India: Energy sector at crossroads

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Foreword

Energy is the backbone of India's economic progress, shaping industries, infrastructure, and the daily lives of over a billion people. As the country strides towards becoming a global economic powerhouse, its energy sector is undergoing a profound transformation. The challenge lies not just in meeting the rising energy demand but in doing so sustainably, efficiently, and equitably.

From being heavily dependent on fossil fuels, India is now embracing a future powered by renewable energy, innovation, and policy reforms. The push for solar, wind, and hydrogen energy, alongside advancements in grid modernization and energy storage, reflects the country's commitment to cleaner and more resilient energy solutions.

India's energy sector, with a focus on self-reliance, energy security, and climate leadership, is poised to play a pivotal role in the global shift towards sustainability. As the country continues to invest in clean energy, innovation, and infrastructure, it is positioning itself as a key player in shaping a sustainable and resilient global energy future.

The knowledge paper explores India's ongoing energy transformation, focusing on the critical areas of policy development, renewable energy integration, power generation and distribution modernization, and technological advancements. It aims to offer insights into the steps necessary to create a balanced and sustainable energy future for India.

India's energy landscape presents a complex interplay of burgeoning demand, diverse resource availability, and evolving strategic priorities. As a major global economy, India's energy consumption is substantial and continues to rise, driven by economic expansion and a large population. This dynamic environment necessitates careful consideration of both current realities and future trajectories.

The country's transition to cleaner energy is central to its commitment to reducing carbon footprints and strengthening energy security. Yet, this transformation presents challenges, particularly in integrating renewable energy while ensuring grid stability and energy security.

Modernizing the power sector and developing resilient infrastructure are key to meeting the country's increasing energy needs while ensuring affordability and reliability. As India strives to improve energy access, the role of emerging technologies and strategic policies becomes ever more important in driving efficiency and sustainability across the sector.

The report delves into the key drivers of India's green transition, energy security, and the modernization of its power sector, while highlighting the role of emerging technologies and policies in enhancing infrastructure and operational efficiency.

India stands at a pivotal moment in its journey towards a sustainable, low-carbon energy future. As the world's most populous country and one of its fastest-growing economies, India faces the challenge of meeting its rising energy demands while fulfilling its global climate commitments.

Achieving net-zero emissions by 2070 is not just an ambitious target—it is a critical call to action, requiring a multi-faceted approach that integrates policy interventions, technological advancements and sectoral reforms. The growing shift toward clean energy reflects the country's commitment to reducing carbon emissions and enhancing energy security.

However, this transformation is not without its challenges. Intermittency, grid resilience and energy security are ongoing concerns as renewable energy integration grows. The modernization of India's power sector across the value chain is critical to meeting the country's rapidly growing energy demand while ensuring a sustainable, reliable and affordable supply.

This white paper offers a comprehensive analysis of India's energy transition, focusing on key areas such as policy, power generation and distribution reforms and technological innovations.

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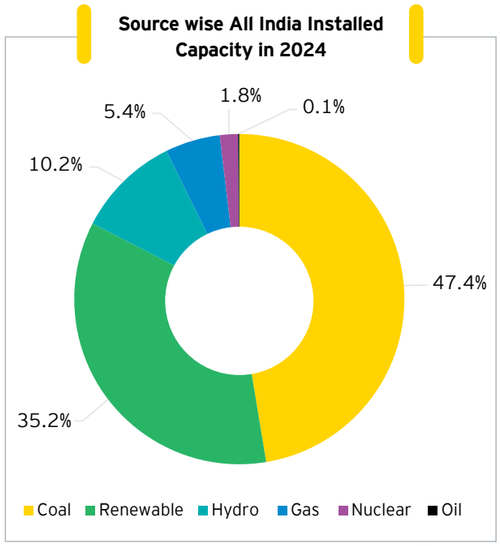
1 Introduction

India, the world's fastest-growing large economy, recorded growth rates of 7% in FY23 and 8.2% in FY24, demonstrating its ambition to attain 'Viksit Bharat' status by 2047. With the dual challenges and opportunities posed by climate risks and rising global temperatures, India is actively advancing its energy transition, committing to achieving net-zero emissions by 2070. The Economic Survey 2023-24 emphasizes that ensuring stable and affordable energy access, in harmony with low-carbon development goals, is fundamental to India's long-term progress. Although India is the third-largest global emitter, contributing 7% of total emissions, its per capita emissions are significantly lower at ~2 tons annually, compared to countries like the UK (4.7 tons) and Australia (15 tons).

India's energy landscape is shaped by its reliance on imported fossil fuels, which account for nearly 40% of the nation's energy demand. This dependence increases vulnerability to global price fluctuations and geopolitical risks. To strengthen its energy resilience, India is focused on developing a diversified and sustainable energy mix, leveraging abundant domestic low-carbon resources to reduce import reliance and bolster energy independence.

India's energy mix is a cornerstone of its power sector, playing a pivotal role in shaping the country's energy policies and economic growth trajectory. The diverse energy mix encompasses coal, natural gas, renewables, nuclear and hydro. Each source plays a vital role in addressing the country's energy needs, but the sector is also shaped by ongoing efforts to reduce carbon emissions, enhance energy efficiency and integrate renewable energy at scale.

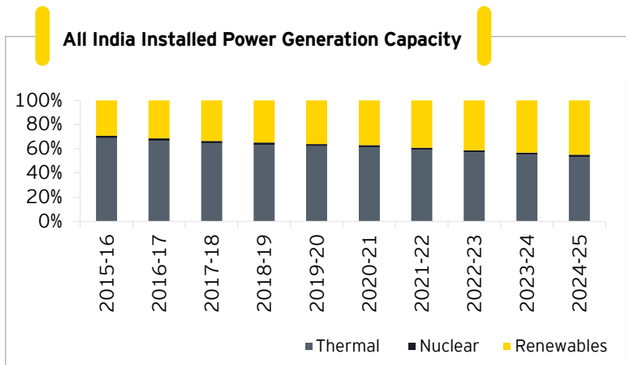


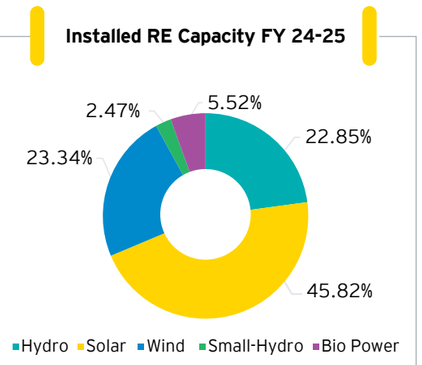
Source: CEA Installed Capacity

As of December 2024, India's total installed electricity generation capacity has reached approximately 462.00 GW, with renewable energy sources forming a critical part of this growth. Coal dominates the energy mix, contributing 47.4% of the installed capacity.

Renewable energy that includes hydro contributes 209.45 GW, making up approximately 45% of the total capacity. Solar energy leads the sector with an installed capacity of 97.87 GW, tapping into the country's vast solar potential. Wind energy follows with 48.16 GW, capitalizing on favorable wind conditions along coastal and inland areas. Large hydro projects generate 52.07 GW and small hydro projects add 5.10 GW, efficiently utilizing river systems to provide reliable and eco-friendly energy. Bioenergy, derived from biomass and biogas, further diversifies the renewable portfolio with a capacity of 11.35 GW. This segment plays a crucial role in converting agricultural residues and organic waste into electricity, reducing environmental waste while enhancing energy security.

This evolving energy mix accentuates India's commitment to achieving energy equity and sustainability while balancing affordability and reliability. India's growing focus on RE highlights its strategic shift away from traditional fuels. This transition supports the nation's sustainability goals and strengthens its position as a key contributor in the global energy transition.





2 Energy mix and policy interventions for green energy balancing

Shifting trends in India's energy mix

1 India's Green transition and climate commitments

Under the UN Framework Convention on Climate Change (UNFCCC), countries must develop pathways tailored to their unique circumstances. In line with this, India has charted an energy transition roadmap aligned with its economic priorities, aiming to achieve Prime Minister Shri Narendra Modi's vision of 500 GW of renewable energy by 2030[1], amounting to 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources[2] and net-zero emissions by 2070[3]. Key 2030 targets under India's Nationally Determined Contributions (NDCs) include:

Sustainable living practices: Promoting a sustainable lifestyle through the 'Lifestyle for Environment' (LiFE) initiative, emphasizing conservation and moderation.

Cleaner economic path: Adopting a climate-friendly development trajectory distinct from the carbon-intensive pathways of other economies at similar stages of growth.

Emissions reduction: Reducing GDP emissions intensity by 45% from 2005 levels.

Renewable energy goals: Achieving 50% of cumulative electric power installed capacity from non-fossil fuel sources, supported by technology transfer and low-cost international finance, including Green Climate Fund (GCF) resources.

Carbon sink expansion: Creating an additional carbon sink of 2.5–3 billion tons of CO2 equivalent through enhanced forest and tree cover.

Adaptation investments: Enhancing resilience in climate-vulnerable sectors, such as agriculture, water resources, coastal areas and disaster management, through targeted investments.

Resource mobilization: Securing domestic and international funding to bridge resource gaps for mitigation and adaptation efforts.

Technology and R&D collaboration: Establishing frameworks for deploying cutting-edge climate technologies and fostering joint international research and development initiatives.

India is expected to see the largest global increase in energy consumption over the next three decades, according to the International Energy Agency (IEA). While the country is committed to expanding renewable energy sources, coal continues to play a critical role in addressing immediate energy demands.

Oil import dynamics and economic impacts amid geopolitical conflicts and sanctions

India, the world's third-largest oil consumer, is highly dependent on crude oil imports, sourcing over 85% of its requirements from global markets. Since 2020, the energy landscape has been shaped by a series of unprecedented disruptions: the COVID-19 pandemic, geopolitical conflicts such as the Russia-Ukraine war and the Gaza crisis, and evolving U.S. sanctions on Russian oil exports. These events have triggered sharp fluctuations in global oil prices, impacting India's oil import bill, fiscal balance, and foreign exchange (FOREX) reserves.

COVID-19 Pandemic (2020–2021)

- Global oil demand plummeted during the early phase of the pandemic, with Brent crude prices falling below US$20 per barrel in April 2020.
- India's oil import bill dropped to US$62.2 billion in FY 2020-21, compared to $101 billion in FY 2019-20.
- Lower oil prices eased fiscal pressures and contributed to a current account surplus of 0.9% of GDP in FY 2020-21.

Ukraine Conflict and Price Surge (2022-2023)

- Russia's invasion of Ukraine in February 2022 disrupted global energy supply chains, pushing Brent crude to $120 per barrel by mid-2022.
- India's oil import bill surged to US$158 billion in FY 2022-23, driven by higher prices and increasing reliance on Russian crude, which accounted for 34% of India's imports in 2023.

Gaza Crisis and U.S. Sanctions on Russian Oil (2023-2025)

- The Gaza conflict (October 2023–present) heightened concerns over supply disruptions in the Middle East, leading to renewed oil price volatility.
- U.S. sanctions on Russian oil exports intensified in January 2025, targeting major producers and shipping networks. Brent crude reached US$81.31 per barrel in January 2025, reflecting tightened supplies.

Source: Ministry of Petroleum and Natural Gas (India), RBI, IEA - G7 Price Cap Analysis, tradingeconomics.com

India's oil import bill has progressively increased since 2021:

- FY 2020-21: US$62.2 billion
- FY 2021-22: US$119 billion
- FY 2022-23: US$158 billion
- FY 2023-24: US$132 billion

FOREX reserves and currency stability

- FOREX reserves declined from US$642[4] billion in September 2021 to US$640.28[5] billion as of December 2024, as higher oil imports increased dollar demand
- The rupee depreciated from INR73/US$ in 2021 to INR85.79/USD[6] in 2024

Role of Russian crude

- Russian oil imports, offered at steep discounts of US$15–US$20 per barrel below Brent, helped India save an estimated US$5 billion in 2023.
- Further sanctions in 2025 after President Donald Trump takes charge could disrupt this supply, compelling India to diversify source

India's oil import dynamics between 2020 and 2025 reveal the vulnerability of an import-dependent economy to global disruptions. The dual challenges of rising oil prices and geopolitical uncertainties necessitate strategic diversification, energy security measures, and renewable energy investments to ensure long-term economic stability.

1. Press Information Bureau (PIB
2. Ministry of Power
3. Press Information Bureau (PIB)
4. RBI data for forex reserve
5. Other Source: MoPNG, Reuters, IEA
6. RBI data for forex reserve

2 Securing energy independence

Energy security is a critical issue for India, driven by the need to balance energy availability, affordability and sustainability. As the country transitions towards cleaner energy sources, it faces several challenges, including volatility in international energy markets, rising inflation and potential impacts on public finances. **Moreover, geopolitical shifts and economic fragmentation have made energy security even more paramount, with increasing risks associated with energy supply disruptions.**

Way forward to energy independence

India, the world's third-largest oil consumer, is highly dependent on crude oil imports, sourcing over 85% of its requirements from global markets. Since 2020, the energy landscape has been shaped by a series of unprecedented disruptions: the COVID-19 pandemic, geopolitical conflicts such as the Russia-Ukraine war and the Gaza crisis, and evolving U.S. sanctions on Russian oil exports. These events have triggered sharp fluctuations in global oil prices, impacting India's oil import bill, fiscal balance, and foreign exchange (FOREX) reserves.

Diversifying the Energy Mix

- India is strategically working to diversify its energy mix to reduce dependence on energy imports and mitigate the risks posed by fluctuating global energy prices. Key areas of focus include:
  - Expanding renewable energy sources like **solar, wind, and hydro** to reduce reliance on fossil fuels
  - Promoting **alternative fuels** such as ethanol, compressed bio gas, and natural gas for cleaner energy use
  - Developing **nuclear energy** and offshore wind projects to ensure a stable and diversified energy supply
  - Advancing **battery manufacturing and energy storage systems** to support renewable energy integration and efficiency

Reducing Import Dependence

- The government has adopted a multi-faceted approach to reduce crude oil import dependency
- Transport electrification: Promoting EV adoption via charging infrastructure and PLI scheme for battery manufacturing
- Ethanol blending: Achieving foreign exchange savings and supporting farmers through the Ethanol Blending Program
- Alternative fuels: Encouraging the use of CBG, biodiesel, and bioenergy through initiatives like SATAT and the National Bioenergy Programme
- Renewable energy: Expanding non-fossil capacity with initiatives like PM-KUSUM, Green Hydrogen Mission, and offshore wind projects

Addressing the Energy Deficit

- India's recent energy transition policies, such as the National Green Hydrogen Mission, Ethanol Blending Program (EBP), PM-KUSUM Scheme, Production-Linked Incentive (PLI) Scheme for Batteries, and Ultra Mega Renewable Energy Parks, aim to address the growing energy deficit. These policies focus on expanding energy capacity, improving efficiency and promoting sustainability. They emphasize reducing energy imports, fostering renewable energy adoption and supporting domestic manufacturing, thereby creating a diversified and resilient energy landscape.

