India’s Green Transition and the Emerging Green Divide: A Sectoral and Regional Analysis of Inclusive Growth

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Abstract

Climate change, environmental degradation, and resource depletion have emerged as some of the most pressing global issues of recent times. Transitioning towards a low-carbon economy that safeguards natural resources is therefore imperative for achieving a sustainable future. In this context, India's ambitious targets of achieving 500 GW of non-fossil fuel-based power generation capacity by 2030 and net-zero emissions by 2070, underscore the urgency of a green economy transition capable of meeting the nation's burgeoning energy demands in a sustainable yet reliable manner. This paper analyses India's green transition by examining sectoral pathways of decarbonisation across key domains—urbanisation, transport, industry, and MSMEs. It explores the country's evolving energy landscape, focusing on the growth trajectory and changing composition of non-fossil fuel-based installed capacity, while also highlighting the regional disparities and policy drivers underpinning renewable expansion. To capture these regional dynamics, a comparative case study approach is employed, analysing Gujarat, Tamil Nadu, and Bihar as representative examples of high-, medium-, and low-performing states in the green transition. This approach provides deeper insights into how policy frameworks, institutional capacity, and investment flows influence renewable energy outcomes. Further, the study constructs a Green Inclusiveness Index (GII), composed of four equally weighted indicators, to assess the extent of regional inclusiveness in renewable energy deployment. The findings reveal that, although India has made consistent progress in expanding its non-fossil fuel capacity and diversifying its energy mix, the distribution of renewable energy remains spatially uneven, reflecting a distinct green divide among states. The paper concludes with evidence-based policy recommendations aimed at promoting a just and inclusive green transition.

Keywords: Green Transition, Green Inclusiveness Index, Energy Transition Trajectory, Green Industrial Corridors, Transport Decarbonisation, Green Divide

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1. Introduction

India's pursuit of sustainable and inclusive economic growth has gained significant momentum in the past decade. As one of the fastest-growing economies and the world's third-largest emitter of greenhouse gases, India faces the dual challenge of promoting development while reducing carbon intensity. Under the Paris Agreement, the nation has pledged to achieve net-zero emissions by 2070 and ensure that 50% of its installed electricity capacity comes from non-fossil fuel sources by 2030 (Ministry of Power, 2025). Aligning with the Sustainable Development Goals (SDGs 7, 8, and 13), this transition is driven by flagship initiatives such as the National Green Hydrogen Mission, Production-Linked Incentive (PLI) schemes for solar and battery manufacturing, the PM Surya Ghar–Muft Bijli Yojana, and the PM E-Drive program promoting electric mobility.

Despite these advancements, India's green transition has unfolded unevenly across regions and sectors. Progressive states such as Gujarat, Tamil Nadu, and Karnataka have become leaders in renewable energy adoption and green industrialization, while others, including Bihar and Jharkhand, continue to lag behind due to infrastructural limitations and weaker institutional capacities (World Economic Forum [WEF], 2025). This asymmetry has given rise to what researchers describe as a "green divide," where the economic and social benefits of sustainability, such as employment, clean energy access, and investment, are concentrated in more developed states (WEF, 2025).

Across key sectors, similar disparities persist. In agriculture, initiatives like the PM-KUSUM scheme are helping reduce diesel dependency through solar irrigation. The industrial sector is integrating renewable technologies and green hydrogen, yet Micro, Small, and Medium Enterprises (MSMEs) still struggle with financing, outdated machinery, and a lack of skilled labour (Centre for Study of Science, Technology and Policy [CSTEP], 2024). Likewise, the transport and urban sectors, responsible for nearly half of India's greenhouse gas emissions, face challenges in scaling electric mobility and clean infrastructure (Council on Energy, Environment and

Water [CEEW], 2025).

India’s journey toward green growth is therefore not just an environmental goal but a test of its ability to achieve equitable and regionally balanced development. Understanding these dynamics is vital for ensuring that the green transition contributes to inclusive, resilient, and sustainable economic progress.

2. **Literature Review**

The United Nations Environment Programme (2011) defines a green economy as one that is low carbon, resource efficient, and socially inclusive, aiming to improve human well-being and social equity while mitigating environmental risks and ecological scarcities. Transitioning toward such an economy requires reducing dependence on fossil fuels, whose combustion emits greenhouse gases that trap heat in the Earth’s atmosphere. To facilitate this shift, investments must be redirected toward clean, replenishable, affordable, sustainable, and reliable energy sources (United Nations). Although the concept of a green economy has been deliberated for decades, it has gained significant traction in recent years in response to escalating global environmental and socio-economic challenges (Bholane, 2025; Zhang et al., 2022).

In this context, renewable energy has emerged as a critical pillar of the green transition. According to the International Energy Agency (IEA), the deployment of renewables across electricity generation, industrial processes, and transportation is a key enabler in limiting the rise in global temperatures to below 1.5°C. In India, this global transition is reflected in the rapid growth of the renewable energy (RE) sector. Installed renewable power capacity has expanded fivefold, from nearly 24 GW in FY 2014-15 to 136 GW in FY 2024-25 (Ernst & Young, 2024). This expansion not only underscores India’s commitment to climate change mitigation and energy security but also reflects its efforts to diversify its energy portfolio and reduce reliance on fossil fuels (Bapuly, 2025). However, this progress has not been uniform across the country. Empirical evidence reveals significant regional disparities in renewable energy adoption. Gupta and Guha (2024) find that while both solar and wind capacities contribute positively to state-level economic performance, the magnitude and direction of their effects on Gross State Domestic Product (GSDP) vary across states. These variations point to uneven regional progress in renewable deployment, shaped by differences in resource endowments, institutional capacity, and policy effectiveness.

To achieve India's ambitious target of 500 GW of renewable energy capacity by 2030 and net-zero carbon emissions by 2070, a robust, integrated strategy is essential. Such a strategy must combine proactive policy measures, continuous technological innovation, and targeted sectoral reforms to address the complex socio-economic and environmental dimensions of the transition. This involves a gradual shift from conventional sources such as coal to renewables like solar, wind, and hydro, thereby enhancing energy efficiency and reducing import dependency (Mondal et al., 2024).

At the same time, scholars highlight the importance of rethinking India's development paradigm to make this transition sustainable. Bholane (2013) argues that a green transition requires moving beyond GDP-centric development models by aligning fiscal, environmental, and social policies with proactive state intervention. Building on this, Anjanappa (2025) emphasizes the need for strong governance, institutional coordination, and a long-term clean energy roadmap to ensure policy stability and coherence.

