufacturing while establishing Hydrogen hubs at Kandla, Paradip and Tuticorin.

- **Energy Storage Policy and National Electricity Plan:** Similarly, Sharma and Joshi (2022) highlight that energy storage, particularly battery and pumped hydro systems, will be crucial for integrating variable renewables and ensuring grid stability. Yet, challenges such as high costs, limited domestic manufacturing, and lifecycle inefficiencies remain significant. India will require 82GWh of storage by 2026-27 and 411 GWh by 2031-32, with a long-term pathway for 100GW of umped storage to support the round-the-clock (RTC) renewable power.

- **Green Open Access (GOA):** Open access regulations have played a vital role in democratizing renewable energy, especially for commercial and industrial users. Rao and Agarwal (2021) report that the revision of the open access threshold from 1 MW to 100 kW has significantly expanded market participation. However, they emphasize the need for regulatory clarity, grid modernization, and tariff reforms to enable effective decentralization and prevent friction between stakeholders such as DISCOMs and third-party power providers. By reducing the eligibility threshold to 100kW and launching the GOAR portal, solar open access installations grew to 24.6 GW (June 2025) and 27.9GW (September 2025).

- **PM-KUSUM:** The PM-KUSUM scheme aims to solarize irrigation pumps and promote decentralized solar installations in rural areas. Patil and Singh (2022) find that this initiative not only reduces grid stress but also improves rural livelihoods through improved electricity access and income from surplus power sales. Nevertheless, limited awareness among farmers, delays in subsidy disbursements, and technical capacity gaps have hindered the scheme's effectiveness. Continues to promote agricultural solarization through standalone and grid-connected solar pumps, helping reduce diesel dependence and supporting farmer income through surplus power sales.

- **PM Surya Ghar Muft Bijili Yojjana:** Encourages large-scale residential rooftop solar adoption, strengthening India's distributed renewable energy and reducing financial pressure on state utilities.

- **Bio-Energy Expansion:** India's 11GW bio power capacity (bagasse cogeneration, non-bagasse biomass, and waste-to-energy) supports agricultural residue management and rural energy access.

- **Carbon Credit Trading Scheme (CCTS):** Market-based mechanisms such as the Carbon Credit Trading Scheme (CCTS) are gaining momentum as tools for monetizing emission reductions and enhancing project bankability. Agarwal and Jain (2023) argue that integration with global carbon markets can unlock additional finance, but success will depend on the credibility of verification systems and institutional oversight. Additionally, there is growing interest in green bonds, viability gap funding, and blended finance models to attract private capital into the sector. A national carbon market was initiated with emission-intensity targets across nine industrial sectors, with carbon trading scheduled to begin in late 2026, creating a new economic incentive for industries to procure wind, solar and green hydrogen based energy.

- **Grid Integration and Transmission Infrastructure:** India's ambitious renewable energy targets require corresponding investments in transmission infrastructure. The Green Energy Corridor (GEC) initiative, launched by the Central Electricity Authority (CEA), seeks to address this need. According to a CEA report (2022), while Phase I has improved renewable energy evacuation in high-potential states, land acquisition challenges, coordination delays, and forecasting inefficiencies remain key obstacles. There
- is growing consensus on the importance of smart grids, real-time monitoring, and flexible power systems.

3. APPROACH FOLLOWED FOR THIS RESEARCH

This chapter outlines the data used to evaluate the impact of emerging policies on the renewable energy sector in India. Given the complexity and multidimensional nature of energy policy, a qualitative, exploratory approach was adopted. The methodology integrates secondary data analysis, policy review, and case studies, supplemented by expert interviews to enrich understanding of ground-level realities.

A qualitative research framework was chosen due to the need for interpretative insights into how policy instruments influence outcomes across institutional, technological, and socio-economic dimensions. The study is descriptive and analytical in nature, focusing on:

- Understanding the policy formulation and implementation process
- Evaluating sectoral responses to specific policy interventions
- Identifying structural barriers and enabling factors
- Discussion with the Industry experts who have deployed several projects in India
- Own experience in deploying several renewable energy projects in India

This methodology is well-suited for policy research, especially in the context of developing economies, where institutional complexity and regional variation play a major role in policy outcomes.

