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From Petro-State to Electro-State

India's Energy Transition at a Crossroads

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By

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About the Author

Parth Seth is a research fellow at the India Foundation. His interest lies in the themes of multilateralism, development, middle powers, and great power competition. He focuses on South Asia, the Middle East and North Africa (MENA), and Chinese foreign policy. While interning at several think tanks, he has assisted researchers in the domains of strategic studies, public policy, and international development. He has written for websites and journals on the themes of South Asia, China, MENA, and the intersection of political philosophy and policy. He completed his postgraduate studies in International Relations from the London School of Economics and Political Science and holds an undergraduate degree in political science from the Ramjas College of the University of Delhi.

Abstract

Global energy consumption is at a defining inflection point, shaped by the imperatives of the Fourth Industrial Revolution, accelerating climate change, and geopolitical realignments. In 2024, global primary energy consumption reached 186,383 TWh, driven by extreme climate events, the expansion of electricity-intensive industries, and the proliferation of data centres. Against this backdrop, a structural bifurcation is emerging between "petro-states" — economies entrenched in fossil-fuel dependence — and "electro-states" — those pivoting towards electricity as the dominant medium of final energy consumption. This report examines India's position along this spectrum and interrogates the pace, quality, and sustainability of its electrification and green transition agenda.

India occupies an ambivalent position. Its primary energy consumption exceeded 11,300 TWh in 2024, ranking third globally, yet its per capita energy use remains typical of lower-middle-income economies. While fossil fuels continue to dominate India's energy mix, the country has made substantial strides in renewable energy deployment, surpassing 50% non-fossil-fuel installed capacity five years ahead of its nationally determined contribution targets. Installed solar capacity has reached 136 GW, wind capacity 55 GW, and railway electrification is nearly complete at 98%. India's adoption of clean energy, notably, is proceeding faster than China's at a comparable level of per capita GDP.

Despite this progress, significant structural impediments persist. State distribution companies carry debt exceeding INR 800 billion, and intra-state transmission infrastructure lags generation capacity by a wide margin. Biomass co-firing mandates remain largely unimplemented, and cold chain logistics, MSMEs, and rural economies continue to depend heavily on fossil fuels. Himalayan hydropower, while essential for grid stability, poses acute ecological risks that demand rigorous cumulative impact assessments before further expansion. India's clean energy supply chains remain disproportionately reliant on Chinese imports, and private-sector

investment in research and development for clean technologies is insufficient relative to the scale of the transition required.

The report concludes with a set of policy recommendations. These include rationalising the project approval framework from a single-window to a single-approval system, establishing an intergovernmental coordination mechanism for transmission planning, scaling up BioCNG as a dispatchable green fuel, strengthening nuclear liability provisions under the SHANTI Act, and extending electrification incentives to under-served sectors such as aviation, cold storage, and freight logistics. Crucially, the transition must remain inclusive, with green financing instruments tailored to the needs of MSMEs and the rural economy.

Keywords: Electrification; Decarbonisation; Petro-states; Electro-states Green Transition; Net Zero; Grid Stability; Climate Change

The course of human history has been shaped by the evolution of energy sources and the methods and technologies available to harness them. The periodisation of history—from pastoral–nomadic to settled life, the onset of the agricultural revolution, the production of surplus to support the rise of urban, river-valley civilisations; the Iron Age, and the four Industrial Revolutions (Childe, 1950)—is a gradual progression in human energy demand and consumption. Innovations to improve the efficiency and effectiveness of energy utilisation and transmission have been among the starkest differentiating variables between countries at different stages of development (Roser, 2023).

As humankind grapples with the dilemmas and opportunities presented by the Fourth Industrial Revolution, the availability of energy has again taken centre stage. The widespread mushrooming of data centres, the automation of human activities, mechanisation, and the linkages harnessed through blockchain and decentralised networks have multiplied the need for uninterrupted power. In 2024, the world consumed 186,383 TWh of primary energy, an increase of nearly 5000 TWh in the span of only a year (Ritchie, 2020). Primary energy consumption has witnessed a secular rise since the onset of the century, interrupted only by the sub-prime crisis in 2008 and the COVID-19 pandemic in 2020. High-income countries still dominate primary energy usage, characterised by high per-capita usage and a transition towards energy-intensive industries and services.

Global energy use in 2024, however, reflected shifts in both structural and incidental factors. Global energy demand rose by more than 3% YoY, largely owing to the high incidence of extreme climate events (Ibid). Demand remained concentrated in high- and upper-middle-income countries, though growth was only 1%, having shrunk in 2023. By contrast, emerging market and developing economies saw a slowdown in power demand growth, falling below 4%, largely owing to the slowdown in China. The following table highlights the countries with the highest power consumption.

S. No.	Countries	Energy Consumption
1	China	48,987 TWh
2	USA	26,529 TWh
3	India	11,336 TWh
4	Russia	9,049 TWh
5	Japan	4,795 TWh

Data sourced from Ritchie (2020); table created by author.

