

Research Article

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India's Green Energy Transition: Assessing Synergies and Trade-offs across Sustainable Development Goals

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Abstract

The United Nations Sustainable Development Goals (SDGs) offers a global framework for socially inclusive and ecologically responsible development, as SDG 7 prioritizes universal access to clean and modern energy, India's green energy approach driven by solar, wind, e-mobility and decentralizes solutions is central to its SDG commitments and climate goals. This paper analyzes the alignment between India's key green energy policies and selected SDG targets. The study identifies strong synergies with SDGs 3,8,9,11,12 and 13 by using policy mapping, literature review and state level case examples. On the other hand, state wise disparities, technology deployment delays, financing constraints and monitoring challenges also highlighted. The findings draw to the attention for need of integrated policy planning, improved coordination, and targeted support for low performing areas and emphasize strengthening data systems and investing in inclusive energy access are essential for India's sustainable energy transition and long-term SDG success.

Keywords

Green energy,
Sustainable
Development Goals,
Renewable energy,
Responsible
development

Introduction

The global transition to sustainable energy systems is imperative to mitigate climate change, enhance energy security, and foster inclusive economic growth. Central to this transition is the United Nations Sustainable Development Goal 7 (SDG 7), which aims to ensure access to

affordable, reliable, sustainable, and modern energy for all by 2030. For countries like India, achieving SDG 7 is both a national priority and a global responsibility. India has undertaken one of the most ambitious clean energy transitions globally. Between 2017 and 2023, the country added nearly 100 GW of new electricity capacity, with approximately 80% sourced from non-fossil

fuel-based resources. This expansion is driven by landmark policies such as the National Solar Mission, Pradhan Mantri Kisan Urja Suraksha Evam UtthaanMahabhiyan (PM-KUSUM), Ujjwala Yojana, Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME II), and the Green Energy Corridor. These initiatives have significantly contributed to increasing renewable energy generation, improving access in underserved regions, and decarbonizing transport and industry sectors.

Despite significant progress in India's green energy transition, numerous challenges remain. The SDG 7 Energy Progress Report (2024) highlights that global efforts are currently insufficient to achieve the 2030 targets, with persistent disparities in energy access and efficiency gains. In India, these challenges manifest as state-wise inequalities, delays in technology deployment, financing constraints, and gaps in monitoring and evaluation. For example, while states such as Tamil Nadu and Gujarat have emerged as leaders in renewable energy adoption, northeastern states continue to face infrastructural and terrain-related barriers, limiting equitable energy access.

This paper examines the alignment between India's major green energy policies and selected SDG targets. By systematically mapping initiatives to relevant SDG indicators, the study evaluates the synergies between renewable energy growth and broader sustainable development outcomes. Furthermore, it identifies critical policy and implementation gaps that hinder progress and incorporates regional case studies to provide context-specific insights.

Review of Literature

The global transition to sustainable energy systems is crucial for mitigating climate change, ensuring energy security, and fostering inclusive economic growth. The Energy Progress Report 2024, a collaborative effort by the International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations

Statistics Division (UNSD), World Bank, and World Health Organization (WHO), provides a comprehensive assessment of progress toward SDG 7: Affordable and Clean Energy. The report evaluates energy access, energy efficiency, renewable energy deployment, clean cooking, and international cooperation. Despite some progress, 685 million people lacked access to electricity in 2022—an increase of 10 million from 2021—with 83% residing in Sub-Saharan Africa. Moreover, 2.1 billion people relied on polluting fuels and cooking methods, with projections suggesting 1.8 billion will still lack clean cooking access by 2030 if current trends persist (IEA et al., 2024). These findings highlight the urgent need for accelerated global action to achieve SDG 7 targets.

In the Indian context, Mascarenhas et al. (2016) highlight the complexities of achieving universal energy access and sustainable energy transition. While India has made strides in renewable energy adoption and efficiency improvements, systemic challenges such as infrastructure deficits, reliance on fossil fuels, and high transmission and distribution losses (estimated between 40–50%) hinder progress. Moreover, a substantial share of the population continues to lack access to modern energy services and clean cooking technologies, impacting health and gender equity. The study emphasizes the role of urban areas as critical agents of change through planning, building codes, electric mobility deployment, and decentralized renewable energy adoption. Strengthening institutional integration across national, state, and urban governance structures is identified as essential to create synergies and facilitate India's energy transition.

