

# Energy, Equity, and Empowerment: Understanding India's Clean Power Revolution

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**Abstract**—A decisive implementation stage has begun for India's energy transition, as indicated by the accomplishment of 51.93% of non-fossil fuels capacity (266.78 GW of 513.73 GW) by December 2025—five years prior to the 2030 target. This is a testament to the rapid implementation of pledges made under the Paris Agreement and further emphasized through India's national policy instruments. The move from targets to outcomes is a testament not only to India's commitment to its policies but also to institutional coordination between governments at all levels.

This research paper aims to examine the expansion of utility-scale solar parks and onshore wind corridors, as well as the rapid growth of distributed rooftop photovoltaic systems within urban and semi-urban areas. The expansion of large-scale solar parks and wind corridors has been achieved through competitive auctions and decreasing costs of technology, as well as improved transmission capabilities. At the same time, distributed generation has improved energy availability, reduced transmission losses, and enabled households and small businesses to take a direct role in energy production.

One key factor in this process has been the growing inclusion of energy storage solutions, which include battery energy storage systems and pumped hydro storage, with the goal of managing intermittency and ensuring grid security. Investment in smart grid technologies, forecasting tools, and flexible dispatch has also allowed for higher penetration levels without compromising security.

In addition to this, the paper also explores the socio-economic aspects of the transition. For example, the expansion of renewable energy sources has created jobs across the manufacturing, installation, operation, and maintenance sectors. It has also encouraged the development of green skill sets. In the rural areas, the development of solar pumps, mini-grids, and lease schemes for renewable parks has encouraged the diversification of incomes. However, the structural challenges associated with the transition, particularly in the case of the coal industry, cannot be ignored.

The study also assesses the resource security-related concerns, such as dependence on critical minerals, and biodiversity conservation for the project sites. Overall, the findings indicate that the clean energy transformation in India marks an infrastructural shift and a socio-economic shift towards inclusive, resilient, and sustainable development.

**Index Terms**—Renewable Energy Transition, Solar Energy, Wind Energy, Biodiversity Conservation, Sustainable Development.

## I. INTRODUCTION

For many years, India has talked about its plans for an energy future. The country is one of the fastest-growing large economies in the world. It has had an uphill task. The country has always required huge amounts of electricity to power its industries, businesses, homes, transportation systems, and digital technologies. It has also had the challenge of reducing pollution and its contribution to global climate change. The answer was obvious, yet complex. It was renewable energy. Going back to 2015 and 2016, as the world was increasingly discussing issues of climate, India announced some very ambitious plans. The country, under the UN framework and the Paris Climate Agreement, decided to increase its non-fossil fuel-based power generation capacities. At that point, people were skeptical about whether India could achieve these targets. India was still largely dependent on coal as an energy source. A majority of India's electricity was produced by coal. It was cheap, and it was easily available.

India has spent years talking about its ambitions for 2030. The policy community has debated gigawatts of new solar parks, offshore wind farms, hydroelectric and nuclear additions. The government has launched schemes for promoting rooftop solar, incentives for

manufacturers, and auctions for large renewable energy projects. Yet, there have been doubters too. Can a nation with more than 1.4 billion people achieve a transformation like this in a few years?

By June 2025, India had accomplished something that had been anticipated only at the end of the decade. Half of India's total power capacity had come from non-fossil fuels. This wasn't just a matter of achievement; it was a matter of transformation. By December 2025, the figures had only become more staggering. From a total installed capacity of 513.73 GW, 266.78 GW had come from non-fossil fuels. That meant 51.93% of India's total power capacity had been clean.

The largest role was played by solar energy. During the past decade, India developed some of the largest solar power plants in the world. Rajasthan and Gujarat are states that enjoy an abundance of sunlight and open spaces. These states emerged as powerhouses of renewable energy. Huge solar power plants covered large areas of desert land and open spaces, capturing sunlight and converting it into electricity on an unprecedented scale. Meanwhile, rooftop solar installations began to emerge across neighborhoods, commercial areas, and industrial areas. Solar panels and batteries became cheaper and more affordable.

Wind energy too played an important role. The coastal states of Tamil Nadu and Gujarat increased their wind farms, and new ones explored the possibilities of offshore winds too. Wind turbines covered areas that used to be occupied by agricultural land or simply open coastlines. Technology improved the efficiency of wind power generation, allowing for more power to be harnessed even from moderate winds.

Hydropower continued to be a stable source of energy. Large dams constructed over the years continued to provide a stable source of electricity. Small hydel power plants were developed in mountainous areas. Storage capacity was another advantage of hydropower. It was easy to manage the supply of electricity according to the demand. During the night, the sun does not shine, and the wind does not blow.