The demand for energy closely tracked the variations in GDP growth in 2024: there was a 1% difference between the rate of GDP growth and energy growth (Global Change Data Lab, 2025). However, electricity demand for final consumption grew faster than GDP. Demand increased at the greatest rate ever observed, excluding the spikes in years when the world economy recovered from recession. This reflects structural trends such as expanding access to electricity-intensive devices like air conditioners and their growing use on a warming planet. Nevertheless, nearly 54% of the world's overall energy continues to be met by hydrocarbons, followed by renewables, which account for a little over 30% of the sources (Schwab, 2016). Overall, the power industry accounted for three-fifths of the increase in the world's energy demand.

The rise in electricity-centric power demand is attributable not only to the growing use of electricity as a power source, but also to electrification as an end in itself and to the proliferation of electricity in final energy demand. Electrification serves two purposes. Firstly, electricity is an efficient energy source that optimises power utilisation and is cost-effective to transmit; secondly, it helps reduce dependence on

fossil fuels. Electrification is considered low-hanging fruit: its penetration in mobility and heating solutions is considerable, offering benefits to health and comfort, viz., the absence of tailpipe emissions and cooling from heat pumps.

Countries are prioritising electrification as a scalable and rapidly deployable decarbonisation pathway within their net-zero strategies. However, achieving a durable and sustainable transition to an electricity-led economy requires diversified investment in renewables, nuclear energy, and green hydrogen, as well as heavy investment in the harmonisation and flexibility of grids and transmission and distribution networks. Synchronising transmission requires systems-level coordination and stable regulatory signals. This becomes particularly urgent as the world has already crossed the 1.5°C threshold (UNFCCC, 2015). Countries are lagging their decarbonisation and electrification targets. For instance, electricity accounts for only 21% of the EU's energy matrix.

The pace of decarbonisation and the green transition will, in large measure, depend on India's net-zero transition. India is one of the fastest-growing large economies in the world (UNCTAD, 2024). The share of the tertiary sector is supported by India's aim to achieve its net-zero target by 2070, a commitment it announced during COP-26, founded on common but differentiated responsibilities and respective capabilities. Although India's historical greenhouse gas emissions contributed nearly 4% of the total global cumulative emissions, India's emissions in 2025 outpaced the global average, growing by 1.4%, a drop from 4% growth in 2024 (IBEF, 2024). According to Global Energy Consumption Data computed by the Global Change Data Lab, India's primary energy consumption in 2024 exceeded 11,300 TWh, ranking behind the US and China. However, per capita consumption in India aligns with the trend displayed by lower-middle-income countries: India's per capita energy usage is less than 10,000 kWh; for illustration, China's per capita energy

usage was over 34,000 kWh in 2024, whereas Norway's per capita energy usage was computed to be nearly 100,000 kWh.

India's per-capita energy use has steadily grown since the pandemic, aided by the integration of zonal and regional grids into a national grid, which enables the transfer of power from surplus to deficit areas and has significantly reduced the incidence of load-shedding (IBEF, 2024). In 2023, India achieved near-universal household electrification, with 2.8 crore households connected to the electric grid. However, electricity's share of final energy consumption remains below 20% (IEA, 2025), below the global average of 21%, and well behind the Nordic states, where electricity accounts for more than 1/3rd of the total energy mix.

India needs to address three pre-conditions before ensuring a viable, sustainable electrification pathway: improving access and affordability to counter energy poverty; building resilience to supply chain shocks and technological and geopolitical disruptions; and maintaining consistent investment, especially in indigenously led research and development in power transmission and grid stability. It is important to invest in baseload and variable renewable energy to ensure that the electrification of the economy is complemented by its decarbonisation.

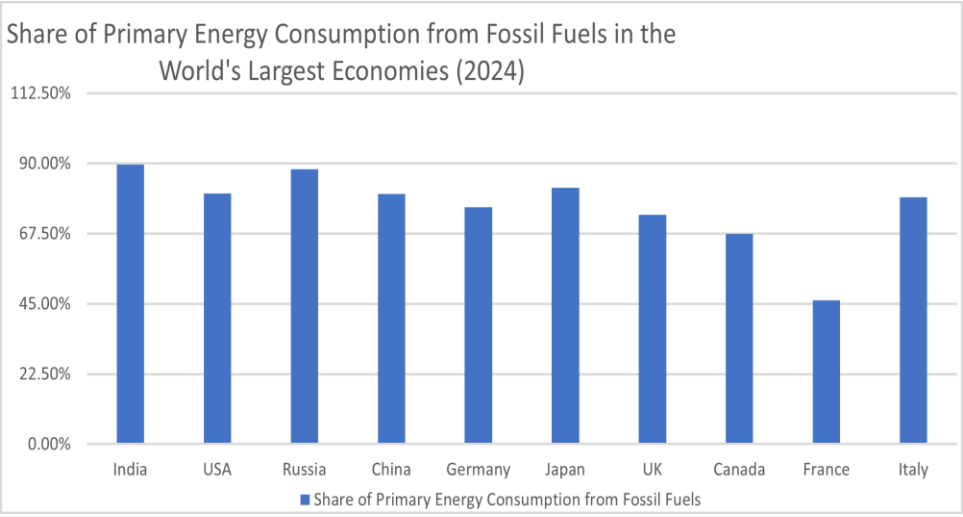
Methodology

This report is based on discussions at the "High-Level Policy Dialogue on Electrifying Sectors, Greening Electricity" (IF, 2026), held in New Delhi on January 29, 2026. The discussion featured policy-makers, senior bureaucrats, industry experts, and climate advocates.