Finally, the success of a green transition hinges not only on government and business actions but also on active citizen participation. As the World Economic Forum (2025) notes, fostering public trust through transparent data sharing, clear communication of policy reforms, and regular disclosure of outcomes is vital to enhancing accountability and promoting sustainable behavioural change. Collectively, these dimensions—policy integration, institutional capacity, technological advancement, and civic engagement—form the backbone of India's evolving green economy framework.

Gap Analysis

While previous studies have examined India's renewable energy expansion, limited research has addressed the spatial and structural inequalities influencing the inclusiveness of this transition. Much of the existing research focuses on national-level achievements or sector-specific energy trends, overlooking regional disparities and the distributional outcomes of green growth. There is limited understanding of how different states and sectors are positioned within India's low-carbon transition and whether policy efforts have translated into inclusive benefits such as green employment and equitable access to clean energy.

Addressing this research gap is crucial to determine whether India's green economy trajectory represents a truly transformative and equitable development pathway.

3. Research Objectives

1. To examine India's transition towards a green economy by analysing sectoral pathways of decarbonisation across key domains—urbanisation, transport, industry, and MSMEs.
2. To evaluate the progress of India's low-carbon transition through an analysis of the growth trajectory, composition, and regional distribution of non-fossil fuel-based installed electricity capacity.
3. To assess the inclusiveness of India's green growth by investigating inter-state variations and identifying whether the transition reflects an equitable transformation or a widening green divide.

4. Methodology

4.1. Research Design

The present study employs a descriptive, analytical, and mixed-method research design to investigate India's transition toward a green economy and the emerging regional disparities in renewable energy adoption.

This research relies on secondary data collected from credible and publicly available sources, including reports, academic journals, policy briefs, and government publications. The study period covers 2015 to 2025, allowing for a decade-long analysis of India's green transition trajectory and enabling the identification of key structural and policy shifts during this phase.

4.2. **Construction of a Green Inclusiveness Index**

This study employs a quantitative composite index approach to evaluate whether the benefits of India's green economy transition are distributed equitably across states. Accordingly, a Green Inclusiveness Index (GII) is constructed, which integrates environmental progress with socio-economic outcomes such as employment generation and energy access.

The composite index framework allows for a comprehensive evaluation of green transition performance and facilitates inter-state comparison, thereby supporting an assessment of inclusiveness and regional balance in India's sustainable development trajectory.

4.3. **State Selection and Comparative Framework**

To capture structural variation in green transition performance, three states were selected using a stratified comparative framework:

- Gujarat: represents a high-performing state with strong renewable capacity and industrial depth.
- Tamil Nadu: reflects a mature green economy with diversified renewable and manufacturing sectors.
- Bihar: represents a structurally constrained state with relatively low renewable penetration.

This selection enables identification of regional disparities and supports the study's central hypothesis regarding the emergence of a "green divide."

4.4. **Indicator Selection Criteria for the Green Inclusiveness Index**

The Green Inclusiveness Index is designed as a multidimensional measure capturing both the scale and distributional outcomes of the green transition. The index aggregates four indicators representing energy transition, labour-market inclusiveness, accessibility of clean energy, and decarbonisation efficiency.

To identify which indicators should be included in the construction of the Green Inclusiveness Index, the following three selection criteria were used.

1. Relevance and policy responsiveness: Indicators capture key environmental and socio-economic dimensions of inclusive green growth and reflect areas amenable to policy intervention.
2. Data availability and comparability: Indicators are based on reliable, publicly available data that are consistent and comparable across Indian states and over time.
3. Non-redundancy: To avoid overlapping information, indicators are selected such that they capture distinct aspects of the green transition.

Based on these criteria, renewable energy capacity share and per-capita renewable generation capture the scale and distribution of clean energy deployment; green jobs per million population reflect employment inclusiveness; and carbon intensity reduction represents environmental performance. The resulting indicator set integrates energy, employment, and emissions outcomes, ensuring conceptual coherence and suitability for inter-state comparison.

A summary of indicators, definitions, and data sources is provided in Appendix A.

5. **Limitations**

This study is limited by its reliance on secondary data, which may include inconsistencies across states and years. The focus on specific representative states, restricts the generalization of findings to all regions. Additionally, the 2015–2025 time frame may not capture long-term policy effects, and the Green Inclusiveness Index (GII) simplifies complex sustainability factors. Despite these constraints, the analysis offers valuable insights into India’s regional disparities in green growth

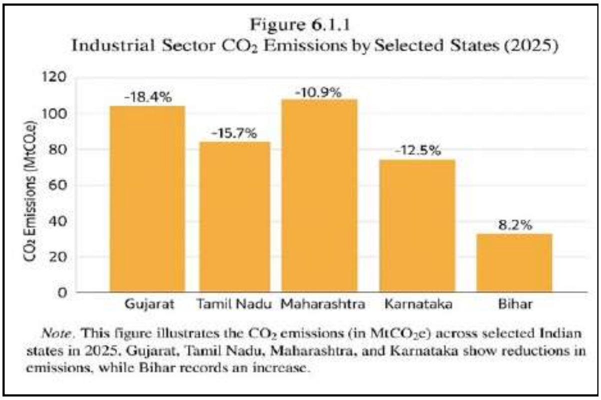
6. **Sectoral Pathways for India's Low-Carbon Transition**

India's low-carbon transition is inherently sector-specific, shaped by distinct energy-use patterns, technological constraints, and institutional capacities across industries, cities, and transport systems. Examining these sectoral pathways reveals how targeted decarbonisation strategies can align economic growth with emissions reduction.

6.1. **Decarbonising Industrial and Manufacturing Hubs through Clean Energy Integration**

- Clean energy integration in industrial corridors

India's manufacturing sector stands at a crossroads, generating nearly 30% of GDP while producing approximately 24% of the nation's greenhouse gas emissions (WEF, 2025). Making these industries cleaner isn't optional; it's fundamental to achieving the country's net-zero by 2070 commitment while keeping the economy growing.

