

India's Clean Energy Revolution: A Sustainable Roadmap for the 21st Century

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Abstract:

India is navigating a critical phase in its development trajectory. With its burgeoning population and growing energy demands, the country faces a complex dual challenge—ensuring energy security while addressing the imperatives of climate change. Historically dependent on fossil fuels, particularly coal, India is now undergoing a transformative shift towards clean energy. The urgency of the global climate crisis, coupled with domestic needs for economic growth and environmental protection, has propelled the country into one of the most ambitious energy transitions in the world. India's clean energy revolution is no longer ambitious—it is a reality in motion. This transformation is guided by a robust policy framework, strategic investments, and international cooperation. At the forefront of this effort are key targets: achieving 500 GW of non-fossil fuel energy capacity by 2030, fulfilling 50% of the country's power needs from renewables, by reducing carbon intensity by 45%, and reaching net-zero emissions by 2070. This article examines India's clean energy journey—its evolution, achievements, regional leaders, policy drivers, and challenges—while proposing a roadmap for a resilient and sustainable 21st-century energy landscape

Keywords: Energy Security, fossil fuel, coal, Renewable Energy, clean energy, Climate change, Sustainable Development.

1.Introduction:

India, the world's second most populous country, consuming about 930 million tons of oil equivalent (MMtoe) of energy, which is about 6% of the world's total primary commercial energy consumption. In terms of energy consumption, India ranks third in the world after China and the USA. While the global energy mix is balanced between energy sources like coal, oil and gas, India is skewed towards coal, which constitute more than 50% in the India's energy basket. Further, the non-commercial sources of energy, like fuel wood, dung cake and agricultural waste, which was the main sources earlier, is still constituted over 30 percent of total energy supply in India. India is the sixth largest crude oil consuming country in the world after USA, China, Japan, Russia and Germany. Over the past few years, India's primary energy requirement grew at 4.8% per annum. India's heavy reliance on coal, minimal domestic oil output, and low natural gas share (only ~5.7%) create persistent energy security risks and import dependence—particularly for refined petroleum and LNG.

In response, India has rolled out an "Energy Security" plan aligned with its goals of supplying affordable, clean, and reliable energy to a population exceeding 1.4 billion. To support projected economic growth of 8–10 % annually over the coming decades, India must multiply its primary energy supply by 3–4 times by 2031-32 and by increasing renewable energy resources to sustain this high growth trajectory.

In response to increasing concerns about the effect of greenhouse gases on global climate, international action has agreed to reduce emissions. Renewable energy is being explored with renewed commitments as an intelligent solution to be tapped for addressing challenges such as poverty and global warming. If the world is to develop sustainably, it has been recognised that it

is then necessary to secure access to affordable, reliable, sustainable, and modern energy services while reducing greenhouse gas emissions and the carbon footprint of the energy sector.

2. India's energy mix:

Coal continues to be a cornerstone of India's energy framework, playing a vital role in maintaining grid stability and ensuring fuel security amid increasing energy demand. Beyond its energy contributions, coal remains integral to employment generation, government revenues, and the transportation sector. The record levels of coal production achieved in the financial year 2023–24 further underline its enduring relevance in supporting base-load power and overall energy resilience.

As of 2024, India's crude oil reserves estimation stood at around 671.40 million tonnes, marking a modest annual increase of 0.29%. Among the Indian region, the Western Offshore region holds the largest share that contributes around 32% of the nation's total crude oil reserves. Similarly, natural gas reserves were estimated at 1,094.19 bcm (billion cubic meters). Again, the Western Offshore leads in natural gas resource concentration with about 31% of the reserves, followed by the Eastern Offshore, which holds 24%.

India remains heavily reliant on energy imports. In FY 2023–24, the country imported nearly 89% of its crude oil requirements, 46.6% of its natural gas, and 25.86% of its coal. This high dependency highlights the strategic importance of enhancing domestic energy production and diversifying the energy portfolio.

In its commitment to combating climate change, India has set a target of achieving net-zero carbon emissions by 2070. A major milestone on this path includes reaching 500 GW of non-fossil fuel-based power capacity by 2030 and reducing the emissions intensity of its GDP by 45% compared to 2005 levels.

India's renewable energy sector has seen remarkable growth. From a capacity of 78 GW in FY 2014–15, it surged to 199 GW by FY 2023–24. Solar energy has been the primary driver, contributing around 80% of newly added capacity. To meet the 2030 target, about 90 GW of renewable projects are currently under construction, with another 44 GW in the pipeline. In support of this ambition, the government has announced plans to auction 50 GW of renewable energy capacity annually through FY 2027–28.

3. Availability of Energy Resources: Supply and demand

The accessibility and availability of energy resources are crucial for a country's socio-economic progress, particularly when it comes to reducing poverty and enhancing quality of life. In a country like India, where the energy requirement is steadily increasing, accurate and timely data on energy availability is essential for sound policy-making and long-term sustainability.