The report follows from the problems, progress, and opportunities identified during discussions. It is, therefore, a *post hoc* report that seeks to assess the scale and

direction of India's electrification agenda without proposing pedantic solutions. The report, however, rests on an assumption: the division of the world's political economies into petro-states and electro-states, based not only on their energy dependence but also on their foreseeable trajectory. To ensure policy relevance, the report concludes with a set of recommendations to address the persistent issues obstructing India's clean transition and electrification agenda.

Petro-States vs Electro-States



Data sourced from Ritchie (2020); graph created by author.

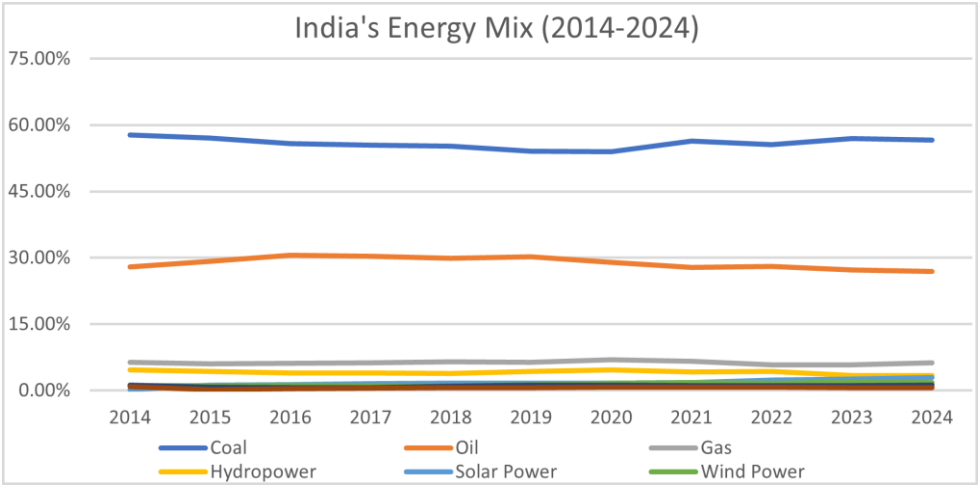
India's power sector stands at a defining juncture. India, as well as the global economy, is at a crossroads in choosing the appropriate energy mix—the choice between a petro-state and an electro-state. To illustrate, the United States increasingly relies on fossil fuels to meet its energy needs, and its fossil fuel exports have climbed by over 600% since the onset of this century. The share of electricity in final consumption remained at 21% in 2024, and the share of renewables in

electricity generation also remained under 25%. Oil and natural gas together contributed to over 80% of carbon emissions emanating from the country.

On the other hand, China is gradually emerging as the world's first "electro-state." Electricity security is firmly entrenched in China's policy agendas, including Made in China 2025 (MoFA, 2020; Rhodium Group, 2025). Although over 60% of China's power-generation needs continue to be met by coal, the structural direction points towards rapid electrification and the scaling of renewables, even as coal remains central to energy security and industrial competitiveness in the medium term. China has made the highest investment in renewable energy, totalling 29% of global investment inflows in the sector. It has scaled up across the value chain and has become indispensable in renewable energy supply chains. By formulating an export-led strategy for its RE and cleantech, China has offered scalable alternatives, facilitating a market-led approach to decarbonisation. China's clean tech exports are dominated by lithium batteries and photovoltaic cells, locking in Chinese dominance in the green transition in both the Global North and South.

Energy shocks and geopolitical events are pushing the European Union towards becoming an electro-state. Russia's invasion of Ukraine and the ensuing diplomatic and economic measures to compel a ceasefire and the withdrawal of Russian forces exposed the EU's dependence on Russian energy imports. Although the EU has reduced its dependence on Russia, new dependencies have emerged. The United States (US) has become the leading provider of oil and liquefied natural gas (LNG) to the EU and ranks second in natural gas behind Norway (EU Commission, 2023). Moreover, oil and gas imports remain heavily reliant on a limited number of suppliers. The four leading gas suppliers to the EU accounted for 86% of imports in 2021 and continued to supply 83% in 2024. Oil imports are more diversified, yet reliance has scarcely shifted. The five main oil suppliers to the EU accounted for 60% of imports in 2021 and 54% in 2024.

India: A Petro-State or an Electro-State?



Data sourced from CEA (2024); graph created by the author.