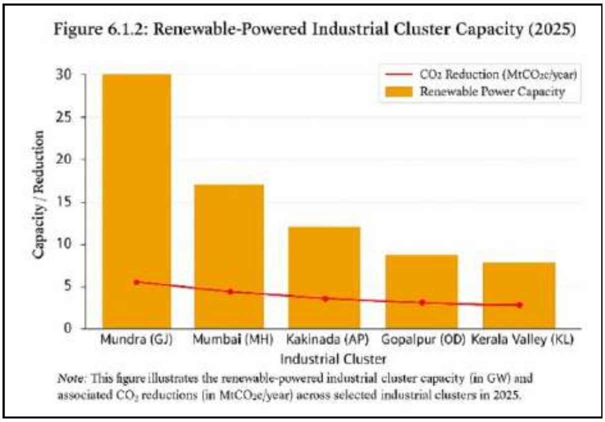


Source: Data from Council on Energy, Environment and Water

Infrastructure is expanding rapidly. The Green Energy Corridor program has laid over 11,000 circuit kilometres of transmission lines and established 22,000 MVA of substation capacity, enabling more than 20 GW of renewable power to reach industries (Ministry of Power, 2025; CEA, 2023). Gujarat exemplifies this shift; its industrial emissions, which represented 36% of total state emissions in 2022, are projected to drop 43% by 2035 through green hydrogen, electrification, and carbon capture (Assessment of

Net Zero Scenarios for Gujarat, 2024). The state's renewable energy jobs surged from 35,000 in 2015 to over 120,000 by 2025.

- Yet formidable challenges persist. Over 60% of solar modules and virtually all industrial batteries are imported (WEF, 2025). India faces a \$3.5 trillion funding shortfall against its \$10.1 trillion green transition needs through 2070, plus a looming skills gap of 1.7 million workers by 2027 (WEF, 2025)
- .Policy responses include Production-Linked Incentive schemes, the ₹19,744 crore National Green Hydrogen Mission, and the new National Framework for the Indian Carbon Market (Ministry of Power, 2025). The Mundra cluster alone aims to produce 250,000 tonnes of green hydrogen annually by 2030, eliminating approximately 2.9 million tonnes of CO_2 equivalent (WEF, 2025).



Source: Data from Council on Energy, Environment and Water

The picture is clear; progressive states are pioneering low-carbon manufacturing, while others lag, creating a two-speed transition that demands inclusive financing and coordinated planning.

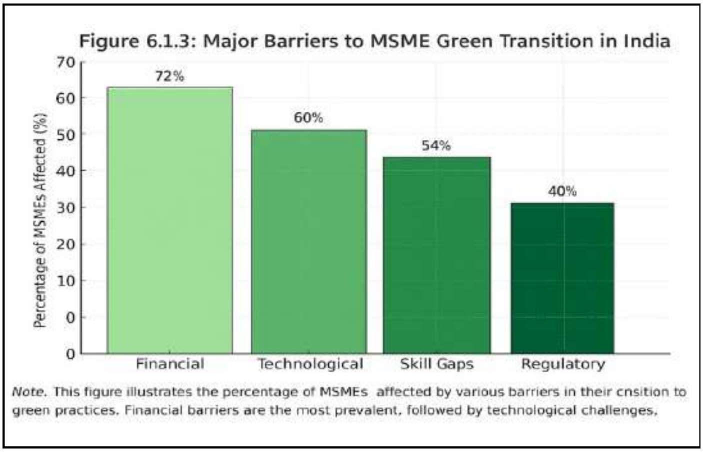
- **MSME'S**

India's Small Businesses Face Big Green Challenges

Micro, Small, and Medium Enterprises (MSMEs) are the backbone of India's economy, contributing nearly 30% of GDP, 45% of manufacturing output, and employing over 110 million people (Anjanappa, 2024; CSTEP, 2024). About a third operate in energy-intensive sectors like textiles, metals, and ceramics, consuming 20 - 25% of industrial energy and emitting roughly 150–200 million tonnes of CO_2 annually (CSTEP, 2024). Getting these small players to go green is absolutely crucial for India's net-zero by 2070 goal.

There's been real progress. The Bureau of Energy Efficiency has developed over 375 technology-specific project reports and identified more than 350 energy-saving measures, resulting in annual savings of approximately 25,000 tonnes of oil equivalent and mobilising ₹330 crore in private investments across 20 industrial clusters (BEE, 2020). A study across 66 MSME units found emission-reduction potential ranging from 13% to 87%, with efficient alternatives offering payback periods as short as four years (CSTEP, 2024).

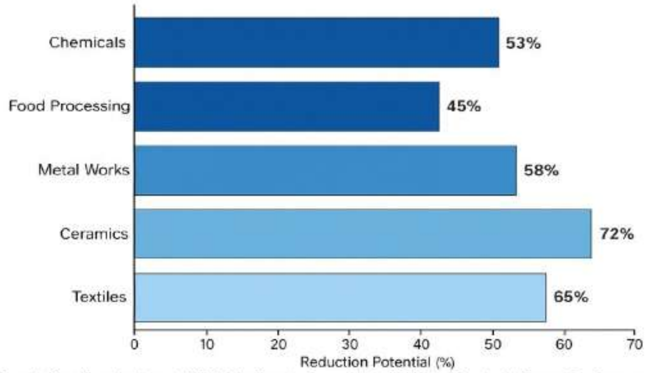
But the barriers are daunting. A staggering 72% of MSMEs cite high costs as a deterrent to green technologies, while 68% of loan applications for green projects get rejected due to credit risks (Anjanappa, 2024). Over 60% still use outdated machinery (Abdullah, Saraswat, & Talib, 2023), and only 18% have adopted Industry 4.0 technologies (Anjanappa, 2024). Around 54% face skilled worker shortages, and less than 25% invest in employee training (Anjanappa, 2024).



Source: Data from Council on Energy, Environment and Water

The solution lies in cluster-based approaches where small businesses share renewable microgrids, waste-treatment facilities, and technology hubs (Anjanappa, 2024; CSTEP, 2024). Innovative financing like green credit guarantees and blended-finance models can ease the financial burden. Large-scale training through the National Skill Development Corporation can address skill gaps (Anjanappa, 2024).

Figure 6.1.4: Emission Rduction Potential by MSME Sector



Source: Compiled from 'Decarbonising the MSME Manufacturing Sector in India' (2023) and Sustainable Green Manufacturing (2021).

Source: Data from Council on Energy, Environment and Water

India's green transition won't succeed without bringing its millions of small businesses along. They need targeted support, not just ambitious policies to turn environmental necessity into economic opportunity.

6 .2. **Urban Growth, Energy Consumption, and Emission Trends in India**

India's rapid urbanization has emerged as a major force shaping the country's energy demands and carbon footprint. Over the past century, cities have grown at a pace that has far outstripped efforts to improve energy efficiency or plan infrastructure thoughtfully (Franco et al., 2017). The result? Indian cities have become energy hungry hotspots, even though they house a relatively smaller portion of the nation's people.