India, being among the fastest-growing economies globally, faces a significant and varied demand for energy. As of 2023–24, coal and oil fulfil nearly 88% of India's primary energy requirements. Coal remains a dominant source of energy, especially in the power generation and industrial sectors. Oil continues to be essential, particularly for transportation and industry. Over the past decade, India has remained heavily reliant on imported crude oil, with imports consistently surpassing 80%. This dependency climbed to 89% in 2023–24 due to rising domestic demand. The fluctuation in global oil prices, driven by geopolitical developments, adds another layer of complexity to ensuring energy security. Furthermore, trends in vehicle ownership and increased road transport have contributed to this growing demand.

Natural gas, recognized as a relatively cleaner energy source compared to coal and oil, is increasingly being used across residential, industrial, power, and transport sectors. In 2023–24,

it made up 6.9% of India's primary energy mix. In an effort to address air pollution and move toward greener fuels, India aims to raise the share of natural gas to 15% by 2030. A significant portion—about 46%—of the country's natural gas is sourced through imported Liquefied Natural Gas (LNG), placing India among the world's top four LNG importers.

To build an energy system that is secure, affordable, and sustainable, India has also been expanding its use of renewable energy (RE). This transition is key to narrowing the gap between energy supply and demand while reducing environmental harm. Interestingly, during the COVID-19 pandemic in 2020–21, renewable energy witnessed a 7% increase compared to the previous year, 2019–20. This shift supports the goals outlined in Sustainable Development Goal 7 (Affordable and Clean Energy), which promotes universal access to energy by 2030. Expanding renewable energy sources in a timely and adequate manner will be critical for India's continued development and equitable energy access.

4. India's Clean Energy Progress and the Need for Transition

India's energy landscape is undergoing a significant shift, moving steadily away from a dependence on fossil fuels toward a cleaner, more sustainable future. In the fiscal year 2022–23, the country's installed renewable energy capacity (excluding large hydropower) expanded by 12.2%, while thermal capacity grew by only 0.49%. This contrast illustrates India's strong commitment to transforming its electricity generation portfolio, with renewables gaining increasing prominence.

Among the other renewable sources, solar energy leads the sector, its share alone approximately 53.4% of the installed capacity, followed by wind energy at 34.1%, bioenergy and waste-to-energy projects at 8.2%, and hydropower shares 3.9%. In terms of renewable capacity installation, India positioned 4th globally, with total renewable energy capacity of 191 GW. This includes approximately 81 GW of solar, 46 GW of wind, and 64 GW from hydro and biomass combined.

During the UNFCCC COP26 agreement, India had taken the pledged with a determined future vision of increasing 500 GW of non-fossil fuel-based energy capacity by 2030 and achieving net-zero emissions by 2070. The year 2024 marked a remarkable milestone, because India has placed a record of increasing its renewable energy capacity. Like, solar installations increased by 24.5 GW, while wind capacity grew by 3.4 GW. These advances were driven by supportive government policies, improved domestic manufacturing capabilities, and increased investment in clean technologies.

Solar energy continued to dominate the renewable sector, representing 47% of total renewable capacity. States like Rajasthan, Gujarat, and Tamil Nadu led this growth, collectively contributing 71% of India's new utility-scale solar capacity. Another strong growth from the rooftop solar segment, which was witnessed 4.59 GW added in 2024, reflecting a 53% high from the previous year. The PM Surya Ghar: Muft Bijli Yojana, launched in 2024, was a major contributor, enabling 7 lakh households to install rooftop solar systems within just ten months. Furthermore, the off-grid solar market expanded significantly, adding 1.48 GW, a 182% increase, helping to enhance rural energy access.

5. Why the Shift to Clean Energy is Essential

Energy Security: India relies on imports for 80% of its crude oil and nearly 50% of its coal, exposing it to volatile international markets. Expanding domestic clean energy capacity will reduce this dependency and strengthen national security.

Employment and Green Growth: According to the Economic Survey 2022–23, the renewable energy sector in India has the potential to create up to 3.5 million jobs by 2030, ensuring a just transition to a low-carbon economy.

Climate Goals: India has pledged to cut 1 billion tonnes of carbon emissions by 2030 and reach net-zero by 2070, positioning itself as a proactive player in global climate negotiations under the Paris Agreement.

Public Health Benefits: Fossil fuel combustion is linked to more than 1.7 million premature deaths annually in India. Expanding clean energy use will reduce air pollution and significantly ease the burden on the healthcare system.

Rapid Growth in Renewables: With 191 GW of renewable capacity already in place and a target of 500 GW of non-fossil capacity by 2030, India is accelerating its clean energy momentum at an impressive pace.