4. DATA COLLECTION SOURCES

a. Primary data

- Expert interviews: Semi-structured interviews with policymakers, renewable energy developers, consultants, Industry colleagues and researchers.
- Stakeholder feedback: Opinions from grid operators, financial institutions collected through informal discussions as part of carrying out the job.

b. Secondary Data

- Academic literature: Doctoral thesis, Conference proceedings, and Peer-reviewed journals
- Policy documents: National Solar Mission, Open Access Regulations of the state, National Green Hydrogen Mission, PM-KUSUM guidelines, Green Energy Corridor updates and Energy storage policy
- Media and industry sources: Economic Times, Mercom India, Bridge to India and Business times.
- Government publications and notifications: Ministry of New and Renewable Energy (MNRE), Central Electricity Authority (CEA), NITI Aayog, Solar Energy Corporation of India (SECI).
- Reports and white papers: IRENA, IEA, World Bank, TERI.

5. POLICY ANALYSIS AND ITS LAND SCAPE

a. Introduction

India's renewable energy policy environment has evolved significantly over the last decade, moving from capacity-based targets to holistic strategies encompassing grid modernization, innovation, market development, and rural empowerment. In this chapter, key emerging policies are examined for their design, objectives, implementation status, and early outcomes. The analysis focuses on their individual contributions as well as overlaps, gaps, and synergies across policy instruments.

b. Green Energy Corridor (GEC)

The Green Energy Corridor initiative aims to strengthen transmission infrastructure for most predominant renewable energy states like Rajasthan, Tamil Nadu, and Gujarat. This program is being executed in two phases. Phase I is near completion; Phase II includes central financial assistance for intra-state lines.

- Transmission lines and substations dedicated to RE evacuation
- Smart grid and forecasting tools
- Central and state funding model
- Improved RE evacuation capacity
- Reduced curtailment
- Land acquisition issues
- Delays in project execution
- Lack of real-time grid flexibility

c. Open Access and Decentralization

Open access regulations allow consumers to buy power from third-party generators, promoting competitive RE procurement. Recent changes reduced the eligibility threshold and introduced reforms to facilitate faster approvals.

- Threshold reduced from 1 MW to 100 kW
- Time-bound DISCOM approvals
- Standardized wheeling and banking charges
- DISCOMs (revenue concerns)
- Inconsistent state regulations
- Lack of infrastructure for small consumers

d. PM-KUSUM Scheme

The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) is aimed at solarizing agriculture through decentralized systems. It supports:

- Standalone solar pumps
- Grid-connected pumps
- Decentralized solar plants on barren land
- 30–60% capital subsidy
- DISCOM partnership for buying surplus power
- Empowerment of farmers through additional income
- Limited farmer awareness
- Delays in subsidy disbursal
- Varied DISCOM engagement across states

e. Energy Storage Policy

Energy storage is a critical enabler of RE integration, providing peak balancing, grid stability, and load shifting. India's draft policy outlines viability gap funding, storage obligations for DISCOMs, and guidelines for pumped hydro and battery technologies.

- Storage capacity targets aligned with RE growth
- Priority access for storage-enabled RE
- Incentives for domestic manufacturing of batteries (linked to PLI schemes)
- High capital costs
- Limited domestic supply chains
- Regulatory uncertainty around cost recovery for DISCOMs

f. National Green Hydrogen Mission

Launched in 2023, the National Green Hydrogen Mission (NGHM) aims to position India as a global hub for green hydrogen production, targeting 5 million metric tonnes per year by 2030. The mission envisions decarbonizing sectors like steel, fertilizer, and transport while boosting energy self-reliance.

- Incentives for electrolyzer manufacturing and green hydrogen production
- Demand creation in refineries, mobility, and heavy industry
- R&D grants for hydrogen storage, safety, and logistics
- Rapid cost reductions in electrolysis
- Establishment of hydrogen infrastructure
- Integration with renewable energy sources to ensure "green" production

g. Carbon Credit Trading Scheme (CCTS)

CCTS seeks to create a voluntary carbon market in India, monetizing emission reductions and attracting green investments. It's intended to complement RE projects with financial incentives tied to emissions avoided.

- Registry for emission credits
- Alignment with international standards
- Monitoring, reporting, and verification (MRV) protocols
- Transparent certification
- Regulatory clarity
- Market linkages with global carbon markets

6. SUMMARY OF FINDINGS

In summary, the above programs illustrates that the success of renewable energy policies in India is contingent not just on technological readiness or policy clarity, but on a complex interplay of institutional strength, financial mechanisms, and stakeholder alignment. Open access policy and PM-KUSUM reflects the challenges of decentralized policy execution in a federal system where farmers, state agencies, and utilities must all work in tandem. The Green Energy Corridor, while more successful, shows that even centralized policies require precise coordination and foresight to avoid delays and inefficiencies.