Research paints a clear picture: as cities expand, so does electricity consumption and reliance on fossil fuels, especially in homes, on roads, and in factories (Franco et al., 2017). City dwellers naturally use more energy per person think air conditioners, refrigerators, cars, and other conveniences of modern life. Meanwhile, urban roads are getting more crowded by the day, with private vehicles multiplying faster than buses and metros can keep up, pushing emissions steadily upward (Franco et al., 2017).

The environmental toll goes beyond just energy use. Indian cities are also drowning in garbage. Government reports reveal that urban areas produce staggering amounts of municipal waste, driven by consumption patterns and weak waste management systems (Press Information Bureau [PIB], 2024). With poor sorting practices and limited recycling, much of this waste ends up releasing methane and other harmful gases, adding yet another layer to the urban environmental crisis.

But here's the important part: urbanization doesn't have to mean environmental disaster. The path cities take matters enormously. Studies from India and around the world show that well-planned, compact cities with energy efficient buildings and robust public transport can grow without wrecking the climate (Tong et al., 2021; World Bank Group, 2025). The danger lies in inaction. If India continues on its current trajectory without smart interventions, its cities could become locked into high-carbon lifestyles for decades to come—jeopardizing both the country's green economy ambitions and its climate commitments.

6.3 **Decarbonizing India's Transport Sector: Expanding Public Transit and Accelerating EV Adoption**

India's transport sector has emerged as one of the most energy- and carbon-intensive components of the national economy. Currently it can be seen that transport is the second-largest element to energy demand and greenhouse gas emissions. Road transport alone accounted for 14% of India's total energy consumption in 2021 and produced over 90% of all transport-related CO_2 emissions (Dawda, 2024). These figures demonstrate why decarbonizing mobility is not simply desirable but absolutely central to meeting India's 2070 net-zero target.

1. <u>Public Transport as the Cornerstone of Low-Carbon Urban Mobility</u>

According to the researchers from India and abroad, cities with strong public transportation systems emit substantially less per capita than car-dependent cities.

- According to Newman and Kenworthy (2015), urban areas with heavy transit usage have 40–70% lower transportation emissions than those that depend on private automobiles.
- ITF-OECD (2020) confirmed that multimodal transit networks cut emissions by 30–60% across multiple city typologies.

India's own experience shows this pattern.

- According to Ghate et al. (2020), private vehicles and two-wheelers have significantly higher emissions per passenger kilometer than the Delhi Metro and Ahmedabad BRTS.
- According to CSE (Centre for science and Environment) and MoHUA (Ministry of Housing and Urban Affairs) investigations, buses and metros lower fuel usage and traffic in addition to CO2 emissions.
- Delhi and Mumbai, where public transportation maintains a comparatively larger modal share, have 30–40% lower per-capita transport emissions than auto-dependent cities like Bengaluru, according to a CEEW (2025) cross-city research.

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All of these results point to the same conclusion which is real transport decarbonization in India depends on people switching from private automobiles to well-designed, integrated public transportation systems.

2. Barriers Holding Back Public Transit Expansion

Despite clear benefits, India faces several structural and behavioral hurdles:

- Extremely high population densities make it difficult to create universally accessible networks (CEEW,2025).
- Vehicle ownership is rising faster than cities can expand transit services (CEEW,2025).
- Poor last-mile connectivity and weak integration across metro, rail, bus, and intermediate public transport reduce public convenience (CSE, MoHUA).
- Electrified buses and trains remain dependent on the broader transition to cleaner grids (CEEW, 2025).
- Social concerns like women's safety, affordability, and reliability, continue to restrict ridership among some groups (CSE, MoHUA).

Public transportation's ability to decarbonize mobility will remain ineffective unless these systemic problems are resolved through coordinated national-urban transport planning.

3. Electric Mobility: A Parallel Pathway to Emission Reduction

Even with optimal public transport, India will continue to have tens of millions of personal vehicles. Since these vehicles contribute over half of all transport-sector emissions, electrifying private mobility becomes an indispensable piece of the decarbonization puzzle (Dawda, 2024).

- India's EV transition remains young but accelerating.
- Penetration is rising, though still less compared to countries like China, where EVs already constitute half of new vehicle sales (NITI Aayog, 2025).
- The government has provided substantial policy support through FAME-I, FAME-II, and now the PM E-DRIVE scheme. These three

programmes collectively mobilized over ₹23,000 crore, supported 1.7 million EV purchases, and helped install about 3,000 charging stations (NITI Aayog, 2025, Inc42, 2025).

- From 2015 to 2025, EV sales increased 127 times, placing India as the third-largest EV market globally (Inc42, 2025, Vahan Dashboard).

However, given current trends, the 30% penetration objective for 2030 is still unachievable.

4. <u>The Transformative Potential of Vehicle-to-Everything (V2X)</u>

A key opportunity lies in leveraging EVs not only as mobility devices but also as distributed energy resources.

V2X technology, allowing EV batteries to feed electricity back to homes, buildings, and the grid, can support both:

- rural households that still lack reliable electricity (2.4% remain unconnected) (World Bank Group, 2025; CEEW), and
- grid stability during peak loads (CEEW).

By charging when energy prices are low and discharging to the grid during shortages, EVs can help reduce household bills and support renewable integration.

5. <u>India's EV Landscape: State-Level Trends (2024–25)</u>

A snapshot of state performance shows significant regional variation:

- Maharashtra: >180,000 EV sales, strong in 4-wheelers (Inc42, 2025; Vahan Dashboard).
- Uttar Pradesh: High registrations driven by 2- and 3-wheelers (Inc42, 2025).
- Karnataka: Leading in charging infrastructure (~3,900 stations) (NITI Aayog, 2025).
- Tamil Nadu: Fast-growing EV manufacturing hub (NITI Aayog, 2025).
- Delhi: Strong 3-wheeler shift due to incentives (Inc42, 2025).

Despite these advancements, data remains insufficient to fully measure pre-policy baselines because EV incentives began almost simultaneously with the emergence of the market.

7. Analysis of India's Clean Energy Transition

India's clean energy transition reflects a dynamic interplay between rapid renewable energy expansion and uneven regional pathways shaping this transformation. Mapping regional trajectories reveals stark variations in adoption patterns, infrastructural readiness, and investment flows, underscoring the uneven geography of India's green transition. These disparities illuminate the differentiated character of the country's renewable energy landscape and emphasize the need for context-specific strategies to sustain an equitable and resilient transition.

7.1. Mapping India's Renewable Energy Expansion: Growth, Composition, and Regional Variations

As per International Renewable Energy Agency - Renewable capacity statistics 2025, India stands 4th globally in Renewable Energy Installed Capacity, 4th in Wind Power capacity and 3rd in Solar Power capacity. The expansion in renewable energy sources has contributed to lower carbon emissions, improved public health, enhanced energy access, job creation, and reduced electricity expenditure for households and the government.