Corporate engagement also contributes significantly to India's renewable energy goals. Adani Green Energy Limited (AGEL), in its ESG Report 2022–23, illustrates strong alignment between corporate renewable energy strategies, national objectives, and SDG 7 targets. AGEL aims to develop 45 GW of renewable capacity by 2030, contributing nearly 10% of India's 500 GW national target. Large-scale projects such as the 15 GW Hybrid Project Park in Khavda, Gujarat,

are emblematic of efforts to scale renewable energy infrastructure while advancing clean energy access (AGEL, 2023). This corporate commitment exemplifies the synergy between private sector initiatives and national and international sustainability agendas.

Policy-oriented literature, particularly the NITI Aayog Annual Reports (2022–23; 2024–25), highlights India's substantial progress in solar and wind energy, which accounted for over 80% of the 100 GW capacity addition between 2017 and 2023. Programs such as PM-KUSUM, Ujjwala Yojana, and Saubhagya have enhanced energy access, although last-mile gaps in clean cooking remain. Analytical and modeling tools such as IESS 2047, TIMES-VEDA, ICED 3.0, and the State Energy and Climate Index (SECI) support scenario-based policy planning, subnational monitoring, and evidence-driven decision-making. The reports also emphasize sectoral decarbonization through technologies like green hydrogen, carbon capture and storage (CCUS), and small modular reactors (SMRs), aligning industrial growth with climate resilience and SDG 13 (NITI Aayog, 2024–25).

Empirical and cross-sectional analyses further underscore regional disparities in SDG performance. Panda et al. (2018) reveal significant inter-state variation, with Kerala, Himachal Pradesh, and Tamil Nadu performing consistently well, while Bihar, Uttar Pradesh, and Jharkhand lag in areas including energy access, health, and education. Dasgupta and Banerjee (2025) identify the energy sector's critical role in achieving SDG 7 and SDG 13 targets, emphasizing renewable energy storage solutions, Renewable Purchase Obligations (RPOs), and integration of sustainability into regulatory frameworks. The *MoSPI SDG National Indicator Framework Progress Report (2024)* further confirms improvements in data availability (92% of indicators supported by regular data) but highlights persistent subnational gaps, particularly in clean energy and last-mile energy access.

Despite extensive progress, research gaps remain. Existing literature provides comprehensive

assessments of India's renewable energy expansion, policy frameworks, and regional disparities. However, few studies systematically map key green energy policies to specific SDG targets, evaluate their synergies, or examine implementation gaps at both national and subnational levels. Additionally, limited research integrates state-level case studies to identify context-specific barriers and solutions for inclusive energy access. Addressing these gaps is critical for evidence-based policy formulation and for ensuring equitable and effective progress toward SDG 7 in India.

Objectives of the Study

1. To systematically map India's major green energy policies to the relevant Sustainable Development Goals (SDGs).
2. To evaluate the synergies between the growth of India's green energy sector and progress toward selected SDG targets.
3. To identify policy, regulatory, and implementation gaps that impede effective achievement of SDG 7 and related sustainability outcomes.

Methodology

This study employs a qualitative and policy-analytical approach to examine the alignment of India's green energy initiatives with Sustainable Development Goals (SDGs), with a focus on SDG 7, as well as related targets in SDG 9, 11, 12, and 13. The research involves systematic policy mapping of major national programs, including Ujjwala Yojana, PM-KUSUM, FAME II, and the National Solar Mission, to assess their objectives, mechanisms, and contributions to SDG targets. A comprehensive literature review of academic publications, government reports, corporate ESG disclosures, and international SDG progress reports provides evidence on policy effectiveness, synergies, and implementation challenges. To capture regional variations, state-level case studies are analyzed, highlighting disparities, infrastructural constraints, and contextual factors influencing energy access and efficiency.

Data from NITI Aayog, MoSPI, IEA, and IRENA are triangulated to ensure robustness, while a comparative framework evaluates policy outcomes and progress toward SDG indicators. By integrating document analysis, empirical evidence, and scenario-based insights, the methodology facilitates a nuanced understanding of India’s green energy transition and identifies actionable strategies to strengthen SDG alignment.