[7]*Source: https://pib.gov.in/PressReleseDetailm.aspx?PRID=2083669&reg=3&lang=1*

7. Yahoo Finance data for currency exchange

3 India's progress towards 500 GW non-fossil fuel capacity by 2030

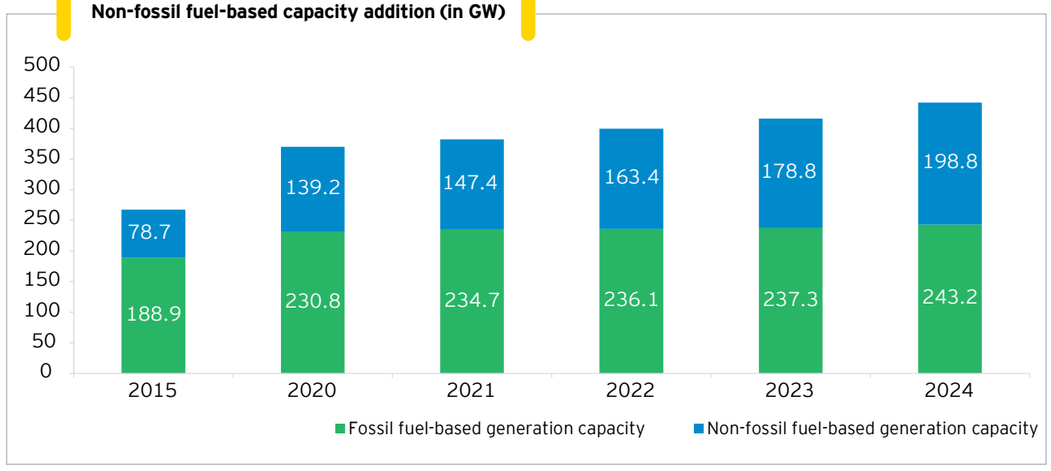
Although not part of its NDC, India has consistently emphasized its goal of achieving 500 GW of non-fossil fuel-based power generation capacity by 2030. Currently, nearly 200 GW is operational, with 90 GW under construction and 44 GW in the development phase.

To meet this target, the government aims to tender 50 GW of renewable energy capacity annually from FY 2023-24 to FY 2027-28, including a minimum of 10 GW of wind power each year. By December 2023, Renewable Energy Implementing Agencies (REIAs) such as SECI, NTPC, NHPC, and SJVN had issued bids for 35.51 GW in FY 2023-24.

Source-wise RE capacity in pipeline			
Particulars	**Under Construction**	**Under Development**	**Total Pipeline Capacity**
Solar	54.7	30.49	85.19
Wind	17.52	12.81	30.33
Hydro	18.09	1.24	19.33
Total	90.31	44.54	134.85

Source: India Climate & Energy Dashboard, Niti Aayog

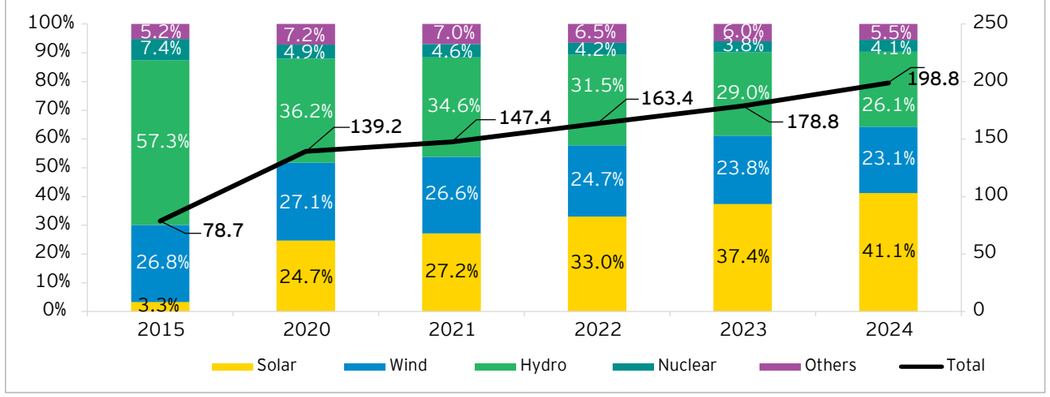
India nearing 50% non-fossil fuel power capacity target: India has significantly increased its non-fossil fuel-based generation capacity, with its share rising from 29% in 2015 to 45% in 2024. This growth positions the country to achieve its NDC target of 50% non-fossil fuel-based installed capacity well before 2030.



Source: CEA

4
Growth in India's renewable energy capacity

Growth in non-fossil fuel capacity (in GW)



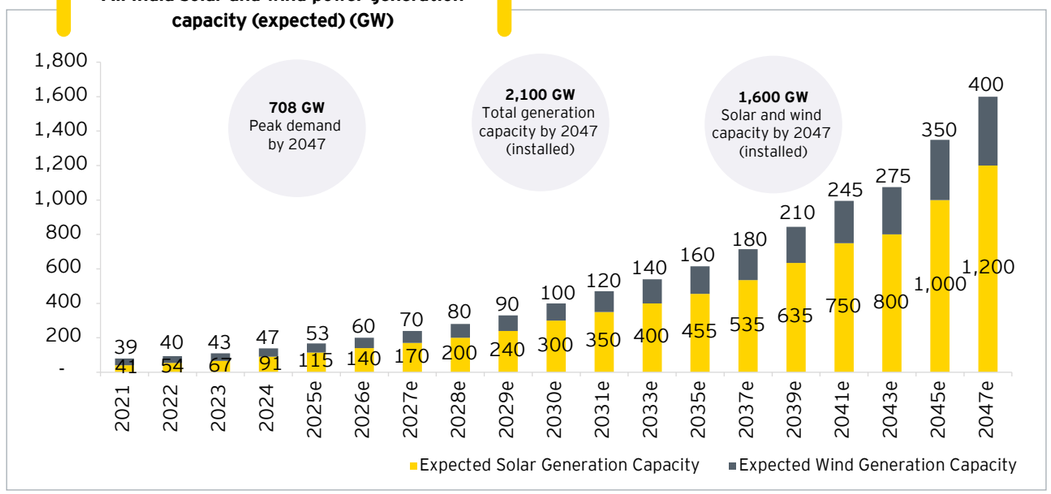
Source: CEA

India's renewable energy (RE) installed capacity has surged from 78 GW in FY 2014–15 to 199 GW in FY 2023–24, driven by a robust policy framework, reduced generation costs and strong investor interest.

In FY 2023–24, a record 18.4 GW of capacity was added, surpassing the previous high of 15.7 GW in FY 2022–23. Over the past three years, annual capacity additions have averaged 16 GW, with solar power contributing 80% of the new capacity, highlighting its dominance in the RE sector. Projected power demand is expected to rise to 708 GW by 2047, necessitating a fourfold increase in installed capacity to 2,100 GW.

India's National Electricity Plan, aligned with its commitment to the Paris Agreement and long-term energy strategy, has laid out an ambitious roadmap for renewable energy growth to achieve a target of 500 GW of installed capacity by 2030. This includes 280 GW of solar power, 140 GW of wind power, alongside significant contributions from hydropower, biomass, and other green technologies. These efforts are aimed at decarbonizing the energy sector, meeting the rising electricity demand sustainably, and enhancing energy security.

All India solar and wind power generation capacity (expected) (GW)



Source: MNRE, MoP, CEA, EY analysis; https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2064702

Future Power Demand and Capacity Expansion

- Projected power demand: 708 GW by 2047
- Installed capacity target: 2,100 GW by 2047 (fourfold increase)
- Comprehensive energy framework integrating diversified and sustainable sources

Renewable Energy Commitments

- 500 GW non-fossil energy capacity by 2030; 600+ GW by 2032
- Reduction of 1 billion tons of carbon emissions by 2030
- Net-zero emissions goal by 2070

Transmission Infrastructure Expansion

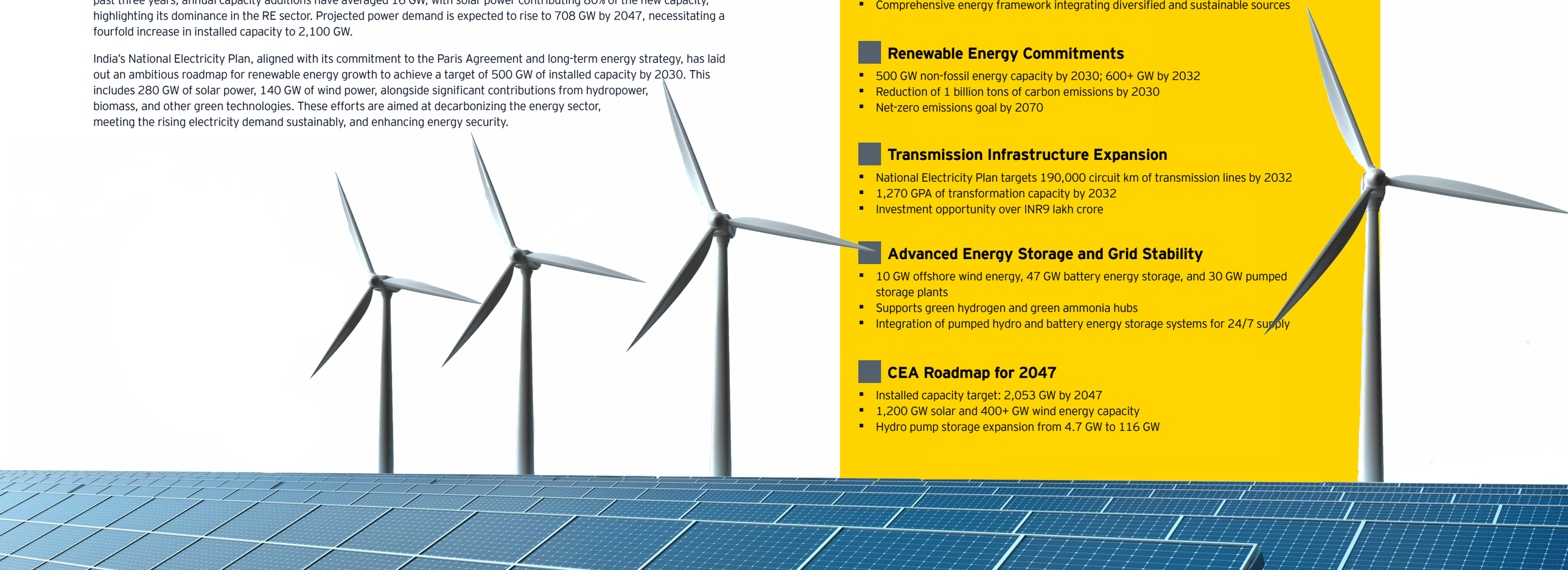
- National Electricity Plan targets 190,000 circuit km of transmission lines by 2032
- 1,270 GPA of transformation capacity by 2032
- Investment opportunity over INR9 lakh crore

Advanced Energy Storage and Grid Stability

- 10 GW offshore wind energy, 47 GW battery energy storage, and 30 GW pumped storage plants
- Supports green hydrogen and green ammonia hubs
- Integration of pumped hydro and battery energy storage systems for 24/7 supply

CEA Roadmap for 2047

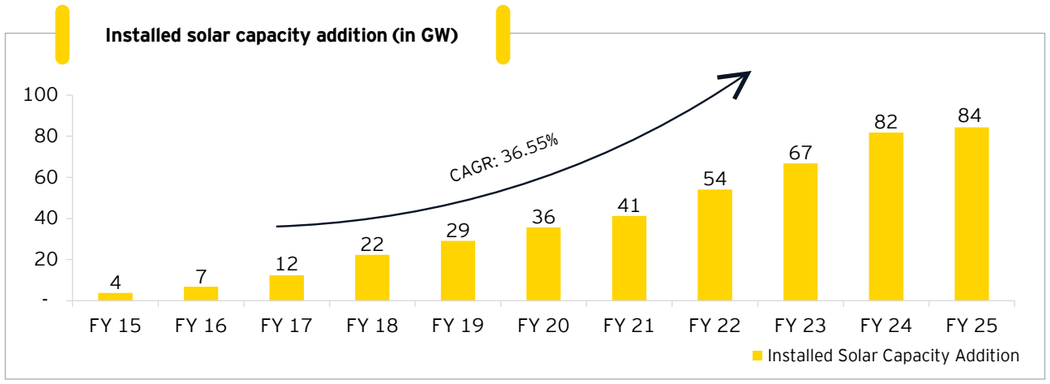
- Installed capacity target: 2,053 GW by 2047
- 1,200 GW solar and 400+ GW wind energy capacity
- Hydro pump storage expansion from 4.7 GW to 116 GW



Facilitating RE growth in India: Key strategies and progress

1 India's leadership in the global solar revolution

With 300 days of sunshine annually, India is well-positioned to harness solar energy, offering an estimated potential of 5,000 BU of electricity per year or approximately 2,500 GW of capacity at current efficiency levels. Over the past 11 years, solar installed capacity has grown at a remarkable CAGR of 36.5%, reflecting India's pivotal role in the global solar energy transition coupled with supportive government policies and a growing uptake of solar projects.



Source: Niti Aayog

Development of Solar Parks and Ultra Mega Solar Power Projects (2014)

India's solar parks have been instrumental in the country's solar transition, with ultra-mega parks attracting both foreign capital and global leadership. The government launched this initiative to harness India's high solar insolation. The original target of 20 GW for 40 industrial solar parks was doubled to 40 GW by 2022.

- As of November 2023, 50 solar parks with a total capacity of 37.49 GW have been approved across 12 states.
- 11 parks with 8,521 MW capacity are complete, and 7 parks with 3,985 MW capacity are under construction.
- A total of 10,237 MW capacity has already been developed.

PM Surya Ghar-Muft Bijli Yojana (2024)

Launched with a budget of INR75,021 crore (US$9 billion), this initiative aims to install rooftop solar systems and provide up to 300 free electricity units monthly to 10 million households.

- The scheme is expected to add 30 GW of solar capacity in the residential sector.
- Households can save on electricity bills and earn income by selling surplus power to DISCOMs.

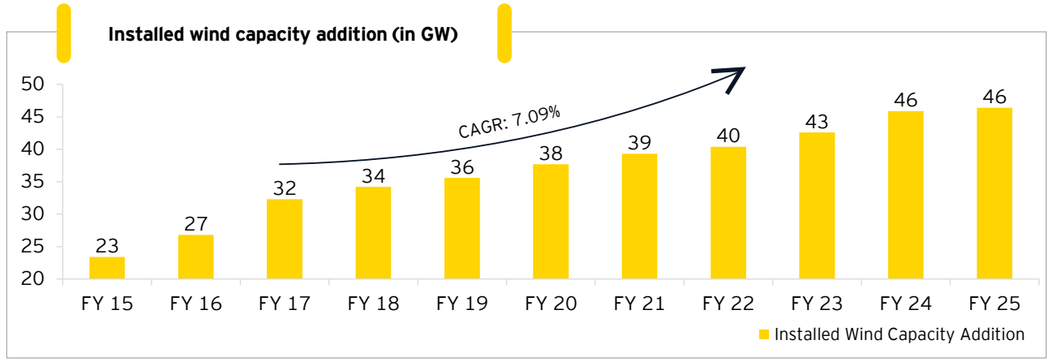
PM Kisan Urja Suraksha evam Utthan Mahabhiyan (PM KUSUM)

This scheme aims to provide affordable power to farmers, comprising three components:

- Component A: Installation of 10,000 MW of decentralized solar or other renewable energy-based power plants on farmland
- Component B: Deployment of 1.4 million standalone off-grid solar water pumps
- Component C: Solarization of 3.5 million existing grid-connected agricultural pumps

2 India's wind energy sector: Growth, potential and future outlook

India's wind energy sector, with a 46.42 GW installed capacity, ranks fourth globally. The 2023 National Repowering Policy drives modernization of aging turbines, while offshore wind targets 30 GW by 2030. Initiatives like the 4 GW seabed leasing plan and INR7,453 crore Viability Gap Funding aim to accelerate capacity expansion. Additionally, hybrid solar-wind projects and infrastructure development in Gujarat and Tamil Nadu support growth. These measures align with sustainability goals and reinforce India's leadership in wind energy advancements.