The following analysis explores the growth trajectory, composition, and regional distribution of India's renewable energy capacity to assess the progress of its green transition.

- <u>Growth in Renewable Energy Installed Capacity</u>

Table 7.1.1: Growth in non-fossil fuel Installed Capacity (in GW)

Year	Solar	Wind	Bio Power	Small Hydro	Large Hydro	Nuclear	Total
2019-20	35.61	37.74	10.22	4.68	45.70	6.78	140.73
2020-21	41.24	39.25	10.53	4.79	46.21	6.78	148.79
2021-22	54.00	40.36	10.68	4.85	46.72	6.78	163.39
2022-23	66.78	42.63	10.80	4.94	46.85	6.78	178.79
2023-24	81.81	45.89	10.94	5.00	46.93	8.18	198.75
2024-25	105.65	50.04	11.58	5.10	47.73	8.18	228.28
2025-26	123.13	52.68	11.60	5.11	50.11	8.78	251.41
CAGR	22.97%	5.71%	2.13%	1.46%	1.55%	4.40%	10.15%

Note: Data for FY 2025-26 has been updated as on August 2025

CAGR: Compounded Annual Growth Rate = ((Current Values/Base Values) ^ (1/no of years) -1) *100

Source: Ministry of New and Renewable Energy and Central Electricity Authority

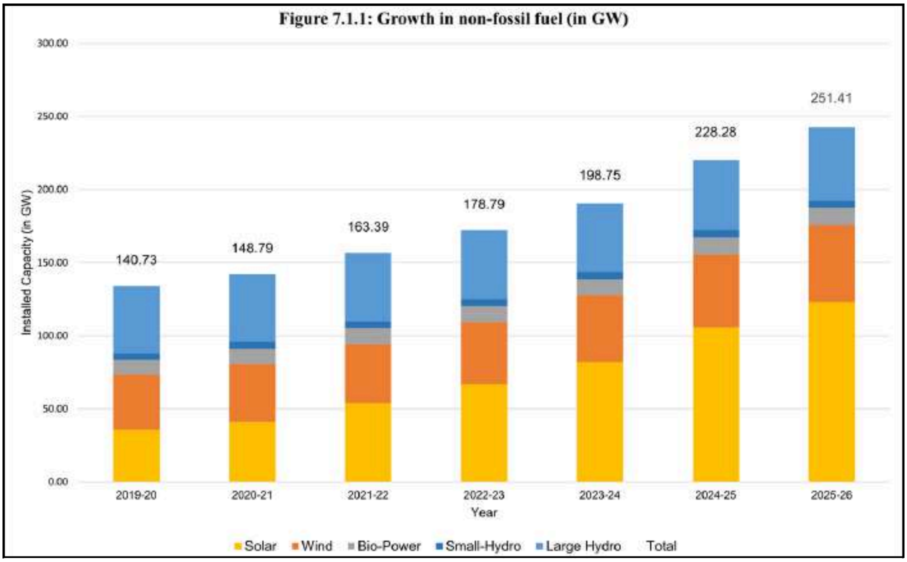
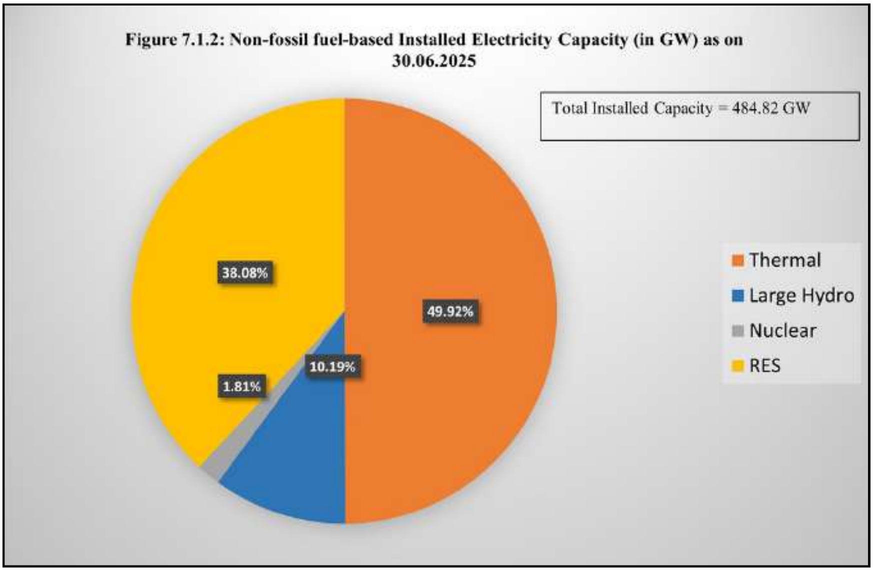


Figure 7.1.1 illustrates a consistent upward trend in India's installed non-fossil fuel capacity, rising from 140.73 GW in FY 2019-20 to 251.41 GW in FY 2025-26 (as updated in August 2025). This expansion reflects India's proactive policy push toward low-carbon energy solutions through instruments such as Renewable Purchase Obligations (RPOs), fiscal incentives like accelerated depreciation, and grid integration reforms.

Among renewable sources, solar power has demonstrated an impressive growth, registering a CAGR of 22.97% over the past seven fiscal years. Large-scale deployment through solar parks and ultra-mega solar power projects, alongside flagship schemes like the PM Surya Ghar: Muft Bijli Yojana and PM Kisan Urja Suraksha evam Utthan Mahabhiyan (PM KUSUM), has been instrumental in accelerating solar adoption by integrating economic incentives with energy access goals. These initiatives have concomitantly made clean energy accessible to households, powered rural electrification, reduced diesel dependence, and promoted energy security.

The diversification of the non-fossil mix has also been reinforced by the government's renewed emphasis on nuclear energy. The Union Budget 2025 underscores its importance in ensuring long-term reliability through indigenous technology development and public-private participation. India aims to expand nuclear capacity from 8,180 MW to 22,480 MW by 2031–32, marking a key step toward a resilient and diversified non-fossil fuel energy portfolio (Press Information Bureau, 2025).

