Confederation of Indian Industry

Energy Security in a Volatile World: Independence, Efficiency and Resilience

Prepared for the 7th International Energy Conference and Exhibition

August 2026

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Foreword

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India stands at a defining moment in its energy journey. As the world's third-largest energy consumer, third-largest crude oil importer, and among its fastest-growing electricity markets, the country is navigating rising demand, an accelerating clean energy transition, and a global environment marked by geopolitical volatility and supply-chain uncertainty. Energy security has become a multidimensional priority - spanning affordability, reliability, infrastructure resilience, and access to the technologies and materials that will power the decades ahead.

This report, *India's Energy Security in a Volatile World: Independence, Efficiency and Resilience,* offers a comprehensive, evidence-based view of that landscape. It traces India's enduring reliance on imported hydrocarbons, the electrification-led shift reshaping the economy, the growing role of firm low-carbon and storage capacity, and the emerging dependence on critical minerals and their supply chains.

Together, these findings illustrate a central theme: the transition changes the nature of energy security rather than removing it, making resilience across the entire energy ecosystem the defining challenge on the path to Viksit Bharat 2047. India's march towards a secure, efficient, and resilient energy future requires an integrated approach.

Insights from Industry leaders and our members shaped this report into a substantive, actionable resource. I hope it serves as a strong basis for discussions at the International Energy Conference & Exhibition, CII's global convening of energy stakeholders, and contributes meaningfully to the national conversation on building a secure, efficient, and resilient energy future for India.

Chandrajit Banerjee

Director General
Confederation of Indian Industry

EY

India's energy system is entering one of the most consequential phases in its history. Over the next two decades, the country must absorb decades of demand growth, strengthen energy security, maintain economic competitiveness and advance its clean energy transition — simultaneously, in a global environment shaped by geopolitical conflict, supply-chain disruption and commodity price volatility. Energy security today extends well beyond fuel availability; it encompasses affordability, reliability, infrastructure resilience, access to critical technologies and the ability to secure strategic supply chains.

This report, India's energy security in a volatile world: Independence, efficiency and resilience, examines that challenge across the full energy value chain. The evidence assembled points to a system in transition rather than a system escaping dependence. Crude oil imports meet around 90% of domestic demand, and the Middle East continues to account for nearly half of India's crude and close to two-thirds of its LNG. At the same time, electricity is emerging as the primary carrier of energy across the economy, with per capita consumption rising to 1,153 kWh and intermittent renewables projected to approach 60% of installed capacity by 2035–36. Firm, low-carbon generation, storage, transmission build-out and digital intelligence will each shape how securely that shift is delivered. Alongside this, a new dependency is taking form: India remains fully import-dependent for 15 of the 23 critical energy transition minerals assessed, in a market where refining capacity for several minerals is concentrated in a single country at levels between 44% and 93%.

What emerges is a clear analytical conclusion: the energy transition changes the nature of energy security rather than eliminating it. Overall import dependence is projected to remain above 43% even as coal import reliance declines, with the sources of exposure shifting from fuels towards minerals, manufacturing capability and technology supply chains.

At EY, we see our role as helping policymakers, industry and investors read these interdependencies accurately and plan for them. We are grateful to CII for the opportunity to serve as knowledge partner for the 7th International Energy Conference and Exhibition, and to the many stakeholders whose insights have informed this analysis. We hope this report contributes usefully to the collective effort towards a resilient, efficient and energy-secure Viksit Bharat 2047.

Somesh Kumar

Partner and Leader
Power & Utilities, EY India

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India's energy security at a geopolitical inflection point

India's energy system is entering one of the most consequential phases in its history. Over the next two decades, the country will need to simultaneously meet rapidly rising energy demand, strengthen energy security, maintain economic competitiveness, and advance its clean energy transition. Unlike many advanced economies where energy demand has largely stabilized, India's energy consumption trajectory remains firmly upward. Sustained economic growth, accelerating industrialization, large-scale infrastructure development, increasing urbanization and rising household incomes are creating structural drivers of long-term energy demand growth. As millions of people move into the middle class, demand for housing, mobility, cooling, consumer appliances, industrial goods and digital services is expected to expand significantly, placing growing requirements on the country's energy system.