Source: Niti Aayog

India's Wind Energy Sector

- Installed capacity: 46.42 GW, ranked 4th globally
- Gross wind power potential: 695.50 GW at 120m, 1,163.9 GW at 150m
  - Shift toward hybrid solar-wind projects with RTC electricity

Recent Developments

- Over 2.8 GW onshore wind capacity added in 2023
- Second-largest onshore wind turbine assembly hub in Asia-Pacific
  - Reliance Industries to set up carbon fiber facility for wind blades in Gujarat

National Repowering and Life Extension Policy 2023

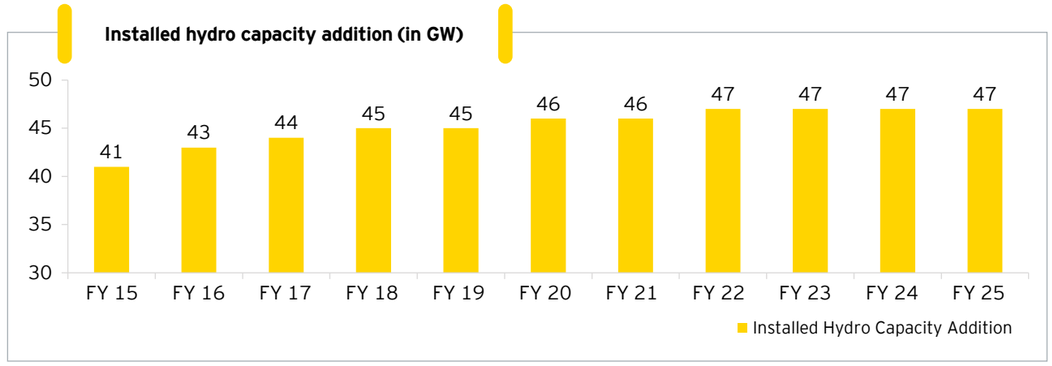
- Focus: Replace aging sub-MW turbines with multi-MW technologies.
- Repowering potential: 25.406 GW for turbines below 2 MW.
- Financial incentives: Concessional loans, interest rebates, and compensation mechanisms.

Offshore Wind Energy Development

- Renewable energy target: 100 GW wind by 2030, including 30 GW offshore wind.
- Offshore Wind Lease Rules (2024): 4 GW seabed leasing in Tamil Nadu.
- Viability Gap Funding: INR 7453 crore approved for offshore projects and port upgrades.
- Transmission infrastructure planned for 10 GW offshore capacity in Gujarat and Tamil Nadu.

3 India's hydropower sector: Growth, challenges and policy support

India's hydropower capacity is expected to increase by over 50%, reaching 67 GW by 2031–32, with 15 GW currently under construction and supported by policies like the Hydro Purchase Obligation (HPO) and infrastructure grants. Despite hydropower's importance for grid stability, its growth has been limited, with 63.20% of the 1,45,320 MW identified potential still unplanned, particularly in the North-Eastern and Northern regions. To unlock the full potential, accelerated project development and addressing regional disparities are essential for advancing India's clean energy transition.



Source: Niti Aayog

Hydropower Growth Potential

- Hydropower potential is set to grow by over 50%, from 47 GW to 67 GW by 2031-32
- 15 GW of hydropower capacity currently under construction
- Government policy support is key to achieving this target

Key Policy Developments

- Hydro Purchase Obligation (HPO): Dedicated consumption obligation from HPPs commissioned post-2019
- Budgetary Support: Infra funding for projects, grants of INR 1.5 Cr./MW for projects up to 200 MW and INR 1 Cr./MW for larger projects

Challenges Due to Climate Change

- Global warming and climate change are impacting hydropower generation
- Flash floods and Glacier Lake Outburst Floods (GLOF) in hilly regions are major concerns
- Low rainfall affected hydropower generation in southern regions during FY 2023-24

Current Utilization of Hydropower Potential

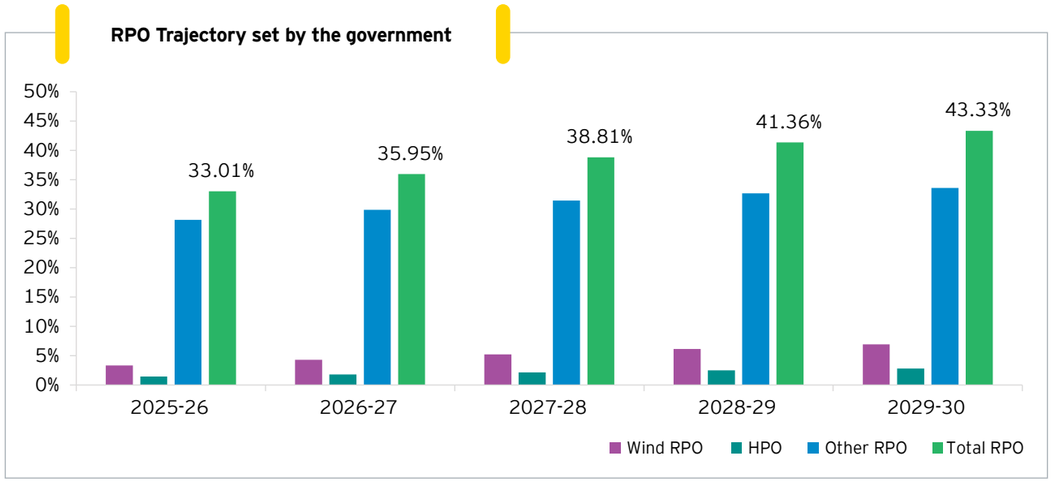
- As of October 2022, India has an identified hydropower potential of 1,45,320 MW, with 63.20% yet to be planned for construction
- North-Eastern and Northern Regions contribute over 75% of the nation's total hydroelectric potential
- Only 28.97% of the total identified capacity is operational

Regional Utilization and Challenges

- Western Region leads in operational capacity utilization with 68.28%. Southern Region: 61.31%, Eastern Region: 47.64%, Northern Region: 37.69%, NE Region: 3.47%
- Held-up construction: 0.80% nationally, with delays in Western (4.92%) and Eastern (3.90%) Regions
- Unplanned construction: 63.20% nationally, with the North-Eastern Region having 92.89% potential unplanned

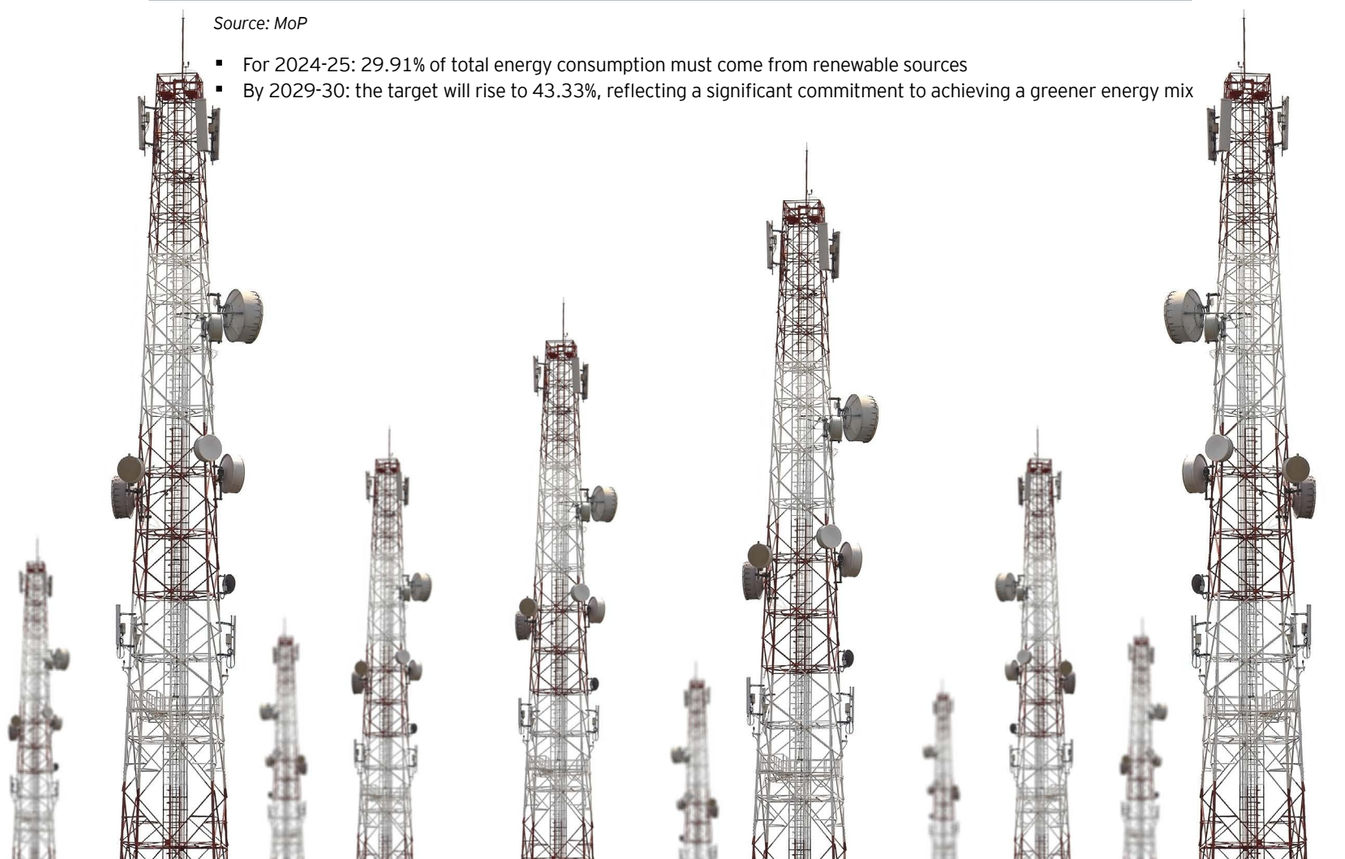
4 Impact of renewable purchase obligation (RPO) on advancing India's energy transition

India has emerged as a frontrunner in the global renewable energy landscape, particularly in the solar and wind sectors. The Renewable Purchase Obligation (RPO), introduced under the Electricity Act 2003, has been a key policy tool for accelerating renewable energy adoption, especially for distribution companies, by ensuring energy security and addressing environmental concerns. The RPO mandates that electricity distribution licensees obtain a minimum portion of their power supply from renewable sources. These obligations have played a crucial role in driving the installation of renewable energy projects. The government has established escalating RPO targets, with a strong focus on solar and wind energy. The current targets include:



Source: MoP

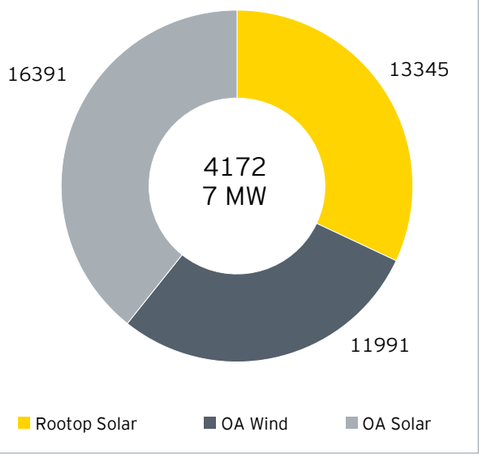
- For 2024-25: 29.91% of total energy consumption must come from renewable sources
- By 2029-30: the target will rise to 43.33%, reflecting a significant commitment to achieving a greener energy mix



5 The role of C&I customers in shaping the future of renewable energy

- India's C&I (Commercial & Industrial) sector, which accounts for 50% of the country's electricity demand, is increasingly adopting cleaner energy sources. The Electricity Act of 2003 has played a key role in enabling access to affordable power through alternative contracts, reducing reliance on local distribution companies.
- In **Q3 2024**[8], corporate renewable capacity grew by 5%, adding **2,011 MW**, bringing the total to **41,727 MW**. This growth was largely driven by corporate power purchase agreements **(PPAs),** supported by government incentives such as transmission charge waivers and net-zero incentives.
- The growth in corporate PPAs was fuelled by **1,322 MW** of solar open access and **689 MW** of rooftop solar installations. Stable solar prices and **consistent PPA tariffs** have further supported this shift.
- The FY2025 budget continues to support renewable energy, including stricter penalties for non-compliance in solar and wind projects. However, the integration of the Perform, Achieve and Trade (PAT) scheme and Renewable Energy Certificates (RECs) into the Indian Carbon Market remains uncertain.

Total corporate renewable capacity (in MW) at end-September 2024



Source: CRISIL- BRIDGE TO INDIA research

6 The role of C&I customers in shaping the future of renewable energy

India domestic coal reserves and coal production

India achieved its highest-ever coal production in 2023-24, reaching 997.826 million tons (MT), an 11.71% increase compared to 893.191 MT in 2022-23. Between January 2024 and December 15, 2024, provisional data indicates coal production of 988.32 MT, reflecting a 7.66% growth from the 918.02 MT produced during the same period in 2023.

Total Coal Supply 963.11 MT

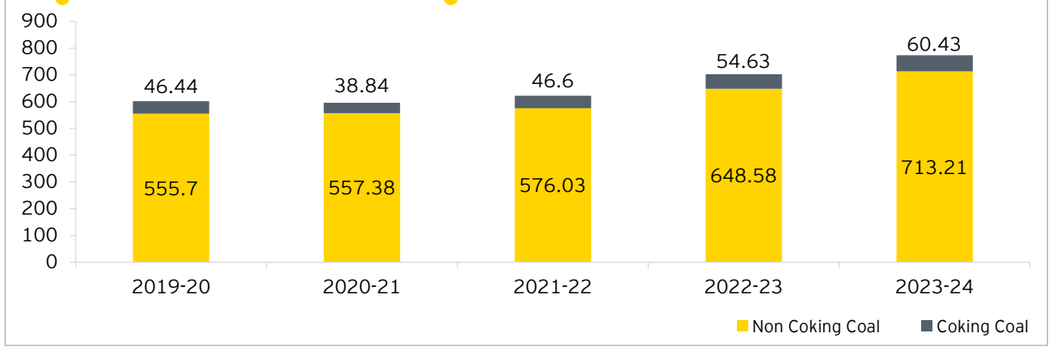
- Supply to Power Sector 792.96 MT
- Supply to Non-Regulated Sector (NRS) 171.24 MT

As of 15 December 2024, the total provisional coal supply for the year reached 963.11 MT, reflecting a 6.47% increase compared to 904.61 MT during the same period in 2023. Of this, 792.958 MT was supplied to the power sector, marking a 5.02% rise from 755.029 MT in the previous year. Additionally, coal supply to the Non-Regulated Sector (NRS) grew significantly by 14.48%, reaching 171.236 MT compared to 149.573 MT in the same period last year.

In FY2023-24, CIL achieved significant growth, producing a total of 773.64 million tons (MT), with non-coking coal contributing 713.21 MT and coking coal contributing 60.43 MT. CIL is targeting a production of 806-810 million tons in FY 2024-25, as per news reports.