Non-Fossil Energy Share in Installed Capacity



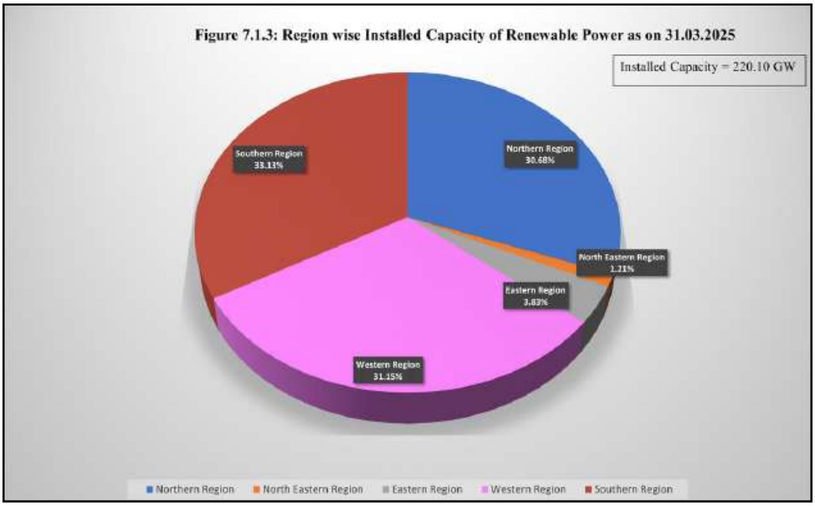
Note: Renewable Energy Sources (RES) comprises Solar, Wind, Bio-Power & Small Hydro Power.

Source: Data from Ministry of New and Renewable Energy

At COP26, India set an ambitious target of achieving 500 GW of non-fossil fuel-based electricity generation capacity by 2030. As of June 2025 (Figure 7.1.2), non-fossil fuel sources contribute 242.78 GW, accounting for 50.08% of the total installed power generation capacity of 484.82 GW—comprising 234 GW of renewable energy (including large hydro) and 8.78 GW of nuclear energy.

This indicates that India has achieved 50% of its cumulative installed electricity capacity from non-fossil fuel sources, five years ahead of the target set under its Nationally Determined Contributions (NDCs) to the Paris Agreement. This marks a transformative shift in India's energy landscape, where non-fossil fuel energy now surpasses thermal power in installed capacity. It underscores India’s growing policy and technological readiness to meet expanding electricity demand sustainably while reducing carbon intensity per unit of GDP.

- Region wise Installed Capacity of Renewable Power



Source: Data from Ministry of New and Renewable Energy

The geographical distribution of renewable energy installed capacity as on 31 March 2025 (Figure 7.1.3) reveals significant regional disparities across India. The Southern region accounts for the largest share (33.13%) of the total installed capacity, followed by the Western (31.15%) and the Northern (30.68%) regions. In contrast, the North Eastern and Eastern regions lag considerably behind their counterparts. While Eastern India has traditionally relied more on coal-based generation, North Eastern region is constrained by limited infrastructure, rugged terrain, seasonal floods, and unreliable power supply. Additionally, weaker institutional capacity, limited financial access, and a shortage of skilled labour further impede renewable expansion (Saini & Tiwari, 2025).

Among states, Rajasthan leads with 15.50% (34.14 GW) of the national renewable energy installed capacity, followed by Gujarat, Tamil Nadu, Karnataka, and Maharashtra. Together, these five states account for nearly 63% of India's total renewable installations, reflecting strong policy ecosystems, land availability, and investment attractiveness. Their experiences offer insights for replicating decentralized renewable models in less developed regions.

7.2. **Case Study Analysis: Regional Perspectives on India's Green Transition**

To evaluate how India's green transition has evolved unevenly across regions, this section analyses three representative states Gujarat, Tamil Nadu, and Bihar. These cases illustrate how differing policy priorities, industrial bases, and institutional capacities shape the inclusiveness of green growth.

1. <u>Gujarat: The Western Leader</u>

Gujarat remains India's benchmark for renewable-energy governance and industrial diversification. Between 2015 and 2025, its installed renewable-energy (RE) capacity increased from 7.8 GW to 35.16 GW, accounting for 15.7 % of India's total RE capacity. Solar installations (19.4 GW) and wind (13.5 GW) dominate this mix (MNRE, 2025). The Khavda Renewable Energy Park, Asia's largest, spans 72,600 ha with a planned output of 30 GW and an investment value exceeding ₹1.5 lakh crore (NITI Aayog, 2024).

Employment in Gujarat's green industries grew from approximately 35,000 direct jobs in 2015 to over 1.2 lakh by 2025, concentrated in operations-and-maintenance, module manufacturing, and construction (CEEW, 2024). Per-capita RE generation rose from 1,700 kWh in 2015 to 2,950 kWh in 2025, while the state's carbon intensity declined by 18 %.

Coastal/industrial belts (Kutch, Jamnagar, Bhavnagar) gain manufacturing jobs and improved infrastructure while agrarian hinterland (Dahod and Banaskantha) face slower uptake and weaker connectivity. For example, Gujarat's industrialised coastal districts have borne the brunt of investment and job creation, whereas its agrarian interior districts still lag, producing intra-state disparities. Bridging this gap requires decentralised schemes (rooftop solar, micro grids in rural zones), and targeted fiscal support for less-favoured districts. Hence, Gujarat's example shows how strong institutional capacity, industrial readiness and policy coherence enable inclusive green growth but also that without deliberate spatial equity measures, a "green divide" can persist.

2. Tamil Nadu: The Southern Pioneer

Tamil Nadu has long been a forerunner in India's renewable-energy trajectory. As of 2025, its total RE capacity stood at 22.3 GW, of which 11.7 GW was wind and 10.1 GW solar (TANGEDCO Annual Report, 2025). Annual green-energy investments reached ₹37,000 crore, supported by the Tamil Nadu Green Energy Corporation Limited (TNGECL). The state also leads in hybrid and storage projects, with two battery-energy-storage systems (BESS) pilots (Karur and Tiruvarur, 45 MWh each) demonstrating improved grid stability.

From 2015 to 2025, Tamil Nadu generated over 52,000 green jobs, driven by manufacturing clusters in Coimbatore and Tirunelveli. The Tamil Nadu Skill Development Mission trained 11,000 technicians in RE installation and maintenance (TEDA, 2024). The state also achieved a 24 % reduction in CO_2 intensity of its power mix.

However, rooftop solar penetration remains at only 1.6 % of potential (1,003 MW installed out of 60,000 MW potential). Grid imbalances and curtailment remain concerns, despite high potential, the seasonal wind patterns cause fluctuating generation and stress the transmission network. For example, Tamil Nadu recorded its highest wind generation day of 5,915 MW on August 16, 2025. While agrarian bases lacking grid readiness, lag behind and rural districts lag behind metropolitan hubs.