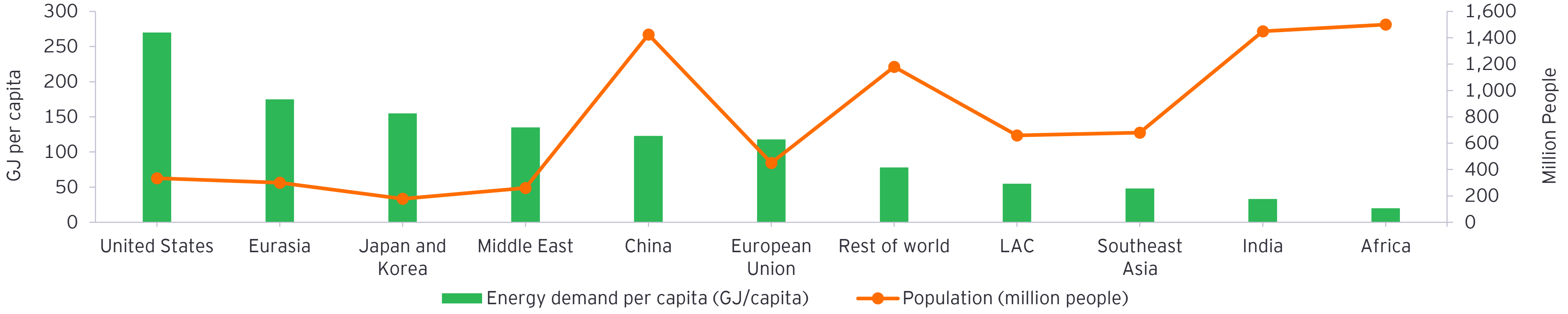
At the same time, the global energy environment has become more complex and uncertain. Recent years have demonstrated how geopolitical conflicts, supply-chain disruptions, commodity price volatility and trade restrictions can significantly affect energy markets. Consequently, the concept of energy security is evolving beyond traditional concerns of fuel availability and import dependence. Today, energy security increasingly encompasses affordability, reliability of supply, resilience against external shocks, robustness of infrastructure, access to critical technologies, and the ability to secure strategic supply chains for fuels, equipment and clean energy technologies. For a country of India's scale and growth ambitions, these dimensions are becoming increasingly interconnected..

A distinctive characteristic of India's energy transition is the combination of a very large population and relatively low per capita energy consumption. Although India is already among the world's largest energy consumers in absolute terms, energy use on a per capita basis remains substantially below that of most major economies. In 2024, per capita energy demand in India is significantly lower than in advanced economies such as the United States and remains well below levels observed in China. This gap reflects both India's development journey and the considerable headroom that exists for future growth. As economic prosperity increases and access to modern energy services improves, energy consumption per person is expected to rise steadily across the residential, commercial, industrial and transportation sectors.

India faces a dual task: Absorbing decades of demand growth while reducing the energy needed per unit of GDP.

Source: https://iea.blob.core.windows.net/assets/9753df19-0a71-422a-b725-012c555763b3/WorldEnergyOutlook2025.pdf

Energy demand per capita and population by region/country, 2024



Note: GJ = gigajoule; LAC = Latin America and the Caribbean. Energy demand per capita corresponds to the rate of total energy demand to population

How efficiency will determine the sustainability of India's growing energy demand

This dynamic makes future demand growth a structural inevitability rather than a policy choice. Rising incomes typically lead to greater ownership of appliances, higher cooling demand, increased mobility requirements and greater consumption of goods and services. Simultaneously, manufacturing expansion, digitalization, urban infrastructure development and electrification initiatives will further increase energy requirements across the economy. Consequently, India's challenge is not whether energy demand will grow, but how that growth can be managed in a secure, affordable and sustainable manner.