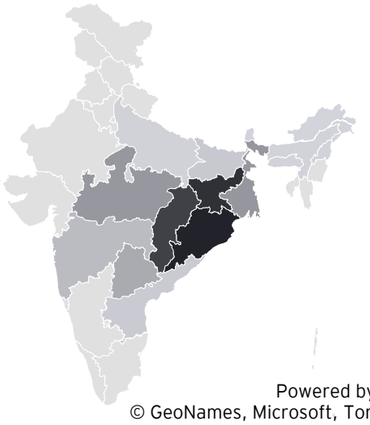
This production aligns with the broader achievements of FY2023-24, where 16 mining projects were sanctioned, and ongoing projects with a combined sanctioned capacity of 895.93 MT per year are being implemented to support such sustained growth. However, these initiatives are subject to challenges such as land acquisition and environmental clearances, which remain critical to project completion and future production targets.

CIL - Coal production in million tons



Source: https://www.coalindia.in/departments/production/

State wise Coal Reserves in 2024

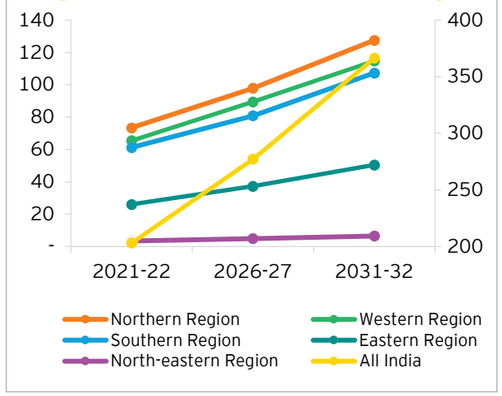


State	Quantity in million tons
Uttar Pradesh	1062
Assam	525
Maharashtra	13352
Bihar	5398
Meghalaya	583
Andhra Pradesh	4172
Odisha	99204
Sikkim	101
West Bengal	33958
Madhya Pradesh	32815
Nagaland	478
Arunachal Pradesh	90
Jharkhand	91812
Telangana	23206
Chhattisgarh	82666

The growing demand vs projected conventional installed capacity in India

The CEA's National Electricity Plan 2022-32 projects a consistent upward trend of peak electricity demand at the power station bus bars across India, reflecting economic growth, urbanization, and evolving energy consumption patterns. From 2,03,115 MW in 2021-22, the all-India demand is projected to rise to 2,77,201 MW in 2026-27 and further to 3,66,393 MW in 2031-32, registering a compound annual growth rate (CAGR) of approximately 6.1%.

Proejcted peak electricity demand (in GW) at power station bus bar (utilities)



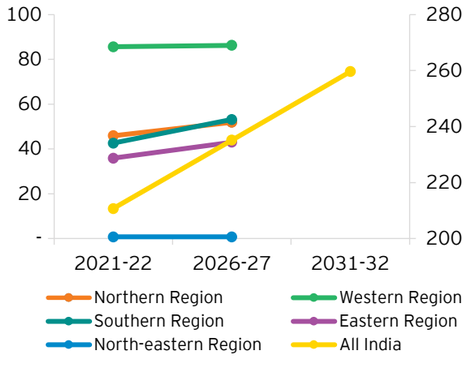
Source: CEA National Electricity Plan 2022-32

8. Other Sources: mopng.gov.in, iea.org, tradingeconomics.com, Reuters, RBI

The projected installed capacity of coal and lignite-based power plants in India reflects a moderate growth trend, indicative of a cautious expansion strategy amidst increasing renewable energy adoption. The capacity is expected to grow from 2,10,700 MW in 2021-22 to 2,35,133 MW in 2026-27 and further to 2,59,643 MW in 2031-32, representing a CAGR of approximately 2.1%. This relatively slow pace of growth highlights the evolving focus on transitioning to cleaner energy sources, while maintaining the coal and lignite-based power plants as base load serving sources.

It can thus be inferred that the slower growth of coal capacity signals a shift towards renewables to meet climate targets, while the continued coal-based capacity additions highlight its role in ensuring base-load supply stability.

Projected all India installed capacity for coal and lignite power plants (in GW)



Source: CEA National Electricity Plan 2022-32

These trends reflect underlying structural, operational, and policy-driven changes in India's energy sector. From 2009-10 to 2020-21, there was a consistent decline in PLF across all sectors.

The overall PLF dropped from 83.90% in 2009-10 to 54.27% in 2020-21. This decline was most pronounced in the private sector, where PLF decreased from 70.90% to 44.68%, reflecting higher vulnerability to market dynamics and operational inefficiencies. State-sector plants also experienced a substantial drop from 85.50% to 61.78%. Conversely, the central sector remained relatively resilient but saw a notable decline from 77.50% to 53.37%.

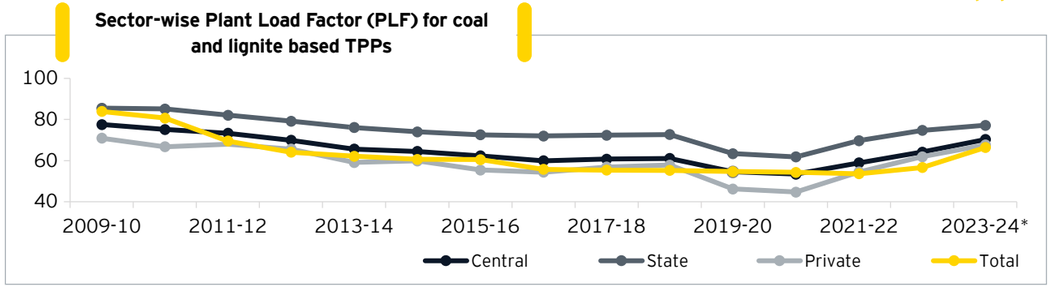
A recovery phase is observed post-2021-22, with PLF increasing across sectors, reaching 66.34% overall in 2023-24. Central-sector plants led the recovery, achieving 70.26% PLF, while private sector plants rebounded to 67.63%, benefiting from improved coal availability and higher electricity demand.

Case study

Rising solar and wind generation drive 'negative' European power prices to record level[9]

"Electricity prices fell into negative territory for 7,841 hours across the continent during the first eight months of the year, according to consultancy ICIS, with prices falling below minus €20 per megawatt hour in some instances. A key driver of the trend has been wind and solar as energy sources growing faster than storage options to deal with excess capacity. Over the past five years, the total capacity of Europe's solar farms has more than doubled from 127GW to 301GW, while wind capacity has climbed from 188GW to 279GW, according to energy think-tank Ember. The growth has helped to reduce reliance on fossil fuels and cut emissions, with the output from wind and solar farms in Europe surpassing that of fossil fuel power plants during the first half of this year for the first time. However, batteries and other storage or flexibility options have not developed as quickly, meaning there are more periods when generators are, in effect, paying consumers to use up excess electricity. Power demand in Europe also has yet to fully recover since the energy crisis that began in late 2021 and 2022 and which led factories to close output. Negative pricing marks the sharp end of the so-called 'price cannibalization' effect of renewables, which sees power prices fall when it is sunny and windy and renewables projects are producing at the same time. The 7,841 hours of negative prices in the eight months to the end of August compare with last year's total of 6,428 hours and 675 hours in total five years ago when the system was more dominated by fossil fuels. Solar energy has been the main driver of negative pricing as solar resources tend to be more consistent, leading to negative prices in particular during the spring and summer and late mornings to early afternoon."

Sector-wise Plant Load Factor (PLF) for coal and lignite based TPPs



**Upto May 2023 (Provisional)*
Source: https://powermin.gov.in/en/content/power-sector-glance-all-india, CEA
9. Financial Times UK article on European Power Prices

The plant load factor (PLF) for coal and lignite-based thermal power plants (TPPs) has undergone significant shifts, highlighting coal based power's resilient role in India's energy mix.

Coal is vital for India's **fuel security,** providing reliable base-load generation that ensures grid stability. With **361.41 billion tons** of domestic reserves, coal reduces dependence on volatile global markets, safeguarding against disruptions like the **COVID-19 pandemic** and the **Russia-Ukraine conflict.** Focused efforts on **coal flexibilization** and **repair and maintenance (R&M)** of plants enhance operational efficiency and support renewable integration, ensuring a resilient energy supply and mitigating supply risks.

Energy security

- *Coal remains vital to India's energy security due to its large domestic reserves (389.42 billion tons), helping reduce reliance on imported fuels and ensuring a stable energy supply.*

Stable energy prices

- *Domestic coal production reached 997.83 million tons in 2023-24, contributing to stable energy costs and reducing exposure to volatile global markets.*
- *Coal, being more price-stable than oil and gas, supports consistent energy pricing.*

Base load power generation

- *Coal is a reliable source of base load power—steady, continuous electricity that is crucial for the functioning of the economy.*
- *Intermittent renewable sources like solar or wind cannot provide consistent energy, and their availability depends on weather conditions.*

Strategic stock piling

- *Coal can be stored in large quantities, creating a crucial buffer during unforeseen situations like the COVID-19 pandemic and the Russia-Ukraine war, which disrupted global supply chains.*

Diversification of coal sources

- *While India imports coal (increasing by 15.9% in 2024), domestic coal production still plays a major role in ensuring energy security. This diversification of coal sources (domestic and imports) helps mitigate risks from supply disruptions in global coal markets.*

Key takeaways from the case

Vital role in grid stability

Coal-based generation is essential for maintaining a steady, reliable power supply, particularly during times of renewable supply variability, ensuring grid stability as a base-load source.

Market stabilization during excess renewable generation

During periods of surplus renewable generation, coal plants absorb excess power, preventing negative pricing and stabilizing the energy market.

Backup power in low renewable output periods

Coal plants serve as a crucial backup when solar or wind generation is insufficient, ensuring a continuous power supply during low renewable output.

Fuel security and stability

Coal provides fuel security, especially in regions with domestic coal reserves, offering a reliable energy source when renewable production is low or disrupted.

7

Strategic growth in India's nuclear energy sector

India's nuclear energy sector holds immense potential for ensuring energy security and cost-effectiveness, making it a reliable source of base load power. Nuclear Power Corporation of India Limited (NPCIL) oversees reactor design, construction, and operations. While FDI is restricted in atomic energy generation, it is permitted in manufacturing equipment for nuclear plants[10] [11] . The government aims to triple nuclear capacity to 22,480 MW by FY32, up from the current 8,180 MW. Development efforts include nine reactors under construction (7,300 MW) and 12 in pre-project phases (8,000 MW)[12] [13].

To meet net-zero emission targets, discussions are underway to attract private investments worth US$26 billion through hybrid models, where private players manage electricity sales while NPCIL retains operational control. Technological advancements like Small Modular Reactors (SMRs), supported by an INR1 lakh crore budget, are pivotal for future growth. With planned deployments of 40-50 SMRs offering scalability and enhanced safety, nuclear energy is set to play a key role in India's clean energy transition[14].

Civil nuclear cooperation agreements

India has established civil nuclear cooperation agreements with numerous countries, ensuring access to advanced technologies, fuel, and operational expertise:

- **Key partners:** France, the United States, Russia, Namibia, Canada, Argentina, Kazakhstan, South Korea, the Czech Republic, Australia, Sri Lanka, and the United Kingdom.
- **Additional agreements:** A Memorandum of Understanding (MoU) with Mongolia and a formalized agreement with Japan in December 2015 for peaceful nuclear cooperation.
- **Nuclear Suppliers Group (NSG):** A significant policy decision [INFCIRC/734 (Corrected)] adopted on 6 September 2008, enables civil nuclear collaboration between NSG members and India. NSG membership would enhance predictability in partnerships, attract investments, and facilitate access to advanced technologies.

International partnerships and contributions

India's robust collaborations have driven technological and commercial advancements in its nuclear sector:

- **Russia:** Supports infrastructure expansion with six VVER-1000 reactors at Kudankulam and explores modular reactor innovations.
- **United States:** Focuses on reactor technology, fuel security, and advanced R&D, strengthening bilateral energy ties.
- **France:** Jaitapur project and modular reactor initiatives, combined with localized training programs, bolster India's nuclear capabilities.
- **Other contributions:** Canada, South Korea, Japan, Australia, and the UK provide uranium supply, reactor technology, and operational expertise, while the UAE and other nations contribute through cooperation in nuclear plant operations, fuel sourcing, and investment.

10. Ministry of Atomic Energy
11. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1655136
12. PIB Press Release dated 25th July 2024
13. Reuters
14. PIB Press Release dated 6th December 2023

Overview of India's nuclear energy sector

India's nuclear energy sector, driven by NPCIL, aims to expand capacity to 22,480 MW by 2031-32. While heavily regulated, opportunities exist in equipment manufacturing. The sector's growth aligns with India's low-carbon energy transition goals.

- Energy security: Safe nuclear energy supports long-term security with a low carbon footprint.
- State dominance: Nuclear Power Corporation of India Limited (NPCIL) oversees nuclear reactor operations.
- FDI policies: Restricted FDI in atomic energy; allowed in equipment manufacturing.

Expansion plans and capacity growth

India plans to significantly increase its nuclear capacity through ongoing and proposed projects. With 21 reactors in various stages of development, the government is taking steps to meet its ambitious energy goals.

- Current capacity: 24 reactors generating 8,180 MW.
- Future targets: Tripling capacity to 22,480 MW by 2031-32.
- Projects in progress: (a) 9 reactors under construction (7,300 MW); (b) 12 reactors in pre-project phases (8,000 MW).

Regulatory and safety standards

The nuclear energy sector operates under stringent regulations, with private participation encouraged to accelerate capacity expansion. Discussions highlight potential investments for adding 11,000 MW by 2040.

- Safety prioritization: High safety and security standards regulate nuclear operations.
- Private participation: Private investments of US$26 billion are being explored under hybrid models.

Small Modular Reactors (SMRs)

India is focusing on Small Modular Reactors (SMRs) for flexible, efficient, and scalable nuclear solutions. Substantial investments in R&D aim to make these technologies a cornerstone of the nation's energy mix.

- Budget allocation: INR1 lakh crore allocated for SMR R&D in Union Budget 2024.
- Deployment plans: 40-50 SMRs planned, with capacities ranging from 30-300 MW.
- Advantages: Modularity, scalability, smaller footprint, and enhanced safety.

Investment and growth opportunities

The nuclear sector presents lucrative investment opportunities, with a shift towards hybrid models and technological innovations. The government's proactive measures aim to position India as a nuclear energy leader.

- Private investments: Hybrid models proposed for private sector roles in electricity sales.
- Emerging technologies: Focus on innovation and next-gen nuclear solutions.

Contribution to energy transition

While nuclear energy currently contributes a small share to electricity generation, its expansion is pivotal for India's clean energy transition. Enhanced focus on sustainability and private involvement will support growth.

- Current contribution: Nuclear energy accounts for 3% of total electricity generation.
- Transition goals: Expanding nuclear capacity is vital for achieving net-zero emissions.