India's policy decisions indicate a two-track energy strategy: due to political economy considerations, India continues to be powered by fossil fuels and non-renewables. However, India has begun building an electro-state. India's fossil fuel consumption is growing at a slower pace than China's; it has taken advantage of the solar and wind energy boom that has driven down prices for solar and wind equipment and its ancillaries, though locking in Chinese dominance in their supply chains.

Undeniably, India's adoption of clean energy is proceeding at a swifter pace than China's at an equitable level of per capita GDP. Last year, solar energy accounted for 9% of electricity generation, and significant investments have been pledged to expand India's hydropower and wind energy potential. India has reached a significant point in history that is aiding an "electro-tech fast-track" (Sinha & Bond, 2026). India is benefiting from consistent innovations in creating scalable and affordable green energy alternatives. Battery storage costs have fallen by over 80% since 2010; utility-scale solar tariffs have fallen by nearly 90% in the same period.

Combustion losses utilising solar and wind energy are negligible, and these sources reduce grid emissions intensity by nearly 90%. As a result, new capacity additions through renewable sources are more cost-efficient. Solar and wind energy frequently undercut new coal plants in terms of levelised costs. With solar tariffs hovering around ₹2–2.5 per kWh in competitive bids, renewable capacity additions are often the least-cost option. Coal, once transport, financing, and environmental compliance costs are factored in, struggles to match this range.[1]

While Chinese dominance across different levels of the RE value chains is reinforced, the trappings of a petro-state increase a country's vulnerability to geopolitical shocks and extraneous disruptions, impelling inflation and denting access and affordability. This is particularly true for countries in South Asia, including India, that have negligible fossil fuel reserves and must rely on trade partners in the Middle East and North Africa and on Russia to meet their energy requirements.

In 2014, India's non-fossil-fuel installed capacity stood at 81 GW; in 11 years, it has grown by 230% to 267 GW today. Installed solar capacity has climbed to 136 GW, while solar module manufacturing capacity sits at 144 GW; 50 GW of solar energy transmission is in the pipeline. In addition to solar capacity, wind energy capacity has grown to 55 GW. Biopower capacity has also increased to nearly 12 GW. Significantly, India has achieved its goal of more than half of its installed power capacity from renewable sources, five years ahead of its nationally determined contributions.

As India aims to reach carbon neutrality by 2070 and generate 500 GW of renewable energy by 2030, it will be critical to decarbonise power capacity in Indian

[1] *On March 26, 2026, the Union government updated India's NDCs to accommodate its ambitious pursuit of carbon neutrality, pledging to reduce emission intensity of its GDP by 47% from 2005 levels, achieve 60% of non-fossil-fuel installed power capacity, and create a 3.5-4 billion carbon sink.*

households, in addition to the sectors of the Indian economy (IEA, 2023). Under the PM Surya Ghar scheme, 28 lakh households have benefited from the installation of solar panels and their integration with the grid. 21 lakh agricultural pumps have been solarised under the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme. 98% of the railways have been electrified (Negi, 2025). India already leads the world in demand for electric three-wheeler mobility. The PM E-DRIVE scheme has been extended until March 31, 2028, with an allocation of ₹10,900 crore (approximately $1.32 billion USD). While incentives for electric two- and three-wheelers will phase out by March 2026, support for larger commercial EVs and the expansion of charging infrastructure will continue. Additionally, India's Goods and Services Tax (GST) Council has maintained a concessional 5% GST rate for all EVs, including luxury models, under the new GST 2.0 framework (Dedhia, 2025). This decision prevents upward reclassification, reinforces affordability, and underscores the government's commitment to accelerating the adoption of clean mobility.

In its pursuit of electrification, the government drafted the National Electricity Policy, 2026, in line with the guidelines set out in its 2005 iteration (Ministry of Power, 2026). Unlike the policy drafted in 2005, the draft is not hamstrung by problems of supply and access; instead, it seeks to develop a resource adequacy framework and address the structural gap in the integration of generation and transmission. Transmission lines, despite substantial expansion in recent years, have followed signals from grid expansion plans, contributing to higher costs and longer timeframes to link areas of supply with demand. In addition, it aims to maximise non-fossil fuel-based generation and to electrify end-use sectors.

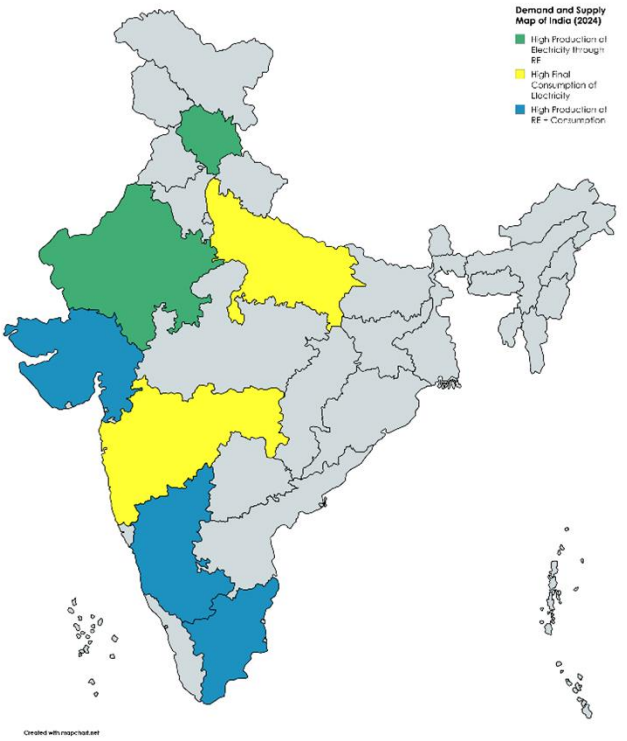
Its salience is particularly evident in the case of India's green transition. Electrification of end-use sectors and the green transition of the grids are key planks of the draft policy. India's renewable energy sources are heavily skewed towards five states, which together contribute more than 50% to its installed renewable energy capacity (PFC, 2024). Statistically, Rajasthan leads renewable energy