The implementation ecosystems—including governance structures, financing instruments, and community engagement—are as important as the policies themselves. These findings lay the groundwork for a broader discussion on system-level integration, which is explored in the next chapter.

7. DISCUSSION

The transformation of India's energy sector is not merely a technological shift—it is a deeply structural, financial, and institutional challenge. The analysis presented in previous chapters shows that while India has crafted an ambitious suite of renewable energy policies, their real-world implementation has several implementation challenges that are as complex as the policies themselves. This section explores the key themes that emerge from the policy landscape and the case studies, particularly focusing on the dissonance between policy intent and outcomes, the central role of distribution companies (DISCOMs), state-level asymmetries, the evolving role of consumers in the energy market, and the challenges of integrating emerging technologies into existing systems. The discussion also reflects on the broader governance and institutional frameworks within which these policies are embedded, arguing for a more integrated, adaptive, and system-oriented approach to energy policymaking in India.

a. Implementation challenges with policy intent

Programs such as the National Green Hydrogen Mission, PM-KUSUM, Green Energy Corridor, and the Green Open Access Rules (2022) all exhibit this disparity to varying degrees. While the policy frameworks are well-conceived and align with global best practices, the capacity to implement them effectively at the state and local levels remains limited.

Similarly, PM-KUSUM, envisioned as a transformative policy for rural energy access and sustainable agriculture, has been hindered by delays in subsidy disbursements, bureaucratic hurdles, and lack of coordination among multiple agencies. Farmers, the end beneficiaries, often remain unaware or find the process too complex.

The Green Energy Corridor (GEC) offers a relatively more structured implementation framework with defined targets and centralized project management. Yet, issues like land acquisition, delays in tendering, and inter-governmental coordination challenges persist, revealing that even technically sound policies require robust execution mechanisms.

b. **Complexity in implementation due to governance**

India's renewable energy governance is characterized by a multi-ministerial, multi-tiered structure that often lacks coherence and clarity in roles. Policies frequently require coordination between entities such as the Ministry of Power, Ministry of New and Renewable Energy, State Electricity Regulatory Commissions (SERCs), DISCOMs, and nodal agencies. In the case of Open Access, this fragmentation is acute: approvals may involve multiple bodies including SLDCs, DISCOMs, and regulatory commissions—each with differing interpretations and timelines.

Overall, policy execution suffers when fragmented governance leads to overlapping mandates, lack of accountability, and procedural confusion. A major takeaway is the need for dedicated project management units, streamlined approval mechanisms, and better inter-departmental coordination.

c. Emerging Technologies – An Integration challenge

As India looks beyond solar and wind to green hydrogen, battery storage, and smart grids, it must overcome both market and regulatory immaturity. Technologies such as energy storage and carbon markets require not just innovation but a supporting ecosystem—pricing mechanisms, off-take guarantees, and risk mitigation tools.

Open Access will play a key role in integrating such technologies by enabling peer-to-peer trading, storage-based time-of-day pricing, and flexible bilateral contracts. However, current open access rules do not fully accommodate dynamic pricing or distributed energy resource (DER) integration. States lack clear norms on energy banking, settlement systems, and dispute redressal—particularly when storage or smart metering is involved.

The National Green Hydrogen Mission and emerging carbon credit platforms face similar hurdles—namely, undefined roles for DISCOMs, unclear commercial models, and regulatory inertia. Until India develops detailed MRV protocols, interoperable data systems, and open trading platforms, these technologies will remain confined to pilot projects.

To mainstream innovation, policies must allow for experimentation and phased scale-up, backed by financial risk-sharing and credible regulation.

8. CONCLUSION

Moving of energy from the convention energy sources to the RE sources in India is not only a response to global climate imperatives but also a strategic necessity for ensuring energy security, economic resilience, and sustainable development. The country has introduced a series of forward-looking policies that aim to redefine its energy future. Programs like the Green Energy Corridor to decentralized schemes like PM-KUSUM, and from market instruments such as carbon trading to innovation-driven missions like Green Hydrogen, are policies which are making the country to move to the next level in sustainable growth and energy security.