Nuclear energy was another source that formed part of the clean mix. Though it was smaller compared to solar and wind, the nuclear reactors supplied baseload power with zero emissions. India invested heavily in the upgrade of its reactors and the development of new standards for safety.

However, it was not just about building new capacities. It was about building an ecosystem that would facilitate the integration of renewables. Grid modernization became the key. Renewable energy, especially solar and wind, is an intermittent source of power. The sun does not shine during the night, and the wind does not always blow. To manage the variability of renewables, India invested heavily in building smart grids and better transmission networks. High-capacity transmission corridors were developed to transport renewable power from the surplus states to the deficit urban centers.

The puzzle piece of "energy storage" became an essential part of the equation. Battery storage systems were developed and integrated with solar parks to store extra electricity generated during the day and use it to fulfill peak electricity demand in the evenings. Pumped hydro storage schemes were revived. In these schemes, surplus electricity is used to pump water up to a height, and it is released later to generate electricity as needed. With the continued decline of battery prices across the world, the solution to energy storage became more viable.

In fact, government policies played a significant role in hastening the progress of the development of renewable energy sources in the country. For example, competitive bidding resulted in a significant reduction in the tariffs of renewable energy sources to record low levels. Long-term policies offered much-needed certainty to investors, and financial incentives attracted much-needed capital to the sector. Companies, state-owned entities, and global energy companies all invested in the development of renewable energy sources in India.

This had significant economic consequences. The renewable energy projects provided employment in the fields of construction, maintenance, manufacturing, and research. The manufacturing of solar panels increased in the country as India sought to reduce its dependency on imported panels. The facilities for the manufacture of wind turbines increased their operations. Training programs were established to train the workforce for the clean energy industry.

Environmental benefits were equally important. The bigger cities in India have always battled the issue of air pollution. While the contribution of transportation and industries is also responsible, the use of coal-based power plants has also contributed towards the

pollution of the environment. The rise in the use of renewable energy has meant that the use of coal has gradually reduced in the overall mix. While the use of coal has not come down to zero, its relative use has come down.

At the international level, India's success has significant symbolic value too. Being a developing nation and a significant energy consumer, India has proved that a huge scale of renewable energy development can be achieved at a very fast pace. Therefore, this has strengthened India's stance in global climate change negotiations, and other developing economies are likely to follow this path too.

But it is necessary to understand what 51.93% really means. What 51.93% really means is capacity, not actual generation share. What this means is that, because renewable energy sources tend to have lower capacity factors than coal or nuclear power plants, the actual share of electricity generated by renewable energy sources may be lower than their capacity share. Nonetheless, reaching the 50% mark in capacity is a significant development in the structure of energy generation in the future.

Challenges still exist. Renewables will require continued investment in the grid infrastructure. Managing the variability of renewables becomes more challenging with increased penetration. The financial situation of electricity distribution companies remains a challenge. Land acquisition for large-scale projects can be an issue. Finding the right balance between development and conservation can be challenging.

Furthermore, coal remains a major source for meeting India's round-the-clock electricity needs. Most of the coal-fired plants are new, reflecting large capital investments. There needs to be a transition that ensures that the economy does not suffer while the share of clean energy increases.

However, the achievement marked in 2025 is not an easy process to reverse. This is because there are more market forces supporting renewable energy sources due to cost reductions associated with them. Additionally, there is an increase in technological advances that improve the efficiency and capacity of renewable energy sources. There is an increase in environmental awareness. There is an increase in corporate sustainability commitments that create a cycle for growth in renewable energy sources.

The path to 2030 continues. India's prior target was aimed at achieving 500 GW of non-fossil power by the end of the decade. The achievement of the halfway mark on the total installed capacity scale by 2025 indicates that this target is achievable as well. The pace at which India is able to increase installed capacity beyond 51.93% will depend on how much support is given to the sector.

The achievement also points to a larger shift in the way Indians think about development. No longer is energy security just a function of the coal reserves within the country's borders. It's a function of solar irradiance levels, wind corridors, hydrological resources, and nuclear capacity. It's a function of battery production, digitalization of the grid, and research into hydrogen power. The very notion of growth is being redefined to meet the needs of a more sustainable world.

In the case of rural areas, decentralized renewable systems are providing electricity to communities that previously had unreliable electricity supplies. Mini-grids and solar home systems replace the use of diesel generators. Farmers use solar-powered irrigation systems, which are environmentally friendly and cut the cost of fuel. In the case of commercial buildings, rooftop systems are used to lower the cost of electricity. Industrial clusters enter into renewable purchase agreements to meet environmental requirements for global markets.