Mapping India’s Green Energy Policies to Relevant SDGs

The Sustainable Development Goals (SDGs) under the 2030 Agenda provide a guiding framework for India’s ambitious green energy transition. To achieve targets such as 500 GW of non-fossil fuel capacity by 2030 and Net Zero Emissions by 2070, India has implemented a range of transformative policies and programs. These include large-scale renewable energy missions, energy efficiency initiatives, decentralized energy projects, and international clean energy collaborations. While these policies

are primarily aligned with SDG 7: Affordable and Clean Energy, their impacts extend across multiple SDGs, including climate action (SDG 13), poverty alleviation (SDG 1), gender equality (SDG 5), industrial innovation (SDG 9), sustainable cities (SDG 11), responsible consumption (SDG 12), and global partnerships (SDG 17).

To systematically assess the contribution of these policies, a policy-SDG mapping matrix has been developed. This matrix links major national-level green energy initiatives to their corresponding SDG targets, highlighting the key outcomes and contributions of each program. By presenting this integrative overview, the matrix demonstrates that India’s green energy strategy is not only focused on expanding energy access and improving efficiency but also promotes social equity, industrial growth, climate resilience, and multi-level institutional collaboration. The matrix thus provides a comprehensive framework to understand the cross-cutting impacts of India’s green energy policies and their role in advancing sustainable development.

Table 1: Mapping of India’s Green Energy Policies to Relevant SDGs

Green Energy Policy / Program	Relevant SDGs	Key Contributions
National Solar Mission	SDG 7, SDG 13	Expands solar capacity and reduces greenhouse gas emissions.
PM-KUSUM Scheme	SDG 1, SDG 2, SDG 7, SDG 13	Promotes clean irrigation, energy access for farmers, and rural income enhancement.
Ujjwala Yojana	SDG 3, SDG 5, SDG 7	Expands access to clean cooking, improving health and gender outcomes.
FAME II	SDG 7, SDG 9, SDG 11, SDG 13	Promotes adoption of electric vehicles and EV ecosystem development.
National Mission for Enhanced Energy Efficiency	SDG 7, SDG 9, SDG 12	Improves energy efficiency in key industrial sectors.
Green Energy Corridor (GEC)	SDG 7, SDG 9, SDG 13	Integrates renewable energy sources like solar and wind into the national grid.
ASSET (State Energy Transition Plans)	SDG 7, SDG 10, SDG 13, SDG 17	Supports states in developing and implementing localized energy transition plans.
International Solar Alliance (ISA)	SDG 7, SDG 13, SDG 17	Enhances international cooperation and technology access for clean energy.
India Energy Security Scenario 2047 & TIMES VEDA	SDG 7, SDG 13, SDG 17	Provides long-term scenario modeling for evidence-based energy policy planning.
BESS (Battery Energy Storage Systems)	SDG 7, SDG 9, SDG 12	Stores electricity to balance supply-demand fluctuations and support grid stability.

Source: NITI Aayog Annual Report 2024–25.

Synergies between Green energy growth and selected SDG targets

India's transition to green energy is advancing far beyond SDG 7 (Affordable and Clean Energy), creating multidimensional benefits across health, employment, industry, and climate goals. Clean fuel programs such as the Pradhan Mantri Ujjwala Yojana and household electrification through the Saubhagya scheme have reduced indoor air pollution, improved respiratory health and enhanced the quality of life for women and children. These interventions directly support SDG 3 (Good Health and Well-Being), particularly Target 3.9, which seeks to minimize health risks linked to environmental pollution.

At the economic level, renewable energy expansion is generating large-scale employment and fostering green entrepreneurship. Investments in solar, wind, and electric mobility—anchored by the 500 GW non-fossil capacity target for 2030—are stimulating both public and private sector growth. Complementary measures such as the PLI scheme for solar modules and decentralized renewable systems are equipping local communities with skills and opportunities, thereby reinforcing SDG 8 (Decent Work and Economic Growth). At the same time, industrial decarbonization efforts, including the National Green Hydrogen Mission and platforms like IESS 2047, are enabling sustainable innovation and resilient infrastructure, directly aligning with SDG 9 (Industry, Innovation, and Infrastructure).

Urban sustainability and climate action remain central to this agenda. Initiatives like the FAME scheme for electric vehicles, rooftop solar adoption, and geospatial energy planning are reducing pollution and shaping cleaner cities, advancing SDG 11 (Sustainable Cities and Communities). Demand-side efficiency measures such as the PAT scheme and Energy Conservation

Building Code are driving responsible consumption (SDG 12), while national renewable energy missions, supported by tools like ICED 3.0 and ASSET, anchor SDG 13 (Climate Action). Overall, India's green energy pathway demonstrates how renewable expansion serves as a cross-cutting driver of sustainable development, simultaneously addressing energy access, health, economic growth, and environmental priorities.