production in India, largely supported by solar parks such as the Bhadla Solar Park, which produces 13.4% of India's renewable energy; it is followed by Gujarat, utilising its wind and solar potential and contributing 12% to the total share; and Karnataka, producing 11% of India's renewable energy, relying on wind power. The power requirements of Indian states are more dispersed and evolving in palpable correlation with the levels of industrialisation and urbanisation (MNRE, 2025).

S. No.	State	Share of Renewable Energy Production (2024)
1	Rajasthan	13.4%
2	Gujarat	12.0%
3	Karnataka	11.0%
4	Himachal Pradesh	10.8%
5	Tamil Nadu	9.2%

Data sourced from MNRE, 2025; table prepared by author

The draft policy aligns with India's climate commitments, aiming to reduce emissions intensity by 45% relative to 2005 levels and to increase per-capita electricity consumption to 2000 kWh by 2030, with a large share of that consumption derived from renewable sources. The policy draft features a calibrated push towards nuclear energy, aiming to expand nuclear capacity to 100 GW by 2047 and to open the sector to foreign investment to set up Bharat's small reactors and modular reactors. Retired and existing thermal reactors will be repurposed as nuclear stations and will be eligible for green bond financing. As a corollary, the policy notes that expanding generation capacity, transmission, and the green transition will require INR 200 lakh crores by 2050.



Despite achieving universal household electrification and integrating local grids into a uniform national grid, the policy recognised the deterioration of state distribution companies (DISCOMs) and state load dispatch centres (SLDCs), underscoring the need to improve efficiency and upgrade and integrate power generation and transmission. DISCOM debt exceeds INR 800 billion, with no resolution in sight (NITI Aayog, 2026). The accumulation of regulatory assets, under-recovery of costs, and delays in tariff determination have undermined the sector's credibility. Capacity gaps in state DISCOMs also impede the effective integration of renewable power generation with the national grid and its transmission. Industries, despite consuming

45% of end-use power, continue to pay elevated tariffs due to cross-subsidies and the bloating of regulatory assets.

The policy also emphasises upgrading storage to store surplus power and distribute it to bridge gaps between power supply and demand. It marks a paradigm shift by underscoring resource adequacy planning at the utility, state, and national levels. It calls for timely tariff orders and adjustments to cover regulatory delays. It further envisions growth in supply licencees and the metamorphosis of DISCOMs into network operators.

Challenges, Bottlenecks, and Opportunities

India's electrification is progressing steadily, but it needs to accelerate to keep carbon emissions in check and slow the rise in temperature. Climate vulnerability is pushing communities further into poverty, which has a detrimental impact on India's entrenched energy poverty. The country needs extensive discom reforms: transmission lines in states operate at sub-optimal capacities, leading to issues with grid integration. No adequate forum exists for states to resolve disputes. State-level transmission infrastructure is weak, and intra-state networks lag behind generation capacity. Transmission plans are not updated dynamically; they need to be revised every 6 months to 1 year to remain relevant, but the institutional agility to do so does not yet exist.

Electrification has not been uniform. While India has made strides in two- and three-wheeler, rail, and public transport, the electrification of private, long-distance road transport, shipping, aviation, and cold storage remains a festering challenge. The growth of data centres in India will lead to an explosion in demand for power, which is expected to grow at a 10% CAGR.

MSMEs and the rural economy, the mainstays of employment generation, continue to depend on traditional hydrocarbon-based energy sources (PFC, 2023). Nearly 80

lakh MSMEs are registered with the Udyam Portal, contributing 29.2% to the country's gross value added. India's key exports, including steel and cement, are associated with high greenhouse gas emissions and rely on outdated technologies. For instance, India's MSME steel sector, particularly re-rolling mills and induction furnace units, contributes significantly to national steel production and employs over 400,000 people. Despite their centrality to employment generation and industrial output, MSMEs struggle to access finance for a sustainable transition to renewable sources.