Bridging this requires scaling rooftop/decentralised solar (especially in farming districts), enhancing storage to stabilise supply, and addressing local job linkages in non-industrial zones. Hence, Tamil Nadu's trajectory exemplifies progressive green growth, but still carries the risk of a territorial green divide unless spatially inclusive policies are strengthened.

3. Bihar: The Eastern Laggard

The state of Bihar's green transition highlights structural disadvantages of less-industrialised regions. As of early 2025, total installed RE capacity was 0.54 GW, among the lowest for large Indian states. The state has nevertheless set ambitious targets: under its Bihar Policy for Promotion of New & Renewable Energy Sources 2025, it targets 23.9 GW by 2030, yet progress remains slow.

Investment inflows during 2015–2025 amounted to only ₹4,200 crore, versus Gujarat's ₹1.5 lakh crore. Green employment creation averaged 3,200 jobs, primarily through government rooftop projects (≈ 110 MW across 12,000 buildings). Despite high solar potential (5.5 kWh/m²/day), poor grid connectivity, distribution-company (DISCOM) finances, limited transmission infrastructure, land-acquisition bottlenecks, low industrialisation and lower levels of private investment engagement (compared to Gujarat or Tamil Nadu). For example, as of August 2025, about 12,000 government buildings had been equipped with rooftop solar in the state, contributing just over 110 MW capacity.

Socio-economically, only 23 % of Bihar's peak demand (8,005 MW) is met through renewables. Female participation in green-energy employment is just 4.6 %, compared to 19 % in Tamil Nadu (ILO India, 2023). The consequences for the green divide are stark. Bridging this requires decentralised solar farms in rural areas, industrial policy linked to green manufacturing, and stronger institutional capacity. The benefits of India's green transition bypass Bihar. Consequently, Bihar illustrates how governance fragility can stall green convergence despite central fiscal support.

7.2.1. **Comparative Insights and the Green Inclusiveness Index**

To quantify regional disparities, a simple Green Inclusiveness Index (GII) was constructed using four equally weighted indicators:

- Renewable share of total capacity (%)
- Green jobs per million population
- Per-capita RE generation (kWh)
- Carbon intensity reduction (%) (2015–2025)

Table 7.2.1: Green Inclusiveness Index (GII)

State	Gujarat	Tamil Nadu	Bihar
RE Share (%)	53.2	46.7	9.4
Green Jobs/ million population	18,000	12,000	320
Per-capita RE (kWh)	2,950	2,420	270
CO_2 Reduction (%)	18	24	4
GII Score	0.82 (Leader)	0.75 (Strong)	0.22 (Laggard)

The findings reveal a clear green divide: high-capacity states achieve stronger environmental and employment gains, while low-capacity states benefit marginally. Policy innovation, industrial readiness, and governance capacity emerge as key drivers of inclusive green growth.

Bridging the gap demands targeted action, fiscal support for lagging regions, green manufacturing hubs, inclusive skill programs, and state-level collaboration. Despite notable progress, India's 2015–2025 green transition remains uneven. Without sustained institutional and fiscal reform, the nation risks reinforcing disparities, moving not toward green growth, but a green divide.

7.2.2. **Estimation of Green Employment**

State-level green employment data are not officially reported in India. Therefore, employment estimates were derived using a capacity-weighted allocation approach, a commonly used method in regional energy economics when disaggregated labour data are unavailable.

$$\text{GreenJobs}_{state} = \left(\frac{\text{RE Capacity}_{state}}{\text{RE Capacity}_{India}}\right) \times \text{Total RE Jobs}_{India}$$

This method assumes that states with higher renewable capacity generate proportionately greater employment opportunities across installation, operations, and manufacturing segments.

To improve comparability across states, employment figures were standardized into jobs per million population, thereby controlling for demographic differences.

7.2.3. **Data Processing and Standardization**

Because the selected indicators are expressed in heterogeneous units (percentages, kilowatt-hours, and employment counts), normalization was required prior to aggregation.

Step 1: Data Cleaning

- Cross-verified observations across annual statistical reports.
- Ensured alignment to the most recent common reference year.
- Screened for missing values; none required imputation.
- Examined extreme values, confirming that variation reflected structural economic differences rather than measurement error.

Step 2: Normalization

The min–max normalization technique was applied to transform each variable onto a bounded scale between 0 and 1.

$$X'_{is} = \frac{X_{is} - \min(X_i)}{\max(X_i) - \min(X_i)}$$

Where:

Xis: actual value of indicator i for state s

X'is : normalised value of indicator i for state s

min(*Xi*) & max(*Xi*): the minimum and maximum values of indicator across all states

This method preserves relative distances while preventing dimensional dominance , a standard practice in composite index construction such as the Human Development Index.

7.2.4. **Weighting Scheme**

Each indicator was assigned an equal weight of 0.25:

$$\mathrm{GII}_s = \frac{RE + GE + PCRE + CI}{4}$$

Where:

- RE = Renewable Energy Share
- GE = Green Employment Intensity
- PCRE = Per Capita Renewable Electricity
- CI = Carbon Intensity Reduction

Equal weighting was adopted to avoid subjective prioritisation and to enhance methodological transparency. Consistent with OECD (2008) guidelines on composite indicator construction, equal weights are used in the baseline specification in the absence of strong theoretical justification for differential weighting.

7.2.5. **Composite Score Calculation**

Following normalization and weighting, the composite GII scores were co mputed as the arithmetic mean of the four standardized indicators.

$$GII_s = \frac{1}{4}\sum_{i=1}^{4} X'_{is}$$

Higher scores indicate stronger integration of environmental transition with inclusive economic outcomes.

States were classified into three analytical categories:

Table 7.2.2: Interpretation of GII Scores

GII Range	Category	Interpretation
0.70 – 1.00	Green Leaders	High renewable adoption with inclusive benefits
0.40 – 0.69	Intermediate	Moderate transition with uneven gains
Below 0.40	Laggard	Limited diffusion of green growth benefits

7.2.6. **Robustness Check**

To evaluate the stability of the index, sensitivity tests were conducted using alternative weighting structures and Principal Component Analysis (PCA). The resulting rankings remained largely unchanged, indicating that the index is not overly sensitive to weighting assumptions and confirming the internal consistency of the composite measure.

7.2.7. **Methodological Note**

The Green Inclusiveness Index is intended as a comparative analytical tool rather than a deterministic ranking mechanism. The results should therefore be interpreted alongside structural economic conditions, institutional capacity, and state-specific policy environments.