Policy and Implementation Gaps Hindering SDG Progress

India has made significant strides in advancing clean energy, yet several policy and implementation gaps continue to limit the full realization of Sustainable Development Goals (SDGs). These challenges extend beyond technological and financial constraints, encompassing governance, equity, and institutional capacity issues. The impact is particularly pronounced in vulnerable geographies such as the North-East, tribal regions, and economically weaker states, where disparities in access and progress remain sharp.

To ensure that India's green growth strategy is fully aligned with the SDG framework, it is essential to identify and address these bottlenecks. Critical areas of concern include uneven state-level performance, last-mile energy access, delays in deploying emerging technologies, financing barriers for vulnerable groups and small enterprises, weak institutional coordination, and gaps in monitoring systems. Addressing these challenges is vital not only for advancing SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals), but also for achieving broader goals related to health, equity, and resilient infrastructure. The following table highlights the core problem areas, the SDG targets they affect, and key policy responses required to overcome them.

Table 2: Policy and Implementation Gaps Hindering SDG Progress

Problem Area	Key Gaps	Affected SDGs	Suggested Actions
State-Level Disparities	Uneven progress; lag in NE and central states	SDG 7.1, 10.2	Provide targeted support via SECI/ASSET models
Last-Mile Access	Limited electricity & clean cooking in rural/tribal belts	SDG 7.1, 3.9	Expand DRE, strengthen LPG refill and delivery networks
Technology Deployment	Delays in hydrogen, CCUS, SMRs approvals	SDG 9.4, 13.2	Fast-track clearances; scale R&D and pilot funding
Financing Gaps	Limited affordable capital for MSMEs, poor households, DRE	SDG 7.a, 17.3	Mobilize blended finance through green funds & PPPs
Institutional Coordination	Weak alignment across central/state agencies	SDG 17.14	Create state energy task forces, strengthen inter-ministerial platforms
Monitoring & Data	Lack of real-time, granular tracking	SDG 17.18, 17.19	Expand ICED 3.0, integrate SDG metrics into state/district dashboards

Source: Adapted from NITI Aayog. (2024). *Annual Report 2024–25*. Government of India. Ministry of Statistics and Programme Implementation. (2023). *SDG National Indicator Framework: Progress Report (v4N)*. *Tracking SDG 7: The Energy Progress Report*. United Nations.

India’s progress toward the SDGs is slowed by persistent policy and implementation gaps that affect both pace and inclusiveness. State-level disparities remain a major concern, with several North-Eastern and central states trailing in clean energy adoption and policy execution. These uneven outcomes undermine national commitments to SDG 7.1 on universal energy access and SDG 10.2 on reducing inequality. Addressing this requires targeted institutional support, such as performance-linked incentives through the Solar Energy Corporation of India (SECI) and specialized assistance under the ASSET initiative, to bridge gaps in lagging regions. At the same time, last-mile energy access continues to be a challenge in rural and tribal belts where electrification is often inconsistent and clean cooking solutions remain limited. This directly affects health outcomes under SDG 3.9, as household air pollution remains a major risk. Expanding decentralized renewable solutions, strengthening supply chains, and ensuring LPG affordability are crucial for tackling this gap.

Technological deployment is another area where delays hinder SDG progress. Slow regulatory clearances and limited R&D funding for innovations such as green hydrogen, carbon

capture, and small modular reactors constrain advancement toward SDG 9.4 (sustainable industry) and SDG 13.2 (climate action). Accelerated approvals, pilot project support, and dedicated funding for clean-tech innovation can provide the momentum required for scaling. Parallely, financing challenges remain acute, particularly for small enterprises and vulnerable households, restricting the growth of decentralized renewable projects. Mobilizing blended finance and operationalizing the National Green Finance Institution are critical steps to expand access to affordable capital, aligning with SDG 7.a and SDG 17.3.