This paper set out to evaluate the impact of these emerging policies on India's renewable energy sector, with a focus on implementation challenges, policy issues, and institutional bottlenecks for implementing these policies. The findings suggest that while policy frameworks are ambitious and generally well-conceived.

Another critical dimension explored in this study is the role of open access and decentralization, which are foundational to a liberalized and competitive power market. Open access reforms allow large consumers to procure electricity directly from renewable energy producers, bypassing traditional distribution networks. While such reforms have the potential to accelerate private investment and improve energy efficiency, they are often resisted by financially distressed DISCOMs due to fears of revenue erosion. Moreover, the decentralized energy landscape—encompassing rooftop solar, mini-grids, and localized storage—is often undermined by procedural delays, restrictive net metering regulations, and lack of capacity at the local governance level.

Nevertheless, India's commitment to its 2030 targets (500 GW of non-fossil fuel capacity) remains robust, and the policy foundation is strong. What is now required is a shift from fragmented efforts to a coordinated, system-wide strategy that not only accelerates renewable energy adoption but ensures that it is inclusive, efficient, and future-ready.

9. RECOMMENDATIONS & LIMITATIONS

a. To set up data monitoring units by investing on them

- Develop real-time monitoring systems for policy implementation using geotagging, mobile-based reporting, and open-access dashboards.
- Institutionalize third-party evaluations of major schemes every two years to assess ground realities, identify bottlenecks, and recommend adjustments.
- Mandate data transparency requirements for all state nodal agencies and DISCOMs to report progress consistently.

b. Deploy emerging technologies by supporting through incentive schemes of the government

- Launch demonstration projects for green hydrogen, storage, and smart grids in select industrial clusters or RE parks.
- Design cost-sharing models for early-stage technologies involving public-private partnerships, viability gap funding, and R&D grants.
- Expedite the finalization and operationalization of the Energy Storage Policy and Carbon Market Mechanisms, with clear guidelines, roles, and timelines.

c. Open Access and Decentralized Energy Markets to be on priority

- Facilitate digital platforms for real-time open access approvals and power scheduling to ease transaction burdens for consumers and developers.
- Harmonize state regulations with central open access provisions to create a uniform legal and procedural framework across India.
- Promote decentralized generation models—such as peer-to-peer trading, virtual net metering, and community solar initiatives—through pilot projects and regulatory sandboxes.

d. Capacity building at state level for program implementation

- Deploy awareness programs and conduct road shows to give awareness on the schemes and the intention of developing these schemes targeting the end beneficiaries like farmers, small business owners.
- Deploy dedicated Project Management Units (PMUs) within state renewable energy departments to coordinate implementation, streamline procedures, and monitor progress and to get the feed back from the end consumers.
- Develop and deploy capacity-building programs at rural, district and state level and ensure that the officers responsible for RE schemes and their implementation, with training on technical, commercial, and procedural aspects.

e. To support DISCOMs

- To support DISCOMs by improving their financial health and reducing the transmission and distribution losses and support them in capacity building on RE technologies and their deployment challenges.
- To support in providing financial guarantees or risk-sharing mechanisms to encourage DISCOMs to enter

PPAs with decentralized producers (e.g., under PM-KUSUM).

- To announce performance-based grants that reward DISCOMs for facilitating open access, timely connections, and grid upgrades.

LIMITATIONS

The number of variables considered at this stage is not sufficient to develop a conceptual model and test it further. Hence, a more quantitative based approach is suggested to follow through proper questionnaire and get the response from various stake holders.

10.FUTURE SCOPE OF STUDY

Its energy future is being shaped not just by global trends, but by the policy choices and governance models it adopts today. The transition to renewable energy presents an unprecedented opportunity to not only decarbonize the economy but to build a more inclusive, decentralized, and resilient energy system. Emerging policies must move beyond high-level announcements and evolve into programs that are people-centric, institutionally sound, and technologically adaptive. Strengthening open access regimes and promoting decentralized energy markets will be critical to empowering consumers, encouraging innovation, and reducing the load on traditional distribution systems.

Continuous learning, transparent governance, and a focus on local capacity are key to unlocking the full potential of India's energy transformation. As India aspires to become a global leader in renewable energy, the success of its emerging policies will be measured not only in megawatts but in the extent to which they empower communities, stimulate innovation, and build a sustainable future for generations to come.

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