Similarly, in rural India, decarbonisation is progressing at a painstaking pace. Economic activities in India's rural landscape, including farming, agri-processing, and stubble-burning, continue to be dominated by energy-intensive fossil fuels. India's goals of achieving a circular economy and generating 500 GW from renewable sources are incomplete without reconciling them with the economic and demographic profile of India's rural hinterland. The government hopes the circular economy will generate 10 million jobs. India's agriculture-dominated economy generates 350 million tonnes of agricultural waste, which is increasingly being transformed into biomass, with the potential to generate 18000 MW of energy. 51% of India's districts are served by 979 biogas plants (Mallya et al., 2024). Compressed biogas has been integrated into carbon credit trading frameworks. Over 42000 custom hiring centres have been established to make crop residue management accessible to small and marginal farmers.

However, a gap remains between policy and practice, best exemplified by biomass co-firing. In 2017, coal-fired plants were mandated to substitute a portion of their coal consumption with agro-residue pellets, with a target of 7% in FY 2025-26 (Ministry of Power, 2023). Across 191 coal-based thermal plants, India's generative capacity is 213 GW; however, in FY 2024-25, actual biomass consumption was only 1.62 million metric tonnes. Only 68 plants adopted co-firing practices, 80% of which are situated in the National Capital Region, contributing to formidable regional disparities in biofuel production. Technical liabilities, exposure to monsoons, and

reverse bidding pressures faced by manufacturers have impeded the adoption of this policy.

Beyond waste generated during livestock management and harvest, wastage and pilferage due to the absence of cold storage facilities is a festering challenge. As of 2024, the number of cold storage facilities was estimated at 8600, and they are largely reliant on fossil fuels for their energy needs. The absence of modern, upgraded cold chain infrastructure leads to high energy consumption and challenges in integrating with renewable energy and in substituting existing refrigerants with low global warming potential (GWP) refrigerants.

Cold chain development is a low-hanging fruit in India's rural decarbonisation pathway. Not only are existing facilities inadequate; they are also energy-inefficient. The proliferation of cold chain facilities should align with decarbonisation goals, which it both needs and can catalyse. Under the Mission for Integrated Development of Horticulture (MIDH) and the Pradhan Mantri Kisan Sampada Yojana (PMKSY), the Indian government is providing financial assistance, credit, and subsidies to construct, expand, and modernise cold storage facilities (PIB, 2025). The government has also launched the scheme for augmentation of cold chain, value addition and preservation infrastructure (CACP), which aims to create a network of cold chain, value addition, and preservation infrastructure in the country. The scheme provides financial assistance to eligible projects for the construction of cold storage facilities, refrigerated transport, and other related infrastructure. The CACP aims to increase the availability of cold storage facilities, reduce the wastage of perishable products, and increase the income of farmers and other stakeholders in the agriculture and food processing sectors. It also aims to improve the quality and safety of temperature-sensitive products, such as fruits, vegetables, dairy, and pharmaceuticals.

Hydro-power is an essential component of India's goal to generate 500 GW from renewable sources. Underscoring its importance, the government has streamlined the

preparation and execution of detailed project reports (DPRs). Hydro-power accounts for the bulk of renewable energy globally and has an inherent advantage over solar and wind for its faster transmission and adaptability to load variations. Hydro-power is less intermittent and less weather-dependent than other renewable sources. This is especially relevant in a unified national grid, which must adapt to seasonal and regional variations in load and demand.

India's installed hydro-power capacity exceeds 50 GW, making it the fifth-largest producer of hydro-electricity in the world. It alone contributes nearly 11% to India's power mix (Srikanth, 2018). Large hydropower projects are concentrated in long, perennial river systems. Two of India's largest hydro-power projects are currently being developed in Arunachal Pradesh: the Dibang multi-purpose project, able to generate 2880 MW; the Lower Siang hydro-electric project, generating 2700 MW; and the Lower Subansiri project, able to generate 2000 MW. Several hydro-power projects are also being developed across Jammu and Kashmir on the Chenab and Jhelum: Baglihar (900 MW), Dulhasti (900 MW), and Uri I/II.

Mapping India's installed hydro-power capacity and scheduled projects, the Himalayas emerge as the epicentre of its ambitions. This serves three-fold purposes: first, to harness the region's vast hydrological potential created by steep river gradients and glacial-fed river systems; second, to strengthen grid stability by developing flexible, storage-based hydropower close to major and historically underserved demand centres; and third, to advance strategic and developmental objectives by integrating remote border regions through infrastructure and energy investments. The International Centre for Integrated Mountain Development (2025) has identified 882 GW of hydropower potential, largely in the Hindu Kush Himalayas. Trans-boundary rivers originating in and feeding the Hindu Kush Himalayas call for cross-border river management and power-sharing arrangements. The Nationally Determined Contributions of the Himalayan states stand at 1.7 TW, whereas the energy potential of the Hindu Kush alone is more than 3.5 TW.

Notwithstanding the region's hydro-power potential, the Himalayas constitute one of the world's largest biodiversity hotspots and are critically vulnerable to the impacts of climate change. The concentration of large and multipurpose hydro-power projects in the Himalayas has adversely affected the hydrological profiles and alluvial deposits of its rivers. Consequently, cloudbursts, torrential rainfall, flash floods, and landslides have become increasingly frequent across the Himalayan states of Uttarakhand, Himachal Pradesh, and Sikkim. Recent disasters, including the Kedarnath floods of 2013, the Chamoli disaster of 2021, and the Sikkim glacial lake outburst of 2023, illustrate how the combination of climatic shifts and unregulated infrastructure expansion can trigger cascading ecological crises (Sangomla, 2026).