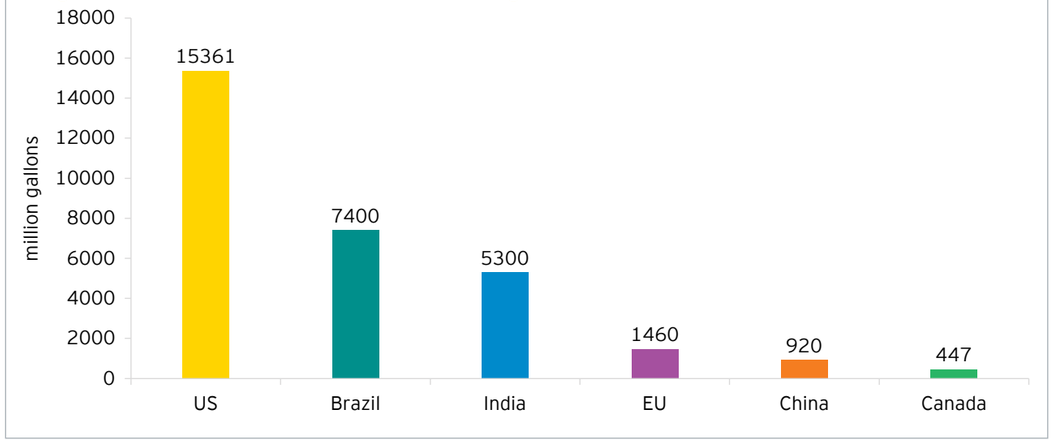
8 Advancing biofuels

India is now the third-largest ethanol producer globally, following the United States and Brazil. The Government of India aims to increase the share of gas in the country's energy mix to 15% by 2030, envisioning a transition to a gas-based economy.

Currently, India imports around 47% of its natural gas to meet domestic demand. The inclusion of biogas in the energy mix can play a pivotal role in supporting this shift by offering several advantages. These include reducing reliance on imported fossil fuels, lowering emissions compared to natural gas, minimizing agricultural residue burning, and providing farmers with an additional income stream.

Bio ethanol	Ethanol blending target of 20% in petrol till Ethanol Supply Year (ESY) 2025-26
Bio jet	1% Sustainable Aviation Fuel (SAF) indicative blending target in 2027 and 2% in 2028 (initially for international flights)
Biogas	CNG Blending Obligation (CBO) shall be 1% (FY25-26); 3% (FY26-27); 4% (FY27-28) and 5% (FY28- 29 onwards)
Bio diesel	Indicative target of 5% blending of biodiesel in diesel /direct sale of biodiesel has been proposed by 2030

India ranks third in global ethanol production (in million gallons)



Source: DOE, US

Bioenergy transitions for mobility and industry applications

India's bioethanol and bioenergy initiatives have made significant strides over the past decade. From 2014 to 2024, ethanol blending increased from 1.53% to 15%, saving INR99,014 crore in foreign exchange, reducing CO2 emissions by 519 lakh metric tons, and substituting 173 lakh metric tons of crude oil. The National Policy on Biofuels, launched in 2018, set a target of 20% ethanol blending in petrol by 2030, with financial incentives for manufacturing capacity and procurement pricing. India achieved a 10% blending target ahead of schedule by November 2022, moving the 20% target to 2025-26.

The government is also promoting the use of compressed biogas (CBG) for transportation and domestic purposes, with voluntary blending obligations until FY2025, after which they will become mandatory. In the power sector, biomass co-firing in thermal plants will be mandated at 5% from FY2024-25, increasing to 7% by FY2025-26. The initiative has supported the economy, with INR1,45,930 crore disbursed to distillers and INR87,558 crore to farmers. India's leadership in the biofuels sector was further highlighted by the launch of the Global Biofuels Alliance (GBA) during its G20 presidency in 2023, aiming to foster knowledge sharing and technology transfer. Ongoing programs like Repurpose Used Cooking Oil (RUCO), Gobardhan, and the Samarth Mission continue to accelerate the country's bioenergy transition.

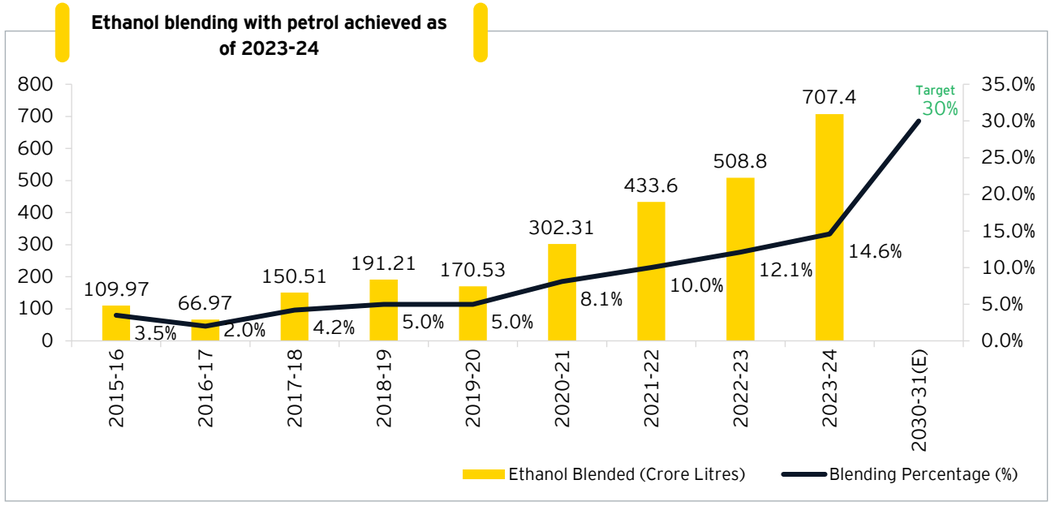
Mandating biofuel blending with fossil fuels

India's biofuel initiatives

India is advancing its biofuel strategy to reduce emissions, enhance energy security, and integrate the agricultural sector. The National Policy on Biofuels aims for a 20% ethanol blend in petrol by 2025-26, supported by government incentives. Beyond ethanol, plans include compressed bio-gas (CBG) blending post-FY2025, biomass co-firing mandates for thermal plants, and a 1% sustainable aviation fuel blend for international flights by 2027. The key initiatives include:

- 20% ethanol blending in petrol by FY26 (advanced from 2030 target), post achievement of 10% blending in 2022.
- Government incentives for domestic ethanol production and procurement pricing.
- Mandatory compressed bio-gas (CBG) blending with natural gas after FY2025.
- Biomass co-firing: 5% in FY2024-25, increasing to 7% by FY2025-26.
- Exploring 1% sustainable aviation fuel blending for international flights by 2027.

Ethanol blending with petrol achieved as of 2023-24



Source: https://iced.niti.gov.in/energy/fuel-sources/others/bio-energy/bio-fuel

9 India's Green hydrogen sector

With its renewable energy capacity, decarbonization goals, and favorable cost structures, India is primed to lead the global Green hydrogen market. Strategic government policies and industry participation aim to establish a self-reliant ecosystem to serve both domestic needs and international demand[15] [16].

Decarbonization initiatives

- Replacement of natural gas in industries such as refineries and fertilizers.
- Current hydrogen consumption in India stands at approximately 6 MMTPA.
- By 2030, GH2 consumption is projected to reach 12 MMTPA, with prices to be approximately US$2-2.5/kg.

Industrial applications

- Adoption in high carbon intensive sectors such as steel, cement, heavy trucking, aviation, and maritime to enable decarbonization.

Energy storage and grid flexibility

- Provides alternative energy storage solution, offering flexibility to grids through physical (compressed gas) or chemical storage (e.g., ammonia).

Energy self-reliance

- India aims to reduce fossil fuel dependence through its green hydrogen mission, fostering energy security.

Competitive production costs

- Low-cost RE generation positions India to be a competitive H2 producer, with electrolyzer costs expected to decrease due to economies of scale and global policy support.

Export potential

- India, along with countries like Argentina, Australia, and Saudi Arabia, is poised to become a key player in the global Green hydrogen and ammonia market.

Green H_2 policy landscape

The government's policy push, coupled with investments in hydrogen production, can create jobs and foster a new ecosystem for growth. Public sector enterprises, such as Oil India Limited and NTPC, are already pioneering Green hydrogen initiatives, further accelerated by supportive government policies[17].

National Green Hydrogen Mission

Budgetary allocation:
Total outlay of INR19,744 crore until FY30.

Strategic goals:
- Annual production target of 5 MMT of GH2 by 2030.
- Addition of 125 GW of RE capacity for GH2 production.
- Mobilization of INR8 lakh crore in investments across the hydrogen value chain.

SIGHT Programme (Strategic Interventions for Green Hydrogen Transition):
- Electrolyzer manufacturing: Allocated INR4,440 crore to support indigenous manufacturing.
- Green hydrogen production: INR13,050 crore for production incentives.
- Green ammonia expansion: Enhanced annual production capacity to 750,000 tons.
- Focused measures to drive cost reductions and boost adoption rates.

State policy initiatives

Adoption across states
- Rajasthan, Uttar Pradesh, Maharashtra, and Andhra Pradesh spearheading Green hydrogen policy implementation.
- Provisions for capital subsidies (up to 30%) and financial support for R&D and land acquisition in Odisha.

Tax incentives:
- GST refunds for equipment and operations related to Green hydrogen.
- Waivers on electricity duties and cross-subsidy surcharges to lower operational costs.

Policy impact:
- Encouraging investments in state-level Green hydrogen hubs.
- Boosting local manufacturing and creating job opportunities.

15. India's hydrogen demand projected at 12mmtpa by 2030; prices expected at $2-2.5/kg, ET EnergyWorld (indiatimes.com
16. Green hydrogen push: India eyes $7-15 billion import substitution, plans $4-12 billion investment, ET EnergyWorld (indiatimes.com)
17. Understanding the Green Hydrogen landscape in India: Demand from industries, global collaborations are the key, ET EnergyWorld (indiatimes.com)

Other policy measures

Transmission benefits:
- 25-year inter-state transmission charge waiver for renewable projects commissioned before 2030. Enhances cost-effectiveness for Green hydrogen producers.

Environmental clearances:
- Exemption for green ammonia plants from prior environmental approvals.
- Reduces bureaucratic hurdles and accelerates project timelines.

Electricity (Promoting Renewable Energy through Green Energy Open Access) Rules, 2022:
- Streamlined open access to renewable energy for Green hydrogen production.
- Encourages industrial-scale adoption and integration.

Green H_2 investments

The sector in India is emerging, and its widespread adoption requires significant support from public and private sectors. Scaling up capacity will necessitate substantial investment to develop a robust ecosystem.

Reliance Industries Limited (RIL)
Along with other conglomerates, plans to set up green hydrogen (GH) and green ammonia (GA) units at Deendayal Port Authority (DDA) in Gujarat, with RIL alone committing INR1 lakh crore (over US$12 billion), one of the largest investments in India's energy infrastructure.

Green Hydrogen Policy impact
The Kerala government has received investment proposals totaling INR72,760 crore from four major companies seeking subsidies under the Green Hydrogen Policy.

Essar Group
Plans to invest INR30,000 crore (US$3.7 billion) over four years to establish a green hydrogen plant in Jamnagar, Gujarat, with 1 GW electrolyzer capacity and associated green molecule production of 1 MTPA.

Hygenco Green Energies
Plans to invest US$2.5 billion over three years to set up green hydrogen projects across various states, currently operating two plants and a 140 KW R&D project in Ujjain and a 3 MW plant in Hisar.

National Thermal Power Corporation (NTPC)
Signed a Land Lease Agreement and, in February 2024, entered into an agreement with AP Industrial Infrastructure Corporation for developing an integrated green hydrogen hub, including a facility with production capacity of 1,200 tons per day.

NTPC Green Energy Limited (NGEL)
Signed an MoU with the Government of Maharashtra for developing green hydrogen, green ammonia, and green methanol up to 1 MTPA as part of Maharashtra's Green Investment Plan, with a potential investment of INR80,000 crore.

H_2 export opportunities: Reversing the energy flow tides

The disparity between the production and consumption could drive the emergence of a tradeable Green hydrogen market[18]. While supply-side incentives have effectively kick-started development, domestic demand will be a key factor in sustaining growth. Currently, 90% of hydrogen in India is used for captive purposes leading to a small market[19]. Until domestic demand is established, exporting could be a vital strategy to achieve economies of scale. The EU, Japan, and South Korea are major importers due to their consumption targets, with the EU aiming to consume 20 million tons by 2030[20]. Recent tenders from Japan and the EU have sparked interest from Indian players.

ACME India

Proposes a 1.2 MTPA Green hydrogen and ammonia project in Odisha, with IHI Corporation of Japan securing an offtake agreement.

Sembcorp Industries

Entered into an agreement with Japan's Sojitz Corp and Kyushu Electric Power Co. to export Green hydrogen from India to Japan.

YARA Clean Ammonia and Greenko ZeroC

Signed an agreement for the supply of renewable ammonia from a production facility in Kakinada, Andhra Pradesh.

18. Harnessing_Green_Hydrogen_V21_DIGITAL_29062022.pdf (niti.gov.in)
19. The East Asian opportunity: Prioritising Japan and Korea in India's green hydrogen strategy (orfonline.org)
20. Green hydrogen push: India eyes $7-15 billion import substitution, plans $4-12 billion investment, ET EnergyWorld (indiatimes.com)

3

Energy Storage Systems in Managing RE Intermittency

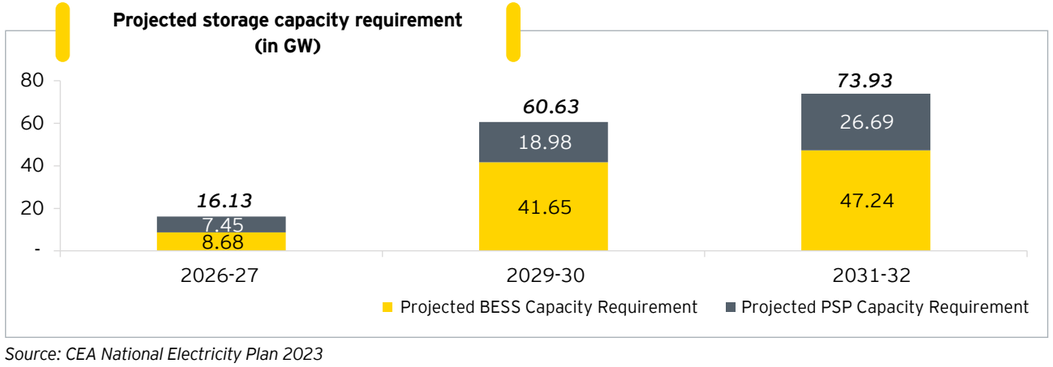
Storage potential in India

With significant future RE capacity additions, the demand for energy storage is projected to grow, with the Central Electricity Authority estimating storage capacity needs of 16.13 GW by 2026-27, rising to 73.93 GW by 2031-32[21].

The Government of India is pursuing a multi-pronged strategy for the development of energy storage and decarbonization of back-up power.

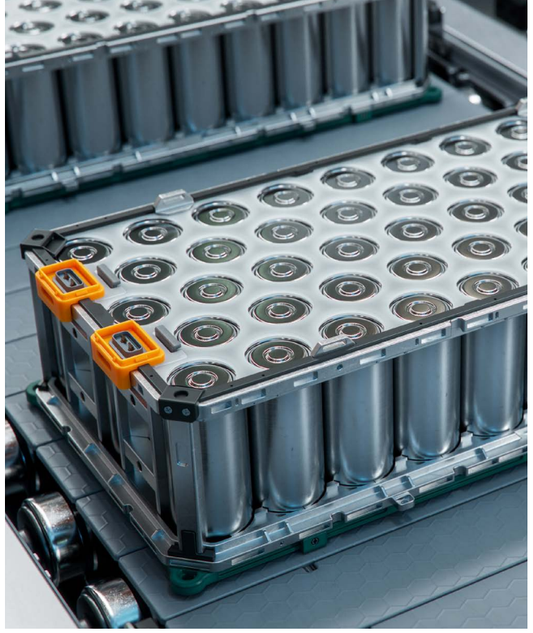
Battery Energy Storage Systems (BESS) offer a versatile energy storage solution that is location-agnostic and can be rapidly deployed. BESS can respond quickly to fluctuations in supply and demand, providing long-term reliability by handling frequent charge-discharge cycles with minimal degradation[22].

