



Original Article

Indian Policy Pathways to Clean Energy Transition

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Abstract

India's accelerating economic expansion, coupled with rising energy consumption, makes a planned shift from fossil fuel dependence to renewable energy sources essential. This paper examines India's clean energy transition architecture, focusing on policy pathways that integrate renewable energy to strengthen energy security and promote sustainable economic development. By analysing existing renewable energy policies, investment structures and implementation barriers, the study finds that India has made substantial progress, achieving 217.62 GW of non-fossil fuel capacity by January 2025—an increase of approximately 396% since 2014. Major initiatives such as the National Green Hydrogen Mission, the PM Surya Ghar scheme and various state-led programs reflect the country's commitment to reaching 500 GW of renewable capacity by 2030. Despite these advancements, key challenges remain, including financing constraints, grid integration complexities and coordination gaps between central and state authorities. The article also offers policy suggestions, including improved feed-in tariff systems, adoption of innovative financing models and reinforcement of institutional mechanisms. Overall, the findings indicate that India's integrated strategy—blending technological progress with supportive policy measures—positions it as an emerging global leader in clean energy transition while addressing vital concerns of energy security.

Keywords: Renewable Energy, Energy Security, Clean Energy Transition, Sustainable Development

Introduction

India's energy sector is undergoing a significant transformation driven by the dual imperatives of energy security and climate responsibility. As the world's third-largest energy consumer, the country faces the challenge of sustaining economic growth while reducing dependence on fossil fuels.¹ India currently imports nearly 85% of its crude oil, around 50% of natural gas and a substantial portion of coal, creating exposure to global price volatility and geopolitical risks. This dependence affects fiscal stability and limits strategic autonomy, making diversification toward domestic renewable energy sources essential. The urgency of this transition is reinforced by rapidly rising energy demand and international climate commitments. Projections indicate that India's petroleum demand may increase by nearly 2 million barrels per day by 2035. Simultaneously, under its updated commitments, India aims to reduce emissions intensity by 45% by 2030 and achieve net-zero emissions by 2070.² These targets require accelerated deployment of renewable energy, energy efficiency measures and low-carbon technologies.

Economic considerations further strengthen the case for transition, as fossil fuel imports cost the country over ₹1 lakh crore annually.³ Expanding domestic renewable energy reduces this burden while enhancing resilience. India has made notable progress, with non-fossil fuel capacity reaching about 217.62 GW by January 2025.⁴ In 2024 alone, over 24 GW of solar and 3 GW of wind capacity were added, reflecting strong policy support and investment growth.

These achievements align with the 500 GW non-fossil fuel capacity target for 2030 under commitments announced at COP26. Despite progress, significant challenges remain in financing, infrastructure, technology integration and institutional coordination. The effectiveness of India's clean energy transition depends on aligning renewable expansion with energy security goals while ensuring sustainable and inclusive growth.

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Review of Literature**▪ Global Context of Clean Energy Transition**

The global shift toward clean energy reflects a structural transition from fossil fuel-based systems to renewable-driven economies. Research highlights that successful transitions require integrated policy frameworks combining regulatory stability, financial incentives and technological innovation. Instruments such as feed-in tariffs (FITs), renewable obligations, and carbon pricing have been effective in accelerating renewable deployment.

FIT policies have played a crucial role in early-stage renewable markets by providing guaranteed returns to investors. Countries such as Germany and Denmark have achieved substantial capacity growth through these mechanisms. Evidence from ASEAN countries shows that FIT-based policies can generate annual renewable energy growth rates between 4.56% and 16.38%, depending on design and implementation. These findings underline the importance of policy consistency and tariff structure in shaping investment decisions. Additionally, global literature emphasizes the importance of enabling technologies such as smart grids, digital systems, and energy storage in managing renewable variability.⁵ The transition is increasingly viewed as an integrated system involving energy, economic development and environmental sustainability.

▪ India's Renewable Energy Policy Evolution

India's renewable energy policies have evolved significantly since the Electricity Act, 2003, which enabled regulatory support for renewable generation through state-level mechanisms.⁶ The National Solar Mission launched in 2010 marked a turning point, initially targeting 20 GW of solar capacity, later expanded to 100 GW.

A major shift occurred with the transition from feed-in tariffs to competitive reverse auctions. This mechanism significantly reduced renewable energy tariffs, making solar and wind power among the cheapest electricity sources in India, often lower than coal-based power. However, aggressive bidding has also introduced challenges such as financial stress on developers, project delays and contractual uncertainties. Recent policy initiatives have expanded focus toward green hydrogen, domestic manufacturing and grid integration, aiming to strengthen both energy security and industrial development.

▪ Energy Security and Import Dependency

India's energy security concerns stem from heavy reliance on imports and exposure to geopolitical risks. Supply dependence on regions such as the Middle East and Russia increases vulnerability to global disruptions. Fluctuations in oil prices have measurable economic effects, with studies indicating that a 1% rise in oil prices can reduce GDP growth by about 0.04%. Renewable energy offers a pathway to reduce these vulnerabilities by enhancing domestic energy production. Diversification of energy sources strengthens resilience and reduces exposure to external shocks, making renewable expansion a strategic necessity.