7.2.8. **Replicability Statement**

All datasets, normalization procedures, and aggregation steps used in constructing the Green Inclusiveness Index are explicitly documented and derived from publicly available sources. The index can be fully reproduced using the formulas and methodological steps described above

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8. **Policy recommendations**

1. Strengthen renewable energy integration through hybrid power projects and eco-friendly technological innovation: The government should make efforts to accelerate public and private investments and promote research to guide effective deployment of technology such as hybrid wind-solar projects, which offer complementary generation patterns and ensure consistent power supply by addressing the problem of intermittency (Garg and Gulia, 2020). Additionally, policies should prioritize improving the management of smart grids and making storage components affordable to ensure optimal use of renewable capacity.

2. Ensure a just and inclusive green transition by balancing the employment gains from green job creation with the potential losses from phasing out fossil fuel industries: Many workers in the carbon-intensive industries may lose their livelihood due to the transition. The government must ensure that new opportunities are created in the clean energy sector so that it offset the job losses and even these dislocated workers find a job. Policies should integrate social justice principles by supporting small businesses, ensuring gender inclusion, and providing social protection for affected workers. According to a ILO report, energy created through solar photovoltaic cells, landfill gas, or biomass plants have a greater number of jobs created per unit of energy produced than energy produced through conventional sources, underscoring the potential of clean energy to create equitable and sustainable employment.

3. The government should earmark funds to develop sustainability competences across the entire workforce: The transition towards sustainable production and consumption necessitates investments in updated skill sets or "green skills" (Bianchi, 2020) to reduce the carbon footprint and specialize in green technologies. The entire workforce and not just occupations arising from the green transition should undergo training to benefit. Investing in human development and skilling the labour force can facilitate access to emerging opportunities in the renewable energy sector.

4. Adopt a multi-pronged approach to foster green growth: It is essential to design a policy framework that integrates key sectors such as agriculture, energy, transport, MSME, and manufacturing. Both regional and national governments can play a crucial role in promoting green growth by offering tax rebates and subsidies to boost adoption of clean technologies like EV, solar panel etc., imposing carbon taxes to internalize the negative externalities of fossil-fuel use, and encouraging public-private partnerships (Khan et al., 2025). A whole-of-society approach involving active participation from citizens and the private sector, will further benefit India's green transition. Collectively, these measures will help optimize resource use, enhance coordination efforts, and advance India's progress toward achieving net zero carbon emissions by 2070.

5. Enhance transparency and coordination in India's green transition: To enhance transparency in the system, it is essential to publish performance rankings of states based on renewable energy growth, decarbonization, and related metrics. This will instil a spirit of competition and encourage individuals to work towards sustainable growth. For instance, initiatives like the Aspirational Districts Programme dashboard have led to improved transparency and accountability by making the platform accessible to the public for monitoring as well as participation in the governance process (Kapoor & Green, n.d.). Additionally, in order to facilitate the successful implementation of sustainable projects at the local level, it is important to strengthen the capacity of local governments, particularly municipal and panchayat authorities, by providing training in green project design, monitoring, and climate funding access.

9. **Conclusion**

India’s transition toward a green economy is at a decisive turning point. Although the nation has made impressive progress in expanding its clean energy sector, it achieved more than 50% of its installed power capacity from non-fossil fuel sources five years ahead of schedule, the analysis shows that this progress is still uneven across sectors and regions.

Due to government programs like PM Surya Ghar-Muft Bijli Yojana and PM KUSUM, solar energy has become the mainstay of India's renewable portfolio and is expanding quickly, while wind, hydro, and nuclear energy are still growing slowly.

States like Tamil Nadu and Gujarat have been able to get large investments in renewable energy and create a good number of green jobs because of their strong institutional capacity, industrial readiness, and policy coherence. While states like Bihar, are behind because of their weak governance structures, inadequate infrastructure, and low levels of private investment. The differences in carbon reduction, job creation, and renewable energy capacity highlight the larger problem of guaranteeing fair and inclusive green growth.

Thus, India's shift to a green economy needs to go beyond meeting overall national goals. To guarantee that every state and community benefits from sustainable growth, it must place a high priority on regional equity, social inclusion, and institutional strengthening. India has the potential to lead the world in renewable energy and serve as a model for inclusive and equitable green transformation if it can match its clean energy goals with a fair and regionally balanced development plan.

Author Contributions

Ashmita Kulabhi - Drafted the abstract, integrating core research insights with the study's objectives and outcomes. Conducted the literature review and contributed to the development of the research objectives and methodology. Additionally, developed visual analyses of India's renewable energy expansion, interpreted trends in non-fossil fuel energy, and formulated evidence-based policy recommendations.

Trisha Dev - Contributed to the development of the research framework by drafting the introduction and methodology sections, conducted comparative state-level case studies (Gujarat, Tamil Nadu, and Bihar) to assess regional disparities in India's green transition, and analysed findings to highlight the emerging green divide and its policy implications.

Ankit Gautam - Contributed to the research, analysis, and writing of the "Decarbonising Industrial and Manufacturing Hubs through Clean Energy Integration" section, including Clean Energy Integration in Industrial Corridors and MSMEs, integrating recent policy developments, statistical insights, and relevant citations. Additionally, led the research and writing of the urban growth and emission trends section.

Jerin Jojy - Worked on the research and writing of the transport section identifying its significance in India's green economy transition, while contributing to the policy recommendations. Additionally, authored the conclusion, synthesizing key findings and emphasizing the study's practical relevance to India's green transition.

Appendix A
Components and Data Sources of the Green Inclusiveness Index

Table 1: Components of GII

Indicator	Description	Data Source
Renewable share of total capacity (%)	Percentage of renewable energy in total installed electricity capacity	Central Electricity Authority (CEA). Installed Capacity Reports. https://cea.nic.in
Green employment intensity (jobs per million population)	Employment generated through renewable energy and green manufacturing sectors	International Renewable Energy Agency (IRENA). Renewable Energy and Jobs – Annual Review. https://www.irena.org
Per-capita renewable energy generation (kWh)	Average renewable electricity generation per person	Ministry of Statistics and Programme Implementation (MoSPI). Energy Statistics India. https://mospi.gov.in
Carbon intensity reduction (%)	Reduction in emissions intensity relative to economic output	MoSPI, Energy Statistics India; India Energy Outlook (IEA). https://www.iea.org

The dataset was compiled through triangulation of official government publications and international institutional databases to ensure transparency and replicability.

- Central Electricity Authority (CEA) provides state-wise installed capacity and renewable generation statistics.
- MoSPI's Energy Statistics offers standardized national energy indicators.
- IRENA supplies globally comparable renewable employment estimates.
- IEA provides decarbonisation metrics and carbon intensity trends.

All sources are publicly accessible, allowing independent verification of the index.

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