Pumped Storage Projects (PSPs) are a key focus for India's energy storage strategy, offering significant advantages such as the ability to store large amounts of energy, rapid start/stop cycles, and efficient ramp-ups/ramp-downs, making them ideal for balancing dynamic energy supply and demand.



Source: CEA National Electricity Plan 2023

21. CEA, National Electricity Plan (2023)
22. Economic Times (September 2023) "Why it is urgent for India to focus on Battery Energy Storage Systems"



Battery Energy Storage Systems (BESS):

Financial incentives and tenders, including Viability Gap Funding (VGF), are promoting the adoption of BESS.

Pumped hydro projects:

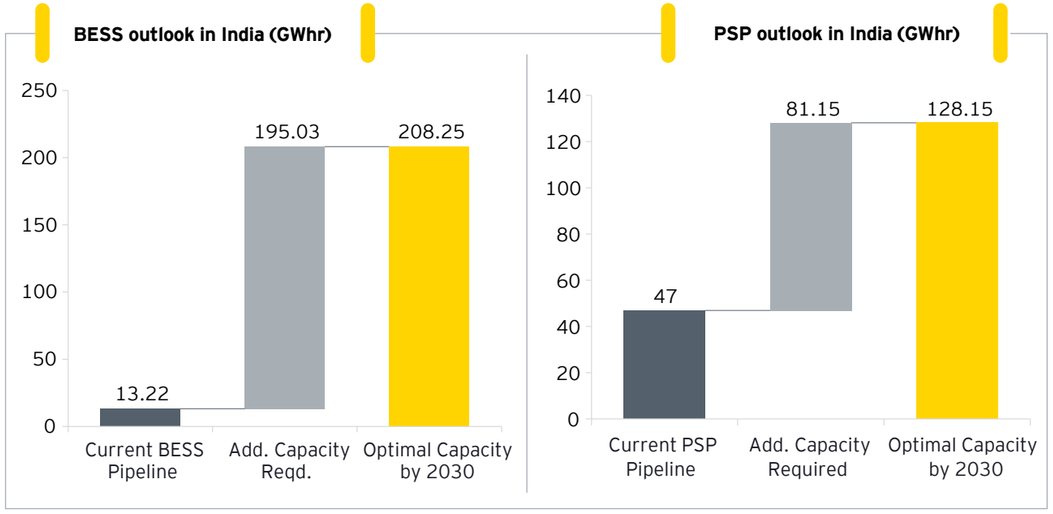
Accelerated approvals and infrastructure development, including road access, are being facilitated, alongside incentives for utilities and industries to source power from BESS and Pumped Storage Power (PSP) systems.

Energy Storage Obligations (ESO):

The Ministry of Power has set a gradual increase in storage capacity obligations for distribution licensees, starting at 1% in FY2023-24 and reaching 4% by FY2029-30.

Replacement of diesel generators (DG):

The Electricity (Rights of Consumers) Amendment Rules, 2022 mandate the replacement of DG sets with cleaner technologies, such as renewable energy and storage solutions, within a set timeline.



1 Energy storage market model

The energy storage market model is a dynamic framework that incorporates various market segments and innovative contracting structures to enhance the efficiency and flexibility of energy systems. The market model is driving the evolution of the energy storage industry, facilitating greater adoption and integration of energy storage solutions in both traditional and renewable energy grids.

Market segments

Ancillary services

- Frequency response
- Voltage control
- Peak shaving
- Backup power

Energy arbitrage

- Leverage price differentials
- Store energy during low-demand periods
- Discharge during peak demand for price differential benefits
- Capacity markets: Contracts for providing future capacity

Innovative contracting structures

- **Standalone capacity**
- **Peak power supply**
- **Round-the-clock renewable supply**
- **Firm-dispatchable renewable energy**

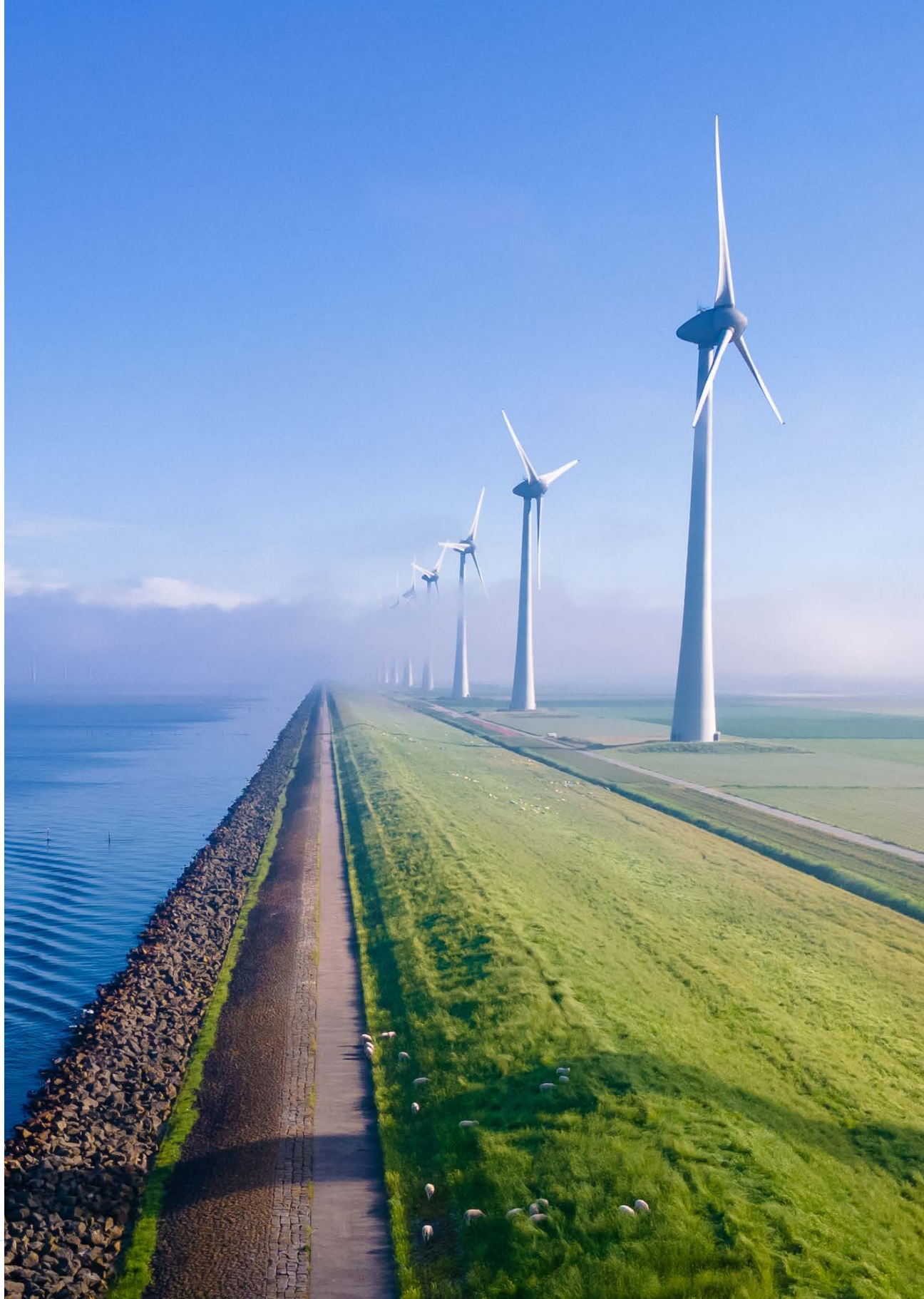
Current market status

- **Awarded storage capacity:** **35 GWh**
- **Storage under tendering:** **30 GWh**

2 Energy storage linked tender categories

India is actively advancing its energy storage infrastructure through a range of tenders in various categories, focusing on both standalone and integrated renewable energy storage systems (RE+ESS). These efforts aim to enhance grid stability and support the scaling of renewable energy by incorporating technologies like peak power, renewable energy integration, and firm and dispatchable renewable energy (FDRE). With a substantial portion of capacity already under execution and additional tenders underway, these projects are critical for improving energy storage capabilities, enabling a more reliable and efficient power system, and meeting renewable energy targets.

Energy storage linked tender categories							
Particulars	Standalone		RE+ESS				Solar + BESS
	BESS	PSP	Peak power	RTC	FDRE peak guarantee	FDRE load following	
Number of tenders	14	14	5	5	8	1	12
Capacity	7.34 GWh	49 GWh	1.9 GWh	2.2 GW (RE)	12.9 GW (RE)	0.6 GW (RE)	8.2 GWh
Under stages of execution	4.1 GWh	27 GWh	1.9 GWh	2.2 GW (RE)	9.3 GW (RE)	0.6 GW (RE)	1.5 GWh
Under tendering	3.2 GWh	20 GWh	-	-	3.6 GW (RE)	-	6.5 GWh



4 Strengthening Generation, Transmission and Distribution

Balancing the generation portfolio

India's rising electricity demand, driven by industrialization and urbanization, highlights coal's vital role in energy security, providing stable base load power and offsetting renewable energy (RE) intermittency. Flexibilization upgrades enable coal plants to efficiently operate under variable loads, complementing RE sources, while repair and maintenance (R&M) initiatives enhance efficiency, reduce emissions, and extend plant life.

As of December 2024, RE, including hydro, accounted for 45% of installed capacity, but coal remains crucial for grid reliability and peak demand. It is projected that medium-term electricity demand will largely rely on coal-fired generation. With rising plant load factors, technological upgrades, and a focus on operational flexibility, coal will continue stabilizing India's evolving energy mix amid growing RE integration.

1 Flexible ramping of coal power generation

Key limitations of renewable power output

Variability | Uncertainty | Concentrated

The generation of renewable energy faces three primary challenges: its inherent **variability,** which fluctuates in real-time; its **uncertainty**, which defies precise forecasting; and its **concentration**, which is limited to specific periods throughout the year. These issues necessitate a dynamic balancing of demand across various time intervals to maintain grid stability, security, and reliability. The intermittency and variability of solar and wind power must be offset by other generation sources to ensure grid resilience. Therefore, it is crucial to enable the **flexible operation of existing coal-fired power plants** to support the security and reliability of electricity supply, while simultaneously maximizing the generation from renewable energy sources (RES) and facilitating their seamless integration into the grid.

To complement the integration of renewable energy and maintain grid stability, the flexible ramping capability of coal power plants is essential. Coal-based generation must operate at lower minimum loads and ramp output rapidly to balance renewable fluctuations. Key performance metrics defined by the Central Electricity Authority (CEA) include achieving a minimum load of 40%, ramp rates of 1-2% per minute, and adopting two-shift operations. However, the shift toward flexible operations for coal power plants presents significant technical, operational, and environmental challenges:

Technological constraints
India's aging, subcritical coal fleet lacks the automation required for flexible operations, leading to increased operational costs and complexity.

Coal quality issues
Poor and inconsistent coal quality hampers stable low-load operations, often necessitating secondary fuels.

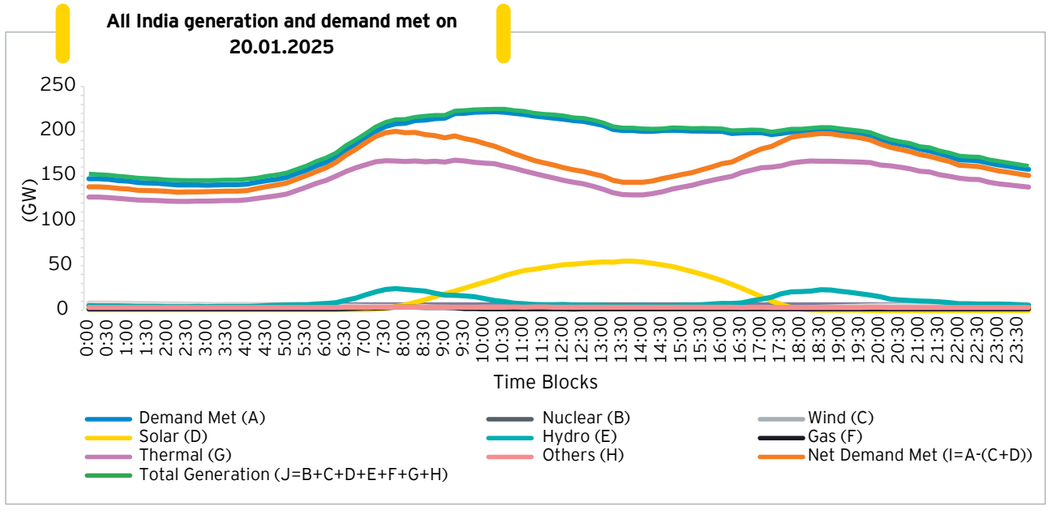
Increased wear and maintenance
Operating at low loads accelerates wear on boilers and turbines, raising maintenance expenses.

Environmental concerns
Emission controls, such as ESPs and FGDs, may underperform at low loads, complicating compliance with environmental norms.

Pilot projects reveal issues like combustion instability and equipment stress at 40% load, underscoring the need for technological upgrades, such as advanced control systems, online combustion management, and condition monitoring. CEA estimates the cost of achieving 40% minimum load flexibility at approximately US$2.7 million/unit.

The increasing variability of renewable energy (RE) generation, specifically from wind and solar sources, necessitates enhanced ramping capabilities in thermal power plants. An analysis of the NLDC's Daily PSP Report for 20 January 2025 reveals significant fluctuations in RE output, with solar generation peaking mid-day and wind generation demonstrating variable patterns. These intermittent shifts create challenges in maintaining grid stability and meeting demand effectively. Thermal power plants, characterized by their ability to provide consistent and controllable output, are essential for addressing the deficits created by the inherent variability of RE sources. The data illustrates that during periods of reduced RE output, thermal generation significantly compensates for the shortfall, ensuring demand met remains consistent. For instance, solar generation varies between 764 MW and 54,967 MW, while wind generation fluctuates between 2,675 MW and 8,257 MW. The stability in demand met, hovering around 200,000 MW, signifies the role of thermal power in bridging these gaps.

Enhanced ramping rates in thermal power plants facilitate a rapid response to sudden changes in RE output. This capability minimizes reliance on gas or other quick-start resources, which may be more expensive or less efficient. Moreover, faster ramping allows for maintaining optimal grid frequency, observed at an average of 50 Hz, even during significant RE variability. Investments in ramping capabilities also support grid resilience against unexpected surges or drops in RE supply, especially with increased integration of solar and wind projects. Advanced technologies like flexible boiler systems, predictive analytics, and real-time grid monitoring can optimize thermal plant operations, ensuring seamless adaptation to demand-supply imbalances. Increasing the ramping rates of thermal plants thus is critical to complementing intermittent RE generation. This ensures grid stability, reduces operational costs, and supports the transition to a cleaner energy mix while maintaining reliability.