These developments underscore a dilemma in India's energy transition and disaster preparedness. Multipurpose river projects, intended to check floods, have paradoxically contributed to their occurrence. While Himalayan hydropower is essential for grid stability and renewable energy expansion, it must be pursued within a framework that recognises the ecological limits of the mountain system. Without comprehensive cumulative impact assessments, improved glacial monitoring, and more stringent environmental safeguards, the expansion of hydropower infrastructure risks undermining the very ecological foundations on which the region's long-term sustainability depends.

Developing scalable renewable energy solutions requires investment in research and development and capital formation. For instance, China registered 8.9% YoY growth in its spending on research and development in renewable energy in 2024, totalling over USD 500 billion, second only to the US. However, China was the biggest investor in clean energy in 2024 (Watts, 2026), accounting for nearly a third of the global share of investments. China's research and development strategy is founded on three pillars: manufacturing and industrial scalability; export orientation; and state-led growth. Nevertheless, China's private enterprises spent USD 200

billion on R&D, and 112 Chinese enterprises, including BYD and CATL, rank among the world's top 1000 R&D spenders.

India has lagged its peers in clean-energy innovation and R&D, which remains overwhelmingly state-led. Although Indian conglomerates have begun investing in battery manufacturing, green hydrogen, and solar module production, India's private-sector R&D ecosystem in clean technologies has yet to match the scale and depth seen in China.

Consequently, while India has successfully expanded renewable deployment, its technological and manufacturing capabilities remain dependent on imported components, particularly from China. Addressing this asymmetry will require deeper private-sector participation in R&D, sustained industrial policy support, and the creation of domestic manufacturing ecosystems across the solar, battery, and green hydrogen value chains. Without strengthening its innovation architecture, India risks becoming a large consumer market for renewable technologies rather than a leading producer in the emerging global electro-tech economy. This dependence subjects India to inflationary pressures from trade headwinds and reliance on China.

In addition to renewable sources such as solar and wind, India is investing in nuclear energy, which ensures a smooth, uninterrupted flow of power to the grid and enhances grid stability. The Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India (SHANTI) Act, 2025, was recently passed, inviting private and foreign investment in nuclear energy and thereby harnessing the potential for innovation (SHANTI Bill, 2025). The Atomic Energy Regulatory Board (AERB) is granted statutory status, enhancing independent licensing and compliance with international standards. The Act introduced capped liability for large operators of up to SDR 300 million to make projects more bankable.

However, the AERB, as a statutory board, is not immune to executive interference, and institutional practices may erode its autonomy (Desai, 2026). The liability cap of SDR 300 million is grossly inadequate, given India's experience with non-nuclear

disasters, such as Sivakasi and Bhopal. Countries have inflated their liability caps, underscoring the immense human and environmental costs associated with nuclear casualties. The Act makes no mention of revenue support, land acquisition, and environmental compliance, all of which obstruct capital-intensive nuclear projects. The two-tier body to settle disputes over decisions taken by the AERB comprises an Atomic Energy Redressal Council and an Appellate Tribunal for Electricity. The Atomic Energy Redressal Council comprises the director of the Bhabha Atomic Research Centre (BARC), the chair of the AERB, and the chairperson of the Central Electricity Authority (CEA), and is led by the chairperson of the Atomic Energy Commission (AEC). The Council exhibits an absence of subject-matter experts, at the expense of bureaucratic intervention, and constrains the liberty to involve ad hoc experts depending on the nature of the dispute.

Recommendations

The draft National Electricity Policy underscores the importance of resource adequacy; however, achieving its objectives will require deeper institutional coordination. The government must move beyond a siloed approach and foster structured collaboration between ministries and the private sector to align regulatory priorities, investment pipelines, and implementation strategies. At present, the regulatory burden remains a significant bottleneck: establishing a power plant requires as many as 116 approvals. This must be rationalised by transitioning from a “single-window” clearance system to a “single-approval” framework, enabling faster project execution and reducing transaction costs.

Transmission infrastructure continues to face structural and institutional constraints. With 14 inter-state transmission projects stalled, there is an urgent need for a formal intergovernmental coordination mechanism, akin to the GST Council, to facilitate consensus-building among states. Transmission planning must also become more dynamic: plans should be revised every 6 to 12 months to reflect evolving demand

patterns and renewable energy pipelines. Additionally, intra-state transmission networks require urgent strengthening, particularly in renewable-rich states where grid infrastructure has not kept pace with generation capacity.

India's energy transition is constrained by insufficient investment in research and development, particularly from the private sector. Scaling renewable energy solutions will require a substantial increase in R&D expenditure, with stronger industry participation and deeper collaboration with academic institutions. At the same time, project execution timelines must be compressed by ensuring that detailed project reports (DPRs) are prepared within clearly defined, expedited timeframes.