Beyond finance and technology, institutional coordination and data systems continue to limit effective implementation. Fragmentation across central ministries, state governments, and sectoral agencies often delays execution even when policies are well designed. Strengthening alignment through state-level task forces and inter-ministerial coordination platforms, as encouraged by NITI Aayog’s SDG vertical, can improve coherence in energy governance. Likewise, monitoring remains weak due to limited real-time and granular data. Expanding platforms such as ICED 3.0 and embedding SDG-aligned

indicators into state and district dashboards will improve accountability and responsiveness. Together, these interventions can address systemic barriers, ensuring India’s green energy transition advances not only SDG 7 and SDG 13 but also broader goals on health, equity, and sustainable growth.

Case studies of Renewable Energy Initiatives in India

India’s states are pursuing diverse renewable energy pathways shaped by their geography and resources, but each faces unique trade-offs.

Gujarat and Rajasthan have capitalized on vast arid lands to emerge as leaders in solar park development, yet their large-scale projects trigger land-use conflicts and ecological pressures. In contrast, Kerala has emphasized decentralized solar solutions, with strong local governance and civic participation, showing how community-driven models can expand access without heavy land requirements—though weak grid support and stressed DISCOM finances limit scalability. Together, these contrasting approaches highlight the balance between centralized, utility-scale capacity and localized, participatory systems.

Table 3: Case studies of Renewable Energy Initiatives in India

State/Region	Energy Focus	Key Highlights	Challenges	Aligned SDGs
Gujarat & Rajasthan	Large-Scale Solar Parks	Leading states in solar capacity with vast potential	Land-use conflicts, ecological risks, displacement of agriculture	SDG 7.2, 15.3, 11.3
Tamil Nadu	Wind Energy & Industry	Strong wind corridors, integration with industrial growth	Grid congestion, storage gaps, land saturation	SDG 7.2, 9.4, 13.2
Kerala	Decentralized Solar	High rooftop solar adoption, panchayat participation, strong civic engagement	Weak grid support, DISCOM financial stress, overlapping policies	SDG 7.1, 11.3, 16.6
North-East India	Hydro & Distributed Solar	Significant hydropower potential and off-grid solar for remote areas	Difficult terrain, low demand density, limited private investment	SDG 7.a, 10.2, 17.9

Tamil Nadu and the North-East regions further illustrate this diversity. Tamil Nadu has integrated its wind-rich corridors with industrial growth, building synergies between renewable energy and economic development. However, issues of grid congestion and inadequate storage demonstrate the limits of scaling without complementary infrastructure. Meanwhile, the North-East, with its hydropower resources and distributed solar opportunities, has the potential to address energy poverty in remote tribal and hilly areas. Yet, terrain challenges, sparse demand, and limited private investment slow progress, underscoring the need for tailored financing and policy support.

Taken together, these state-level experiences reveal that India’s renewable energy transition cannot follow a uniform model. Solar parks, wind corridors, decentralized solar, and hydro all have distinct strengths and constraints. The challenge is to align these regional strategies within a national framework that balances land, equity, and infrastructure concerns while leveraging local advantages. Such an integrated approach would not only accelerate SDG 7 (Affordable and Clean Energy) but also advance related goals on health, equity, and climate resilience.

Conclusion

India's green energy transition is central to advancing the Sustainable Development Goals, particularly SDG 7 on affordable and clean energy. Government initiatives such as the Ujjwala Yojana, FAME II, and the National Green Hydrogen Mission have expanded renewable power, promoted clean cooking, and strengthened decentralized energy access, generating positive spillovers for health, climate action, sustainable industry, and employment. Digital governance platforms like ICED 3.0 and ASSET have further reinforced subnational coordination, enabling evidence-based planning and monitoring. Collectively, these efforts illustrate how a well-integrated energy strategy can serve as a multi-SDG accelerator, benefiting both rural and urban communities.

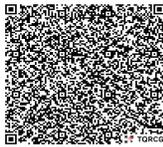
Despite these achievements, significant challenges remain. Regional disparities, regulatory bottlenecks in emerging technologies, limited concessional financing, and fragmented institutional coordination continues to slow progress and restrict equitable energy access. Addressing these gaps requires stronger inter-ministerial coherence, targeted state-level interventions, and inclusive energy planning frameworks. Enhancing real-time data tracking, empowering local governance, and scaling decentralized innovations are crucial for ensuring just and sustainable outcomes. Future research should adopt longitudinal perspectives to evaluate the socio-economic and environmental impact of clean energy, including women's empowerment, rural entrepreneurship, and climate resilience. By embedding equity and adaptability into energy governance, India can not only achieve its SDG targets but also set a global example for a greener and more inclusive development pathway.

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