Source: NLDC Daily PSP Report for 20.01.2025

Key requirements of flexibilization

Management of grid

As the share of variable renewable resources increases, thermal units will face lower minimum loads and higher ramp-up rates

Flexibility for grid support services

Flexibility for grid support is crucial, with thermal units ensuring primary frequency control through sustained and stable operation

Flexible capacity required/available

The thermal units may have to operate below 40% minimum technical load

Ramp rate required/available

Indian grid is comfortably placed in case individual units maintain a basic ramping capability of 1%/min

Source: NLDC Daily PSP Report for 20.01.2025

Flexible operation of coal-fired power plants in India is technically achievable through upgrades, such as control tuning, but converting base-load plants into flexible units would incur additional costs. To assess flexibility, thermal units must undergo tests to evaluate safety, stability, and power output, with a focus on ramp rates and plant-specific retrofits. For low-load operation (around 40%), technical measures like control automation, optimized combustion, and stable mill operation are needed. Subcritical units (500 MW or less) are suitable for flexibilization, while supercritical units require more careful management for load ramping. Coal plants should operate no lower than 35-40% load due to the low volatile matter and high ash content of Indian coal.

The 'CEA (Flexible Operation of Coal-Based Thermal Power Generating Units) Regulations, 2023' establish requirements for ensuring the operational flexibility of coal-based power plants. These regulations mandate that generating units must operate at reduced power levels, achieving a minimum of 40% of their maximum continuous power rating without oil support, and adapt their ramp rates for load adjustments. Units incapable of meeting these benchmarks must achieve compliance through retrofitting within prescribed timelines. The regulations aim to enhance grid stability by aligning plant operations with dynamic load dispatch needs, particularly as renewable energy integration increases. They require minimum ramp rates of 3% per minute for operations between 70% and 100% capacity and phased improvements for lower operational levels.

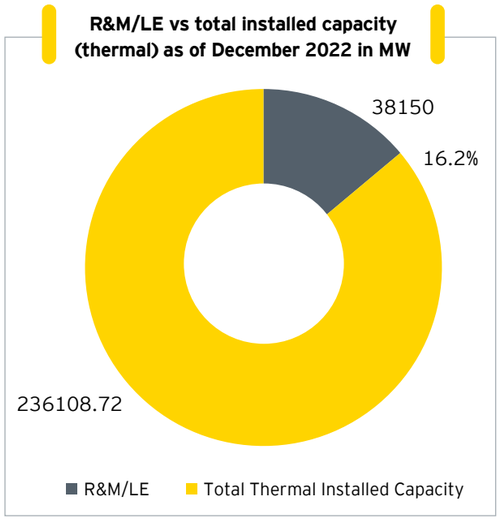
Despite flexibility potential, commercial challenges such as retrofit costs, increased O&M, and heat rate degradation need to be addressed by regulators. Operator confidence is limited due to concerns about equipment failures at low loads, making comprehensive training essential. While two-shift operations are being piloted in some regions, a national strategy for their implementation is required.

Recommendation for regulatory guidelines on flexibilization

The cost of coal and auxiliary consumption will increase with flexibilization, necessitating comprehensive regulatory guidelines. It is crucial to establish such guidelines at both the central and, more importantly, the state levels, as no robust regulations currently exist at the state level for flexibilization. Key aspects to consider include O&M compensation, additional SHR adjustments, and provisions for additional life-cycle CAPEX—whether one-time or phased—to ensure alignment with regulatory frameworks and support the transition effectively.

2 Renovation and modernization of thermal power generation

Renovation and modernization (R&M) has emerged as a cost-effective strategy to boost generation from existing thermal power stations, offering benefits such as better asset management, enhanced generation, and a shorter gestation period. In addition to improving generation and availability, R&M extends plant life, enhances safety, and improves reliability and environmental conditions. However, many thermal plants, including 200/210 MW units, are outdated and have surpassed their economical design life. The 66 LMZ units of 200/210 MW capacity are prime candidates for EE R&M, offering significant potential for improved performance. The CEA has identified 148 units, totaling 38,150 MW, as candidates for R&M/LE works due to their age exceeding 20 years as of December 2022. This represents approximately 16.2% of the total thermal installed capacity, highlighting the critical need for modernization and efficiency upgrades.



Source: CEA Quarterly Review Report R&M of Thermal Power Stations

R&M/LE works in these units must be implemented in three phases to avoid any major energy demand- supply gap. Therefore, draft phasing plan of 148 units along with tentative timelines for implementation of R&M/LE intervention has been prepared and proposed to be implemented in three phases given as under:

Phases		Criteria for thermal units (age as on December 2022)	Timeline
Phase I	Phase IA	Age 35 years and older	01.01.24 to 30.06.26
	Phase IB	Age 30 to 35 years	01.01.26 to 30.06.28
Phase II		Age 25 to 30 years	01.07.28 to 31.12.30
Phase III		Age 20 to 25 years	01.01.31 to 30.06.33

Source: CEA Quarterly Review Report Renovation & Modernization of Thermal Power Stations

Draft phasing plan for R&M (sector wise)

Sector	Phase I				Phase II		Phase III	
Timelines	Phase IA		Phase IB					
	01.01.24 to 30.06.26		01.01.26 to 30.06.28		01.07.28 to 31.12.30		01.01.31 to 30.06.33	
	Units	Capacity (MW)	Units	Capacity (MW)	Units	Capacity (MW)	Units	Capacity (MW)
Central	20	4930	22	6940	11	3180	8	2840
State	32	6690	16	3940	19	4900	14	2980
Private	1	500	0	0	3	750	2	500
Total	53	12120	38	10880	33	8830	24	6320

Source: CEA Quarterly Review Report Renovation & Modernization of Thermal Power Stations

The plan prioritizes the central sector, with the highest number of units and capacity undergoing R&M in the initial phases. In Phase IA (01.01.24 to 30.06.26), 53 units (12,120 MW) will be addressed, with a significant focus on the central and state sectors. As the plan progresses, the number of units decreases, reflecting completed R&M work in earlier phases. Phase IB (01.01.26 to 30.06.28) involves 38 units (10,880 MW), while Phase II (01.07.28 to 31.12.30) and Phase III (01.01.31 to 30.06.33) focus on fewer units. The private sector has a smaller share, with only a few units being addressed in later phases. This gradual, sector-wise approach ensures efficient resource allocation and prioritizes the most critical units first, optimizing the R&M process over time.

Viable business model on R&M/LE

To enhance the efficiency and longevity of thermal power plants, several investment options for R&M (Repair and Maintenance) and LE (Life Extension) schemes are available. These approaches offer different models for financing and executing R&M/LE projects, each with its own set of advantages. The following options are considered practical and feasible:

Conventional Competitive Bidding

- Power utility conducts R&M/LE work, including turbine and boiler modifications, through competitive bidding.
- Equipment supply and erection contracts are awarded based on government guidelines.
- This approach follows the traditional model for procurement and execution.

Joint Venture (JV) Model

- A JV company is formed between the power utility and a private/public company or manufacturer.
- The JV will be responsible for owning, operating, and maintaining the power station, as well as performing R&M/LE work.
- The partner in the JV may also supply equipment, further enhancing collaboration.

Service Model

- The power utility does not need to fund upfront capital costs for R&M/LE projects.
- Payment is made based on actual savings realized from the improvements achieved.
- The R&M/LE work is carried out by a service provider through competitive bidding or nomination, with performance improvement and flexible payment models.

Source: https://cea.nic.in/wp-content/uploads/tprm/2023/08/Final_Report_on_various_aspects_of_RM_and_LE.pdf

Recommendation for regulatory guidelines on R&M/LE

To effectively implement R&M/LE programs, regulatory guidelines must focus on advanced technologies for efficiency, emission control, and flexible operations. These guidelines should prioritize aging higher-capacity units, incorporate techno-economic analyzes for life extension, and streamline processes to reduce delays and costs. State-level alignment is crucial, with guidelines tailored to regional needs, clear CAPEX provisions, and support for private sector participation. Ensuring material supply stability and addressing challenges like higher coal costs and operational complexity are key. Additionally, guidelines should mandate environmental upgrades, including biomass co-firing and water conservation, to align with sustainability goals and enhance the operational life of thermal power plants.

Strengthening the distribution sector

India's rising electricity demand, driven by industrialization and urbanization, highlights coal's vital role in energy security, providing stable base load power and offsetting renewable energy (RE) intermittency. Flexibilization upgrades enable coal plants to efficiently operate under variable loads, complementing RE sources, while repair and maintenance (R&M) initiatives enhance efficiency, reduce emissions, and extend plant life.

As of December 2024, RE, including hydro, accounted for 45% of installed capacity, but coal remains crucial for grid reliability and peak demand. It is projected that medium-term electricity demand will largely rely on coal-fired generation. With rising plant load factors, technological upgrades, and a focus on operational flexibility, coal will continue stabilizing India's evolving energy mix amid growing RE integration.

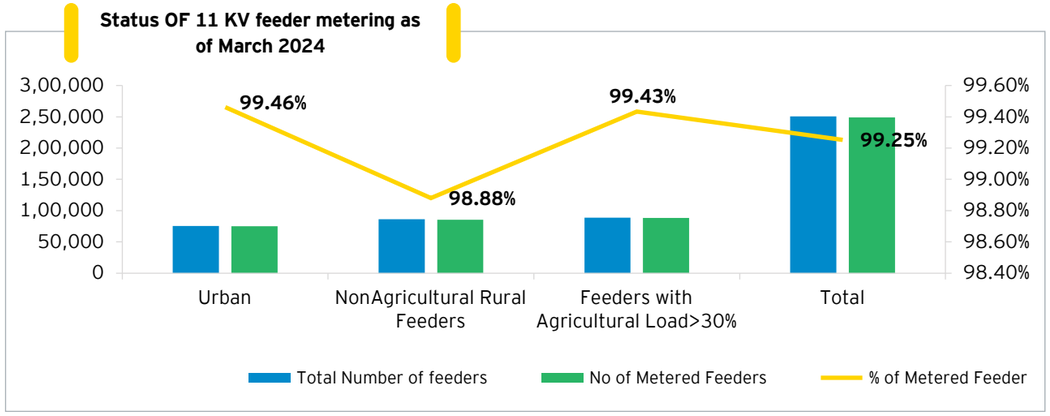
1 Smart metering initiatives and current status in India

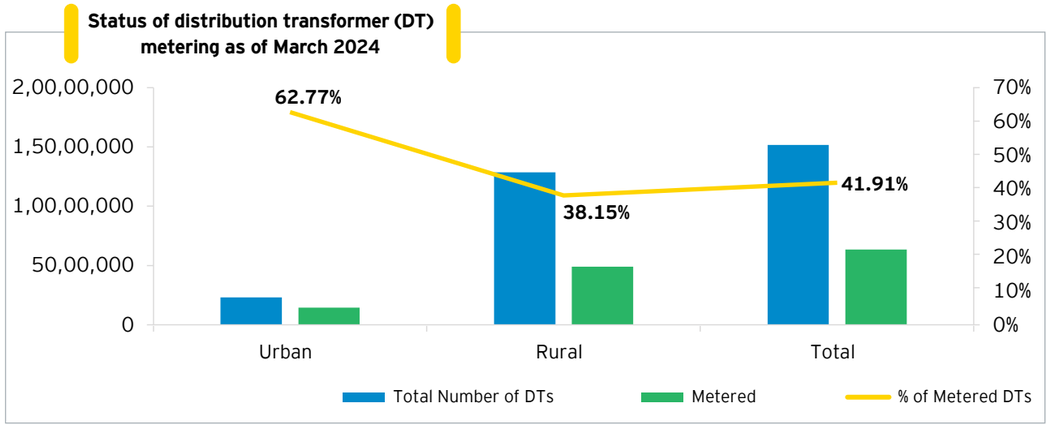
As of 31 March 2024, India has 2.50 lakh feeders, with 75,544 urban (30.12%) and 1,75,268 rural (69.88%) feeders, including 88,856 agricultural feeders (35.42%). Of the 38,691 high-voltage feeders, 98.63% are metered. The National Feeder Monitoring System (NFMS) is being developed to centralize monitoring of power reliability and quality across feeders.

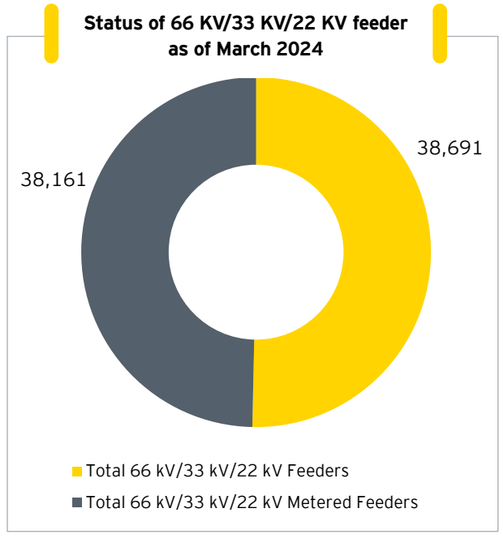
Under the Revamped Distribution Sector Scheme (RDSS), non-communicable feeder meters are being replaced with communicable ones integrated with Advanced Metering Infrastructure (AMI). So far, 1.88 lakh smart feeder meters have been sanctioned. India also has 1.51 crore distribution transformers (DTs), with 15.24% serving urban and 84.76% rural areas. While national DT metering is low, states like Delhi, Kerala, and Goa exceed 80%, while states like Andhra Pradesh and West Bengal have rates below 25%.

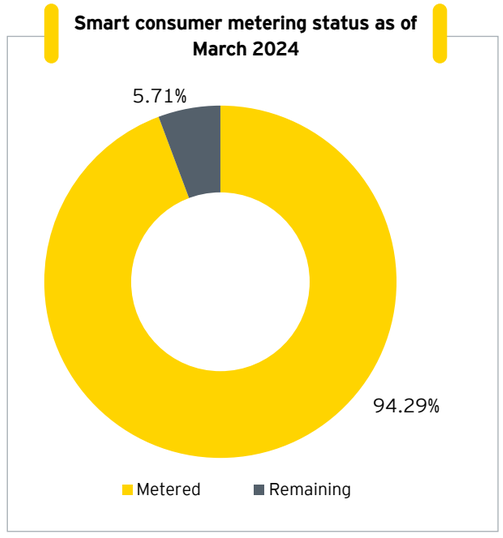
As per MoP guidelines, all DTs (except those supplying agriculture or under 25 kVA) must be metered, with 52 lakh DT meters sanctioned under RDSS.

Regarding consumer metering, there are 34.18 crore consumers, with 94.29% metered. Domestic consumers make up 80%, and urban consumers account for 40.42%, while rural consumers total 59.58%. This metering initiative is crucial for improving energy auditing, supply quality, and supporting future infrastructure development.









Source: CEA - report on status of metering in the country feeders, distribution transformers & consumers metering status

2 Smart metering implications

Advantages of smart meters to distribution:

Enhanced load management:
Real-time data collection allows better monitoring and balancing of electricity demand and supply while facilitating demand response programs to prevent overloading and outages.

Reduced operational costs:
Smart meters eliminate the need for manual meter reading, saving time and labor costs, and help identify losses due to theft or faults, reducing revenue losses.

Improved fault detection and resolution:
They provide instant alerts for power outages or anomalies, enabling quicker restoration of service, and help pinpoint the exact location of faults to minimize downtime.

Enhanced theft detection:
Smart meters use real-time monitoring and anomaly detection to identify irregular usage patterns, pinpoint unauthorized access, and reduce non-technical losses efficiently.

Better energy efficiency:
Detailed consumption patterns allow identification of areas for efficiency improvement, while optimal energy usage is promoted by distributing power based on real-time demand.

Seamless grid interoperability:
Integrates seamlessly with distributed energy resources (DERs) and smart grid technologies through standardized communication protocols.

P2B solar integration:
Enables consumers to trade excess solar energy directly with others, promoting renewable energy consumption.