▪ Financing Mechanisms and Investment Challenges

Financing remains a key barrier to scaling renewable energy. According to the Asian Development Bank, India requires around \$450 billion to meet its 2030 clean energy targets, with a large share expected from debt financing.⁷ However, high capital costs, limited long-term financing, and policy uncertainties constrain investment flows. Innovative instruments such as green bonds and blended finance have improved access to capital, but challenges persist, particularly for smaller developers.⁸ Issues like delayed payments from distribution companies and currency risks continue to affect investor confidence, highlighting the need for stronger financial frameworks.

▪ Technology Integration and Grid Challenges

The integration of renewable energy into the power grid presents technical challenges due to the intermittent nature of solar and wind energy. Maintaining grid stability requires advanced systems such as smart grids, flexible generation and demand response mechanisms.⁹ Battery energy storage systems (BESS) are critical for addressing intermittency, with India projected to require about 47.2 GW of storage capacity by 2032.¹⁰ However, dependence on imported critical minerals for battery production introduces new supply risks.

Additionally, transmission infrastructure must be upgraded to handle large-scale renewable integration. Projects such as Green Energy Corridors aim to address these gaps, but effective implementation remains essential. Overall, technological advancement and infrastructure modernization are crucial for ensuring a reliable and resilient energy transition.

Objectives

- Assessment of Policy Effectiveness and Energy Security Integration.
- Analysis of Financial and Technological Dimensions.
- Identification of Gaps and Policy Recommendations.

Methodology

This study applies mixed methods, combining quantitative renewable energy data analysis with qualitative policy evaluation. It uses government and secondary sources (2014–2025), multi-dimensional analysis (capacity, policy, finance, comparisons, gaps), case studies of key states, and integrates stakeholder perspectives to assess implementation challenges and opportunities.

Analysis and Findings

India's renewable energy sector has expanded at an unprecedented pace, reflecting a structural transformation of the country's power mix and policy effectiveness in scaling clean energy deployment. Installed renewable capacity reached 217.62 GW by January 2025, marking an increase of nearly 396% from 2014 levels, supported by sustained policy interventions and institutional backing from the Ministry of New and Renewable Energy (MNRE) and other agencies.¹¹ Solar energy has emerged as the backbone of this expansion, contributing approximately 97.86 GW (around 47% of total renewable capacity), driven by declining module costs, large-scale solar park development and improved grid integration strategies.¹² Notably, 2024 witnessed record capacity additions, including 24.5 GW of solar and 3.4 GW of wind, more than doubling solar installations compared to the previous year, which indicates accelerating momentum aligned with India's 500 GW non-fossil fuel target by 2030.¹³ Spatial distribution patterns reveal strong regional concentration, with Rajasthan, Gujarat and Tamil Nadu accounting for nearly 71% of

solar additions in 2024, demonstrating the effectiveness of state-level incentives, land availability and transmission readiness.¹⁴ However, this clustering also signals the need for diversification into eastern and northeastern regions to balance grid load and enhance resilience.

Policy Framework Effectiveness

National-Level Initiatives

India's national policy architecture has evolved to integrate emerging technologies with long-term decarbonization and energy security goals. The National Green Hydrogen Mission, launched in 2023 with a financial outlay of ₹19,744 crore, exemplifies a forward-looking strategy aimed at positioning India as a global hub for green hydrogen production.¹⁵ The mission targets 5 million tonnes of annual production by 2030, requiring an estimated 125 GW of additional renewable capacity and early progress includes allocation of electrolyzer manufacturing capacity (1,500 MW) and production contracts for over 412,000 tonnes annually.¹⁶ Complementing this, the PM Surya Ghar: Muft Bijli Yojana, introduced in 2024 with ₹75,021 crore funding, has significantly accelerated decentralized energy access by enabling over 700,000 rooftop solar installations within ten months, resulting in a 53% increase in rooftop additions in 2024.¹⁷ These initiatives illustrate a dual strategy combining centralized large-scale deployment with decentralized household-level energy empowerment, thereby enhancing both grid stability and social inclusiveness.

State-Level Policy Innovation

State governments have emerged as critical drivers of renewable energy deployment through context-specific policy innovations. Gujarat's rooftop solar subsidy schemes (up to 40%) and Rajasthan's Solar Energy Policy (2019) promoting mega solar parks and decentralized rural electrification highlight adaptive governance approaches tailored to regional resource endowments.¹⁸ This competitive federalism has fostered investment-friendly environments, streamlined land acquisition processes and improved regulatory clarity, thereby attracting both domestic and foreign investments.¹⁹ Nevertheless, disparities in policy implementation, regulatory uncertainty across states and fragmented coordination between central and state authorities continue to create inefficiencies, particularly in project approvals and tariff structures.