Education and research centers are also contributing to the process. Universities and technical institutes undertake research on the development of sophisticated materials, grid management algorithms, and energy storage chemistry. Start-ups try out innovations like micro-inverters to artificial intelligence-based demand forecasting. All these elements add to the process of constant improvement. The financial markets have also welcomed the move. Green bonds and climate-focused investment funds help direct investments towards renewable energy. International development banks offer concessionary loans to improve the grid infrastructure and storage. Private equity firms also see opportunities for long-term growth in the expansion of clean energy infrastructure in India.

The social dimension of the transition should not be overlooked. The uncertainty of workers in traditional fossil fuels should be addressed. A just transition to a low-carbon economy means retraining workers, economic development in coal regions, and planning

to avoid social dislocation. Energy policymakers increasingly recognize the social sustainability of an energy policy.

By December 2025, when India's non-fossil capacity stood at 266.78 GW out of a total installed capacity of 513.73 GW, the numbers were a testament to the persistence. All the planning, investment, experimentation, and refinement over the years were leading to this milestone, which was a long shot until now. The 51.93% figure represents more than just a number.

India did not only promise renewable energy transformation; it has implemented it. The achievement is a message for the world: climate ambitions have a way of being turned into achievements with consistent policies, technological developments, and collective actions. The way forward is still a long and winding road, but it has been laid firmly.

As 2030 draws closer, the question is no longer whether India can achieve a high penetration of renewables. The answer is that it has already achieved a historic milestone. The next question is how it can be scaled up and how it can be further improved in terms of reliability, storage, and reduction in emissions, and how it can be made more accessible for all sections of society.

## II. REVIEW OF LITERATURE

### 1. Central Electricity Authority (2023)

The National Electricity Plan, prepared by the Central Electricity Authority, discusses the increasing importance of strengthening India's electricity transmission system to accommodate renewable power generation. The document explains that efficient transmission connectivity plays a major role in transporting renewable energy from production regions to consumption centers. It also indicates that modernization of grid infrastructure is necessary to maintain reliability while supporting sustainable energy development aligned with SDG-7 objectives.

### 2. Council on Energy, Environment and Water (2022)

A study conducted by the Council on Energy, Environment and Water explored the relationship between renewable energy expansion and employment opportunities in India. By examining workforce

requirements across different clean energy sectors, the report shows that renewable energy growth contributes not only to environmental improvement but also to livelihood creation. The findings suggest that clean energy adoption can support both economic progress and sustainable development simultaneously.

### 3. International Energy Agency (2024)

The International Energy Agency analyzed India's future energy scenario through its India Energy Outlook report. The study evaluates long-term energy demand trends and highlights renewable energy as a practical solution for reducing dependence on conventional fuels. The analysis indicates that expanding renewable energy usage can enhance energy availability while lowering emissions, thereby supporting sustainable growth in developing nations.

### 4. International Renewable Energy Agency (2024)

Global renewable energy capacity statistics published by the International Renewable Energy Agency demonstrate continuous growth in renewable installations, particularly in solar and wind energy technologies. The report recognizes India as an emerging leader in renewable energy expansion and emphasizes that increasing installed capacity is essential for maintaining environmentally sustainable industrial and electricity production systems.

### 5. NITI Aayog (2023)

Through the India Energy Security Scenarios 2047 initiative, NITI Aayog presents strategic projections for India's long-term energy planning. The study highlights the necessity of shifting toward diversified energy resources to ensure stability in energy supply. Greater investment in renewable technologies is identified as a key approach to reducing fossil fuel dependence and achieving sustainable national energy security.

### 6. United Nations Development Programme (2023)

The United Nations Development Programme examines the idea of an equitable energy transition, focusing on how renewable energy adoption should consider social welfare alongside environmental goals. The report stresses that policy frameworks must ensure fair employment opportunities and economic

inclusion while moving toward cleaner energy systems.

#### 7. World Bank (2023)

Research by the World Bank investigates operational and infrastructure-related challenges affecting renewable energy integration in India. The study points out that limitations in transmission networks and insufficient energy storage facilities can slow renewable energy deployment. It emphasizes coordinated technological and infrastructural improvements to enable stable and sustainable electricity generation.

#### 8. Wildlife Institute of India (2021)

The Wildlife Institute of India assessed ecological concerns associated with electricity transmission infrastructure, particularly its impact on bird populations. The study proposes preventive and mitigation measures aimed at minimizing environmental damage. The research highlights the importance of balancing renewable energy expansion with biodiversity conservation to achieve sustainable development outcomes.