Vehicle-to-Grid (V2G):
It allows for the integration of electric vehicles into the grid, facilitating energy storage, demand response, and optimizing the use of renewable energy sources by balancing grid loads.

Future of smart metering in India

The implementation of smart meters in India is poised for significant growth as part of the Revamped Distribution Sector Scheme (RDSS), which aims to improve power supply quality, reduce losses, and enhance energy efficiency. The scheme, launched in **FY2021-22** with a budget of **INR3,03,758 crore,** focuses on the widespread installation of smart consumer meters, distribution transformer (DT) meters, and feeder meters across the country.

The future of smart metering in India is poised for significant growth under RDSS. The smart meters are already yielding benefits in states like Assam, where **44%** of consumers saved about **50 units** per month, reducing billing errors and minimizing losses for distribution companies.

The roll-out strategy includes starting with government establishments, followed by commercial, industrial, and high-load consumers. Based on the positive outcomes seen in these categories, the adoption of smart meters is expected to expand to other consumer segments. By the end of the **RDSS scheme (FY2025-26),** efforts worth **INR1.48 lakh crore** will be implemented **across 32 states and union territories**, covering smart metering, system metering, and loss reduction initiatives. Smart metering will play a crucial role in enhancing energy efficiency, reducing losses, and supporting the integration of renewable energy, ensuring a financially sustainable and reliable power distribution system in India.

3 AI & IT / IOT based solutions in distribution mass scale implementation

To ensure affordable, reliable, and sustainable power supply in India, utilities must adopt key enablers, such as advanced metering infrastructure, automated monitoring and control systems, robust GIS with real-time updates, and integrated IT-OT solutions.

IoT based transformer monitoring

Maintaining grid reliability requires real time monitoring of transformer health. Transformers are crucial components in electricity distribution and transmission, representing a significant portion of capital investment in the distribution grid. An IoT based transformer monitoring system enables proactive equipment replacement, preventing failures and ensuring uninterrupted power supply.

Drawbacks of conventional transformers

- Lack of real-time monitoring
- Frequent transformer failures
- No planned downtime
- Absence of incipient fault monitoring

Features of the monitoring system[23]

Overcurrent protection
Includes temperature monitoring with fan activation and disconnection based on thresholds, along with overcurrent protection alerts.

Oil monitoring
Monitors both oil level (using ultrasonic sensors) and oil quality (using optical sensors).

Electrical parameters
Tracks current level, voltage level, KVA, and power factor, with alerts for abnormal readings.

Incipient fault detection
Detects internal faults through flux-based interturn fault detection.

Environmental monitoring
Monitors humidity to assess environmental conditions affecting transformer performance.

23. Research report from https://innovatorsguru.com/iot-based-transformer-monitoring-system/

Dynamics of the monitoring system[24]

Parameter measurement subsystem
This subsystem captures transformer electrical (flux, voltage, current, KVA, frequency, power factor) and physical parameters (temperature, oil level, oil quality, humidity) using sensors interfaced with an Arduino microcontroller.

Protection subsystem
The Arduino controls protection operations, activating a fan and relay to prevent transformer damage during faults (overvoltage, overcurrent, interturn, high temperature). Alerts are sent for issues like low oil quality or level.

Data reception subsystem
This subsystem transmits parameters to an IoT server using platforms like ThingSpeak or Ubidots. In case of minor faults, non-essential loads are disconnected while critical ones remain powered. If transformer capacity is exceeded, all loads are disconnected until parameters normalize, after which loads are reconnected in priority.

GIS-enabled SCADA implementation

The rollout of GIS-based SCADA (Geographic Information System Supervisory Control and Data Acquisition) plays a critical role in modernizing utility operations. This integration enhances the monitoring and control of electrical distribution networks by leveraging geographical data. GIS SCADA enables real-time visualization and decision-making, offering precise location data for network elements, including substations, transformers, and feeders. The benefits of GIS-based SCADA are as follows:

Improved network visualization: *Allows for better tracking of network performance and quicker identification of faults through GIS-based mapping.*

Real-time monitoring: *Provides instant data on system status, enabling faster response times and more effective outage management.*

Enhanced fault detection: *Helps in pinpointing faults with accuracy, reducing downtime, and improving reliability.*

Optimized resource allocation: *Facilitates better planning and management of resources by integrating geographical data with real-time operational data.*

24. Research report from https://innovatorsguru.com/iot-based-transformer-monitoring-system/

Integration of GIS and SCADA

Data mapping
GIS data is imported into SCADA systems to map network elements like feeders, transformers, and substations with their exact geographical locations.

System communication
Both systems are interconnected using middleware or communication protocols, ensuring real-time data flow between SCADA and GIS.

Real-time monitoring
SCADA's operational data (e.g., voltage, current, fault detection) is overlaid on GIS maps, providing a comprehensive view of the network status and geographical context.

Fault location and isolation
By combining GIS data with SCADA's fault detection capabilities, operators can quickly locate faults, identify affected areas, and respond faster.

Advanced analytics
The integration allows for advanced analytics, such as predictive maintenance and optimization, by correlating geographic data with operational data trends.

Source: CEA Guidelines ON INTRODUCTION of Automation in Distribution Sector

4 Regulatory reforms for separation of wires and supply business

The Electricity (Amendment) Bill, 2022, seeks to enhance competition in the electricity sector by enabling multiple distribution companies (discoms) to operate within the same geographical area. To avoid inefficiencies and elevated costs from duplicate infrastructure, the Bill differentiates the distribution business into two components: (i) the "wire" segment, representing the physical network and treated as a natural monopoly due to high capital costs, and (ii) the "supply" segment, covering power procurement, billing, and customer interface, which is designed for competitive operations. This structural bifurcation aims to improve operational efficiency, minimize losses, and empower consumers through supplier choice, thereby fostering improved service quality, competitive tariffs, and greater customer satisfaction.

Critical prerequisites for retail supply competition, as highlighted by the Forum of Regulators (2013), include a developed wholesale power market, cost-reflective tariffs, distinct ownership of wire and supply segments, mechanisms to manage financial and distribution losses, advanced metering infrastructure, and seamless switching processes for consumers. The Bill facilitates multiple discoms in a single area through non-discriminatory open access to networks, shared power purchase agreements, regulated tariff structures, and a cross-subsidy balancing fund, without owning physical "wire" network. However, challenges persist, including potential conflicts of interest where network-owning discoms, also engaged in supply, may hinder competitors to maintain dominance. While the Bill imposes penalties for non-compliance, their adequacy in mitigating these conflicts remains uncertain. Furthermore, operational barriers to open access, such as network capacity claims, restrictive conditions, and delays in maintenance, have historically impeded progress. High surcharges to maintain cross-subsidy levels further restrict consumer choice and market efficiency. Addressing these concerns necessitates clearer regulations, robust enforcement, and structural reforms to ensure equitable access and a competitive, consumer-centric electricity distribution ecosystem[25].

25. PRS India
26. Niti Aayog: Turning Around the Power Distribution Sector

5 Privatization and discom health improvement

> **National Electricity Plan 2022-32**
>
> "The Government of India announced privatization of power departments and power distribution utilities in union territories. The main objectives behind privatization are to improve the quality, reliability of power supply, providing better services to consumers and to achieve global benchmarks in operational and financial efficiencies."

Privatization in India's electricity distribution sector has shown mixed results, with varying levels of success influenced by factors such as governance practices, consumer demographics, and regional challenges. While state-owned discoms dominate the market, private participation has demonstrated efficiency improvements in areas like metering, billing, and collection, as seen in Odisha, Bhiwandi, and Delhi, where Aggregate Technical and Commercial (AT&C) losses fell dramatically. However, privatization is not a universal solution. The experience in cities like Delhi, Surat, and Mumbai highlights success in relatively urbanized and homogeneous regions. Conversely, cancellations of franchisee contracts in states like Maharashtra and Uttar Pradesh underscore the challenges of scaling privatization in diverse geographies. Concerns over job losses, the welfarist nature of state-run discoms, and resistance from state governments further complicate reforms, particularly in rural areas where billing and collection are commercially unviable[26].

The transition to privatization requires a nuanced approach tailored to regional contexts. The central government's proposal to delicense power distribution and foster competition through shared grid infrastructure offers potential benefits, allowing consumers to select suppliers based on service quality and cost. However, implementing such reforms demands careful market design to address structural inefficiencies, manage conflicts of interest, and ensure the viability of operations across diverse consumer bases and geographic regions.

Distribution franchisee model	**Distribution licensee model**
▪ No ownership of physical assets ▪ Engaged in the activity limited to the outsourced department of the licensee ▪ Torrent Power (Bhiwandi, Agra), CESC (Kota, Bharatpur, Bikaner, Malegaon)	▪ Holds equity and ownership of physical assets ▪ Engaged in complete operation of the licensee's activities ▪ Eg: CESC, TPDDL, BSES Rajdhani, BSES Yamuna, etc.

6

Recommendations for future utility reforms to adapt to the disruption of energy transition technologies

Current assessment gap

Governance accounts for only 1 out of 100 marks in the current discom rating system.
Existing criteria are limited to ensuring that one-third of the board comprises independent directors.
Other governance factors, like operational audit committees, separate leadership for MD and CFO roles, and regular quarterly financial reporting, have minor weightage (potential 3-point deductions).

Improvement opportunities

Listing state-owned utilities on stock exchanges will improve governance standards, enhance transparency, and make these entities more accountable to stakeholders.
Stock market listing can also help utilities gain easier access to capital, critical for financing large-scale energy transition projects.

Expand governance evaluation to include a broader range of parameters.
Increase scoring weightage for governance to up to 10% of the total rating.
Develop governance benchmarks tailored for state-owned utilities, including best practices from global utility standards.

Sector expertise

At least 10% of directors should have proven experience in leading RE projects, smart grid implementations, or digital utility operations.
Another 10% of directors should come from financial institutions like PFC, REC, or similar organizations to bring a financial perspective and improve operational practices.

Strengthen autonomy

Empower boards to independently drive operational and strategic decisions.
Establish mechanisms that ensure utilities are managed based on commercial and technical merit.

Independent directors should comprise at least one-third of the board to ensure balanced decision-making.
Emphasis should be placed on professional qualifications, prioritizing expertise in energy transition technologies over political affiliations.

Investment and innovation

Enhance financial independence to attract private-sector collaboration and institutional funding.
Promote the adoption of cutting-edge technologies such as RE integration, smart grids, and EE solutions.
Enable utilities to diversify their revenue streams and access capital through innovative financing models, such as green bonds, infrastructure funds, RE credit financing, and infrastructure investment trusts.

Achieving sustainable cooling solutions in India

India's cooling demand is rising rapidly due to urbanization, economic growth, and increasing affordability of cooling devices. Space cooling already accounts for 60% of total cooling energy use and is projected to represent 28% of India's electricity consumption by 2050. This surge, driven by the growing demand for thermal comfort and refrigeration, poses significant environmental challenges. Without intervention, cooling-related GHG emissions could more than double by 2050, straining energy systems and exacerbating climate change. Sustainable solutions are critical to balancing this demand with environmental goals.

Cooling demand in India: Significant growth expected

- Air conditioning's share in India's peak electricity load is projected to reach 45% by 2050 from 10% today
- Space cooling energy 2X growth by 2050
- India's urban population growth is driving higher demand for cooling

Source: IEA, EESL

1

Key strategies and initiatives

SEAC program

Objective: EESL's SEAC program reduces cooling demand, increases efficiency, and mitigates climate impact.

Phase 1: Procured 100,000 units with 15% better efficiency than 5-star models, investing US$85 million

Phase 2: Introduced ISEER 5.4 units, reducing electricity use by up to 410 kWh/year, saving INR2,000–INR3,000 annually.

Impact: Saved 145.5 million kWh/year, eliminated 1.2 million tons of CO2, and lowered prices by 20%–25%. Scale-up: Aims for 200,000 more units deployed, collaborating with utilities and commercial partners.

27. IEA, EESL, ADB Report on "SUSTAINABLE COOLING How to Cool the World Without Warming the Planet"

District cooling systems

- Gujarat International Finance Tec-City in India has implemented a district cooling system with three plants, each initially designed for a 60,000 RT cooling capacity.
- Through efficient planning, the chiller size for each plant was reduced to 50,000 RT, with 10,000 RT capacity replaced by stratified chilled water thermal energy storage to meet peak demand.
- The first phase of the district cooling system, capable of supplying up to 10,000 RT, has been operational since April 2015 (Patel 2017).

Innovative business models

The business models and energy service contract arrangements that can improve the financial return on energy efficiency upgrades include:

- **Cooling as a Service (CaaS):** Allows users to access cooling without upfront costs by paying for the service instead of purchasing equipment.
- **Pay as You Save (PAYS):** Financing model by EESL where users repay energy-efficient upgrades through the savings generated from reduced energy costs.
- **Incentives and financing:** Includes buy-back options and financing schemes to further encourage adoption of energy-efficient cooling solutions.

National Cooling Action Plan (NCAP)

Considering the climate impact of the cooling sector, several countries have developed national cooling action plans. India's National Cooling Action Plan (NCAP), launched in 2019, is a comprehensive strategy to meet the country's rising cooling demand sustainably while mitigating climate change. The plan emphasizes balancing economic growth, energy efficiency, and environmental sustainability.

- The India Cooling Action Plan (ICAP), launched in 2019, outlines a comprehensive strategy to manage the country's rising cooling demand and mitigate environmental impacts.
- ICAP aims to reduce cooling demand by 20%–25%, refrigerant consumption by 25%–30%, and cooling-related energy consumption by 25%–40% by 2037/38.
- The plan focuses on developing energy-efficient cooling solutions and promoting low-GWP refrigerants to reduce the sector's environmental footprint.
- It emphasizes research and development in cooling technologies, with the recognition of "cooling and related areas" as a key focus under the National Science and Technology Programme.
- ICAP also includes training and certifying 100,000 technicians by 2022/23, supporting the Skill India Mission to build a skilled workforce for the cooling sector.[27]

Notes

Notes

ASSOCHAM

ASSOCHAM initiated its endeavor of value creation for Indian industry in 1920. It brings in actionable insights to strengthen the Indian ecosystem, leveraging its network of more than 4,50,000 members, of which MSMEs represent a large segment. With a strong presence in states, and key cities globally, ASSOCHAM also has more than 400 associations, federations and regional chambers in its fold.

Aligned with the vision of creating a New India, ASSOCHAM works as a conduit between the industry and the Government. The Chamber is an agile and forward-looking institution, leading various initiatives to enhance the global competitiveness of the Indian industry, while strengthening the domestic ecosystem. With more than 100 national and regional sector councils, ASSOCHAM is an impactful representative of the Indian industry. These Councils are led by well-known industry leaders, academicians, economists and independent professionals. The Chamber focuses on aligning critical needs and interests of the industry with the growth aspirations of the nation.

ASSOCHAM is working hand in hand with the government, regulators and national and international think tanks to contribute to the policy making process and share vital feedback on implementation of decisions of far-reaching consequences. In line with its focus on being future-ready, the Chamber is building a strong network of knowledge architects. Thus, ASSOCHAM is all set to redefine the dynamics of growth and development in the technology-driven 'Knowledge-Based Economy. The Chamber aims to empower stakeholders in the Indian economy by inculcating knowledge that will be the catalyst of growth in the dynamic global environment.

Vision
Be the knowledge architect for the Indian economy, with a focus on strengthening India's domestic ecosystem and enhancing global competitiveness.

Mission
Its mission is to impact the policy and legislative environment so as to foster balanced economic, industrial and social development.

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