6. Renewable Energy Potential in India

In recent years, India's focus has been increasing on renewable energy sources as part of its sustainable development and climate action efforts. As of March 31, 2024, the total estimated potential for renewable power generation in India stood at 2,109,655 MW. This potential comes from a variety of renewable sources, including wind, solar, biomass, small hydro, etc.,

Source: Energy Statistic India 2025

7. Energy Outlook and Challenges in India's Energy Sector (2026–2030)

Looking ahead to 2026–2030, India's energy landscape is poised for a significant transformation. Projections suggest that renewable energy will account for around 25% of the total energy mix by 2030, marking a major milestone in the country's clean energy ambitions. This growth is underpinned by sustained investments, policy support, and declining costs of solar and wind technologies. At the same time, India's energy demand is expected to rise at an average rate of 5% annually, fuelled by rapid economic development, urbanization, and increased electrification across rural and industrial sectors.

However, this transition is not without challenges. Despite growing renewable capacity, India remains deeply dependent on fossil fuels, particularly coal and imported crude oil, to meet its base load requirements. This reliance poses risks to energy security, especially given the volatility of global oil and gas markets and the geopolitical tensions that can disrupt supply chains. Furthermore, the existing energy infrastructure faces serious bottlenecks. The national power grid requires modernization to handle the variability of renewable sources, and there is an urgent need for scalable energy storage solutions to ensure reliability and stability. Without addressing these challenges, the benefits of the clean energy transition could be undermined by systemic inefficiencies and external vulnerabilities.

8. Government Policies and Initiatives for Clean Energy and Climate Action in India

India's clean energy revolution is underpinned by a range of forward-looking government policies and initiatives aimed at ensuring energy efficiency, sustainability, and climate resilience. These efforts are not only accelerating the transition to renewable energy but are also aligning India's development goals with its international climate commitments.

India launched the National Hydrogen Mission initiative, with the objective of making India a global hub for green hydrogen production and export. Green hydrogen, generated through renewable energy, offers significant potential to reduce emissions in sectors that are difficult to decarbonize, such as steel production, fertilizer manufacturing, and heavy-duty transport. The

main aim of this is to reduce dependence on fossil fuels, enhance energy security, and promote sustainable industrial growth.

Another key policy tool is the Perform, Achieve, and Trade (PAT) Scheme, implemented by the Bureau of Energy Efficiency (BEE). It incentivizes large energy-intensive industries to reduce their specific energy consumption. Entities that exceed their efficiency targets earn energy-saving certificates that can be traded in the market, creating a financial motivation to go beyond compliance. Over multiple cycles, PAT has contributed significantly to industrial energy savings and emission reductions.

In the transport sector, the government is pushing for a paradigm shift through the Faster Adoption and Manufacturing of Electric Vehicles (FAME) initiative. The third phase, FAME-III, focuses on expanding the adoption of electric vehicles (EVs) by offering purchase subsidies, supporting EV manufacturers, and strengthening charging infrastructure. This program aims to reduce vehicular emissions, lower oil imports, and enhance urban air quality, especially in highly polluted cities.

On the climate front, India continues to demonstrate global leadership. The country's carbon emissions are projected to be around 2.9 billion tonnes of CO₂ by 2025, marking a 4% decline compared to previous years. This drop is largely attributed to the increasing share of renewables in the energy mix and improvements in energy efficiency across sectors. These figures reflect India's progress even as its economy continues to grow.

India has recognized its commitment towards the target net-zero carbon emissions by 2070, a target aligned with the goals of the Paris Agreement. While this is a long-term goal, intermediate targets such as increasing the share of non-fossil fuel energy to 50% by 2030 and reducing the emissions intensity of GDP by 45% (from 2005 levels) which is a critical milestone in the national roadmap.

These government initiatives, supported by robust policy frameworks and international collaboration, underscore India's commitment to sustainable development. The convergence of innovation, regulatory support, and public-private partnerships is shaping an energy ecosystem that is not only cleaner and more resilient but also inclusive and growth-oriented. However, sustained efforts in technology deployment, financing, infrastructure development, and behavioral change will be key to realizing these ambitious goals.

9. Conclusion:

India's renewable energy transformation brings with it a mix of significant challenges and vast potential. With the right blend of forward-looking policies, strategic investments, and technological progress, the country is well-positioned to meet its ambitious clean energy goals and emerge as a global leader in sustainable development. This energy shift is not only critical for enhancing national energy security, but also for fostering economic growth, generating employment, and ensuring long-term environmental well-being.

More than just a strategy to cut emissions, India's clean energy journey represents a new model for development — one that is inclusive, fair, and sustainable. The transition must place the most vulnerable at its core, ensuring that the benefits of green energy reach all sections of society. Simultaneously, innovation and investment must be harnessed to accelerate progress and scale up clean energy deployment.

As the global community searches for effective responses to the climate crisis, India's experience offers valuable lessons on how to balance developmental needs with the urgency of decarbonization. The path ahead is filled with both opportunities and risks. However, with

thoughtful planning and decisive action, India has the potential to become a global hub for clean energy — setting a powerful example in a time of environmental uncertainty. The moment to act is now, not only for India’s future, but for the future of the planet.

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