In the context of grid stability, BioCNG is a viable and underutilised solution. It should be recognised as a firm, dispatchable green fuel capable of replacing imported natural gas in existing gas-fired power plants. This would not only enhance energy security but also provide reliable balancing power in a renewable-heavy grid. To unlock this potential, the government must introduce tariff and regulatory reforms that make BioCNG supply bankable. Incorporating BioCNG production costs into tariff structures or providing viability gap funding will be essential to attract investment. Furthermore, long-term offtake commitments from anchor institutions such as NTPC and major industrial users can help bridge demand–supply gaps and catalyse the development of a robust biomethane value chain.

Electrification must be extended to sectors that remain heavily reliant on fossil fuels, particularly aviation, shipping, and cold chain logistics. In parallel, incentives for commercial electric vehicles and the expansion of charging infrastructure—especially along freight corridors—should be scaled up. The rapid rise in cooling demand driven by rising temperatures necessitates a strong policy push towards electric heat pumps and energy-efficient cooling technologies. Additionally, the growth of data centres requires dedicated policy frameworks that mandate or incentivise the use of renewable energy, for example through renewable purchase obligations.

India’s clean energy transition must also be supported by investment in grid flexibility. Scaling up pumped hydro and battery storage systems is essential to balance variable renewable generation. At the same time, investments in smart grid infrastructure should be promoted through government-to-government (G2G), government-to-business (G2B), and business-to-business (B2B) partnerships to enable real-time grid management and improve system efficiency.

The transition must also be inclusive. Rural economies and MSMEs, which remain heavily reliant on fossil fuels, require targeted support to adopt cleaner energy solutions. This will require the development of green transition financing instruments that balance equity and debt, ensuring accessibility for small enterprises and rural stakeholders. Without such support, the broader goals of decarbonisation and electrification will remain unmet.

Hydropower development, while critical for grid stability and renewable expansion, must be pursued cautiously. Large hydropower and multipurpose river valley projects should be undertaken only after rigorous ecological, social, and cultural impact assessments. The absence of such comprehensive studies, particularly in the Eastern Himalayas, has already led to adverse outcomes, including floods, erosion, and displacement (DTE, 2026). At the same time, hydropower offers an opportunity for India to become a net exporter of electricity. This potential can be realised through strengthened cross-border river management and expanded regional power trade with neighbouring countries.

Finally, nuclear energy can play an important role as a stable, low-carbon baseload source, but its expansion must be accompanied by robust regulatory frameworks. Liability provisions for nuclear accidents should be reviewed and strengthened to ensure adequate compensation and enhance public confidence. In parallel, issues such as land acquisition—especially in scheduled and ecologically sensitive areas—must be addressed through transparent, efficient, and socially responsible mechanisms to prevent delays in adding capacity.

Conclusion

India's electrification plan aims to transform the country's energy structure within a generation and aligns with its target of achieving carbon neutrality by 2070. Electrification of India's fossil-fuel-dependent economy must be gradual yet decisive and sustainable, without compromising the livelihoods of those dependent on it or extending the debt burden on utilities. India's policy direction is clear: India crossed the threshold of 50% non-fossil-fuel-based installed capacity ahead of schedule. The cost of solar power has fallen, reducing the per-unit cost of energy production and making it scalable and competitive. Railways have largely been electrified; universal village electrification was achieved in 2018, when the Leisang village in the Kagpokpi district of Manipur was electrified (Safi, 2018). The policy architecture, from the draft National Electricity Policy 2026 to the SHANTI Act, reflects the structural demands of an electro-state in formation.

However, the question that naturally arises concerns the quality, pace, and economic sustainability of this transition. State DISCOMs require upgradation and currently impede the flow of energy from its point of generation to consumption, causing transmission losses. Electrification, as the data in this report suggest, is heavily dependent on imports from China and requires rapid investment in research and development, particularly from academia and the private sector. Increasing reliance on accessible fuels, including BioCNG, rather than relying on green hydrogen and variable renewables alone, will reduce lock-in periods. Most importantly, it will make India's green transition accessible to the people and institutions who require it the most but can least afford prolonged lock-ins: the rural economy and the MSMEs. Providing accessible, long-term credit with minimal collateral will enable them to participate in India's 2070 goals.

It is also important to focus on hydropower and nuclear capacity, both of which promise substantial improvements in grid stability. However, as the flash floods in the rugged Eastern Himalayas indicate, ecological rigour will need to be exercised

before proceeding with these projects. The nuclear opening, potentially transformative, is circumscribed by institutional design flaws that could compromise both safety and investor confidence.

The electrification of India's political economy and the greening of its grid promise to be among the world's largest and most consequential programmes for achieving global climate and sustainability goals. The urgency is structural, and the opportunity is tangible. To become a developed country by 2047 and a net-zero economy by 2070, India will need to demonstrate sustained policy intent to optimise the use of its renewable endowment and build the economic momentum to become a leading electro-state.

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