#### Problem of the study:

Although India has achieved substantial growth in the development of its non-fossil fuel potential by achieving more than 50% of installed power capacity through clean sources prior to the 2030 target, the transition is associated with various complex challenges. The rapid growth of renewables requires a large investment in the development of associated grid infrastructure and energy storage facilities to ensure their reliability and stability. However, the economic uncertainty of coal-dependent areas is a concern regarding the social dimension of sustainability. The development of renewable energy infrastructure must be balanced with biodiversity considerations as well as the security of associated critical minerals.

Thus, the main issue that this research aims to address is how the growth of renewable energy can be sustained in India while maintaining the stability of the grids, society, environment, and the economy within its energy transition process.

### III. DISCUSSION

#### When The Sun Became a Source of Income

In 2025 India added a lot of energy capacity. This was the highest in one year. Solar energy is leading the way making up 53% of renewable installations. By January 2026 India had installed 140 GW of energy.

What does this actually mean? It means that in villages across Rajasthan and Haryana farmers are seeing the sun as a way to make money. They are installing panels in their fields. These panels are powering irrigation pumps. This way they are generating extra income. For them sunlight has become a crop that grows every day without water.

In Haryana Sumitra Devi installed a pump with a lot of subsidy support. She does not have to spend money on diesel or maintain the pump. She has reliable energy during the day. Her farming costs have. She feels more confident.

#### Homes That Became Power Plants

In 2024 the government launched a scheme. By 2026 2.6 million homes had rooftop solar systems installed. This is a deal. Millions of families are not just using electricity they are also producing it.

For middle-class households' electricity bills used to be a big burden. Now many families are reporting zero bills for months of the year. Of worrying about rising tariffs families are investing in something that pays them back. Energy is no longer something you buy it is something that gives you security.

#### The Winds of Change

India's wind capacity has reached 54.65 GW. Onshore wind farms in states like Tamil Nadu are providing jobs and steady power. India is not stopping there. The country is planning to launch its offshore wind tender. This move shows that India is confident and ready to take the step.

#### Storing The Future

Energy is powerful but it has a challenge. The sun does not shine at night. The wind does not always blow. To keep the grid stable India is building energy storage systems. By 2030 the country will need a lot of storage capacity.

As of December 2025, India has made some progress. The country has tendered 224 GWh capacity and 95 GWh is under execution. There are also pumped

storage projects under construction. Operational battery storage is still small but growing. In 2026 a big battery storage project in Gujarat is expected to go. This will be a step toward grid stability.

The goal is simple: making sure clean power is available whenever people need it.

#### A Transition: Protecting Livelihoods

The change to clean energy is not just about building new industries. It is also about closing ones responsibly. Coal-dependent states like Jharkhand, Chhattisgarh and Odisha face adjustments as old mines shut down. Entire communities depend on coal. India recognizes this reality. It focuses on retraining workers repurposing land and supporting women whose incomes depend on coal-related activities. Change must not come at the cost of dignity.

#### New Jobs, New Dreams

By 2050 India's renewable sector could employ over 3.2 million people. Already many trainees have been certified in hydrogen skills. Young interns are gaining hands-on experience in hydrogen technology and carbon reduction.

For young Indians renewable energy is not just a sector it is a career path full of purpose. In places like Manipur and Tamil Nadu solar-powered sewing machines are helping women double their incomes. Reliable electricity means reliable work and reliable work means independence.

#### Securing The Building Blocks

In 2025 India launched a mission to secure resources of clean energy like lithium and cobalt. At the time a recycling initiative aims to create capacity for recycled minerals. This push toward an economy could generate many jobs and make informal work more stable.

India is not just building plants it is building resilience.

#### Balancing Progress and Protection

Not every step has been easy. Many renewable projects have been delayed because of the transmissions and the environmental concerns. One major issue is about the protection of the endangered Great Indian Bustard as the transmission lines were being built in their natural habitat. The bird is highly vulnerable to colliding with the overhead electrical lines.

The message is clear: climate action cannot ignore biodiversity.

#### IV. CONCLUSION

India's achievement of crossing the 50% non-fossil capacity mark of schedule is impressive. The real success lies elsewhere. It lies in the stories of people like farmers who see the sun as income homemakers who see their rooftops as investments, coal workers who are learning skills and young interns who are stepping into the green hydrogen sector.

India's energy transition is no longer a government mission. It is becoming a shared journey. As 2030 approaches the real challenge is ensuring that this transformation remains inclusive. No region, no worker no community should be left behind.

Because in the end energy is not about electricity. It is about opportunity. It is about dignity. It is about the future India aims to build.

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