Energy Security Integration

India's renewable energy policies increasingly align with national energy security imperatives by reducing dependence on imported fossil fuels and diversifying energy sources. Estimates suggest that renewable energy deployment has helped India avoid fossil fuel imports worth nearly ₹1 lakh crore, thereby improving the balance of payments and insulating the economy from global price volatility.²⁰ Furthermore, diversification across solar, wind, hydro and emerging technologies enhances resilience against geopolitical disruptions, particularly in oil and gas markets. Despite these gains, India's energy demand is projected to double by 2040, implying that renewable expansion must be complemented by storage, grid modernization and domestic manufacturing to fully secure energy independence.

Financing Mechanisms and Investment Flows

The renewable energy sector in India has attracted significant financial inflows, with cumulative foreign direct investment (FDI) reaching over \$6.13 billion by September 2023, reflecting strong investor confidence in policy stability and market potential.²¹ The sector's compound annual growth rate of approximately 15.4% further underscores its investment attractiveness. However, financing constraints persist, particularly for small and medium developers, due to high capital costs, limited access to low-cost credit, and risks associated with power purchase agreements. Competitive bidding has driven tariffs to historically low levels (often below ₹2.80/kWh), which, while beneficial for consumers, raises concerns about long-term project viability and financial sustainability.²² This highlights the need for balanced financial frameworks that ensure both affordability and investor confidence.

Implementation Challenges

▪ Grid Integration and Infrastructure

Rapid renewable expansion has exposed structural challenges in grid infrastructure, particularly concerning intermittency management and transmission capacity. Solar and wind variability necessitates advanced forecasting, flexible grid systems and large-scale energy storage solutions. India's target of achieving 47.2 GW of battery storage capacity by 2032 reflects policy recognition of these requirements.²³ Additionally, transmission bottlenecks, especially in evacuating power from resource-rich regions to demand centers, remain a critical barrier. Although initiatives like the Green Energy Corridor aim to address these issues, delays in execution and coordination challenges continue to affect efficiency.²⁴

▪ Land Acquisition and Environmental Clearances

Land acquisition remains a complex challenge due to fragmented ownership patterns, competing land uses and socio-environmental concerns. The prioritization of non-arable land for solar installations requires balancing ecological preservation with infrastructure development.²⁵ While environmental clearance processes have been simplified for renewable projects, procedural delays and uncertainties still affect project timelines and investment decisions.

▪ Technology Innovation and Manufacturing

India's push for domestic manufacturing through Production Linked Incentive (PLI) schemes has strengthened solar and battery production capacity, yet dependence on imports—especially from China—remains significant.²⁶ The development of green hydrogen and advanced storage technologies represents a strategic opportunity, but commercial viability depends on cost reductions, technological innovation and global market development.

Discussion

India's renewable energy transition reflects an integrated policy approach linking sustainability, economic growth, and energy security. Alignment with global frameworks such as the United Nations Sustainable Development Goals, particularly SDG

7 and SDG 13, underscores a holistic development paradigm. However, institutional coordination challenges between central ministries, state governments and regulatory bodies continue to impede optimal policy implementation. Market reforms, including the shift to competitive bidding, have reduced tariffs but introduced financial stress for developers, suggesting the need for hybrid pricing mechanisms that balance cost efficiency with sectoral stability. Financing innovation—through green bonds, blended finance and dedicated green financial institutions—remains essential to meet the estimated \$450 billion investment requirement for achieving 2030 targets.²⁷ Additionally, international cooperation, exemplified by the International Solar Alliance, enhances technology transfer and financing opportunities while strengthening India's global leadership in clean energy.

Recommendations

Policy reforms should prioritize integrated governance frameworks, including the establishment of a centralized energy-climate coordination body to harmonize national and state-level initiatives. Financial innovation through green banks and blended finance instruments is essential to support emerging technologies and smaller developers. Accelerated deployment of smart grids, storage systems and renewable energy zones can address infrastructure bottlenecks, while hybrid auction models may ensure tariff stability and investor confidence. Strengthening domestic manufacturing through enhanced PLI schemes and supply chain diversification is critical for long-term resilience. Additionally, circular economy approaches for renewable equipment recycling should be institutionalized to ensure sustainability.

Conclusion

India's clean energy transition represents a transformative shift in its energy landscape, characterized by rapid capacity expansion, policy innovation, and growing global leadership. The increase from 24 GW in 2014 to over 217 GW in 2025 illustrates the effectiveness of coordinated policy support and market mechanisms. Integration of renewable energy with energy security objectives has yielded tangible economic and strategic benefits, including reduced import dependency and enhanced resilience. However, achieving the ambitious 500 GW target by 2030 requires overcoming financing constraints, grid integration challenges and policy coordination gaps. India's experience highlights that successful energy transitions depend on long-term vision, adaptive policy frameworks and multi-stakeholder collaboration. As a leading voice in global climate governance, India's renewable energy journey offers a replicable model for developing economies, reinforcing its role as a key driver of sustainable energy transformation worldwide.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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