Addressing this challenge will require a dual strategy of expanding energy supply while continuously improving energy efficiency. Historical experience across major economies demonstrates that technological innovation, process improvements, and efficient energy management can significantly reduce the amount of energy required to generate economic output. Between 2015 and 2024, many countries achieved considerable reductions in energy intensity through industrial modernization, deployment of advanced technologies, adoption of efficient equipment and improved operational practices. These improvements enabled economies to continue growing while reducing the energy required per unit of GDP.

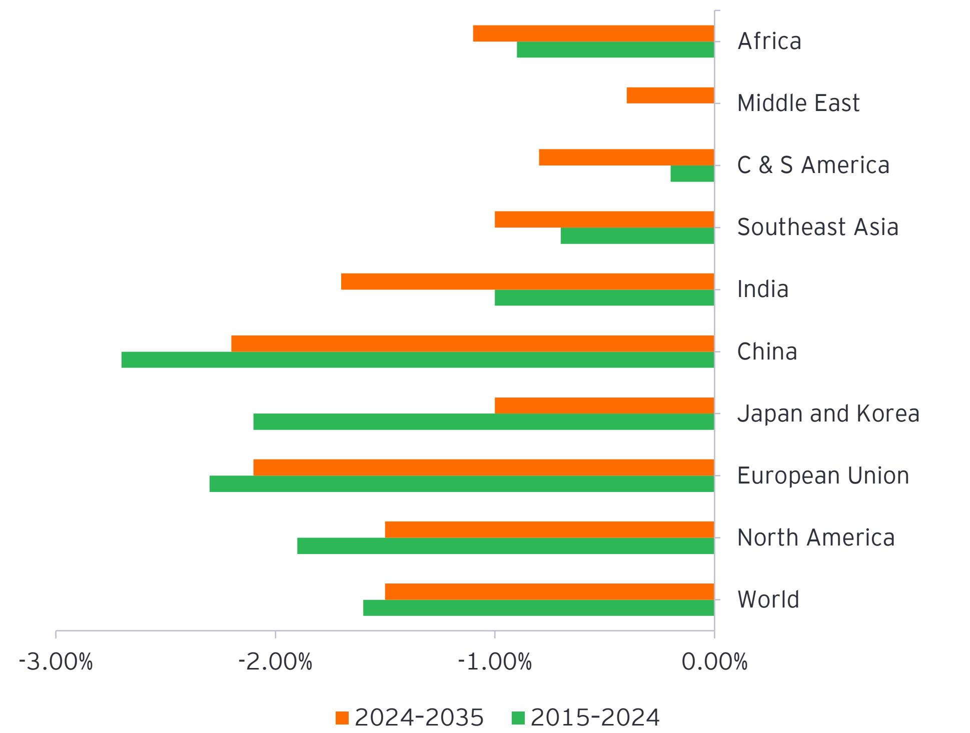
India has also made meaningful progress in this area. Declining energy intensity reflects the country's ongoing efforts to decouple economic growth from energy consumption. Improvements in industrial efficiency, wider electrification, adoption of digital technologies, deployment of energy-efficient equipment and stronger demand-side management practices have contributed to more productive use of energy resources. Looking ahead, energy intensity is expected to continue declining, although achieving additional gains may become progressively more challenging as many of the easily attainable efficiency improvements have already been captured.

The next phase of efficiency improvements is likely to be driven by electrification, digitalization and intelligent energy management. Smart grids, advanced metering infrastructure, predictive maintenance systems, artificial intelligence, automation and data-driven optimization can significantly improve the efficiency of energy production, transmission, distribution and consumption. These technologies can reduce losses, optimize asset utilization, improve reliability and enhance overall system performance, enabling India to derive greater economic output from each unit of energy consumed.

Source: https://iea.blob.core.windows.net/assets/9753df19-0a71-422a-b725-012c555763b3/WorldEnergyOutlook2025.pdf

Taken together, the combination of low per capita energy consumption and continuously improving energy intensity highlights the central challenge confronting India's energy transition. The country must accommodate substantial growth in energy demand while simultaneously ensuring that energy is produced, transported and consumed as efficiently as possible. Simply increasing the energy supply will not be sufficient. Long-term success will require a balanced approach that combines supply expansion with efficiency improvements, infrastructure modernization and technological innovation.

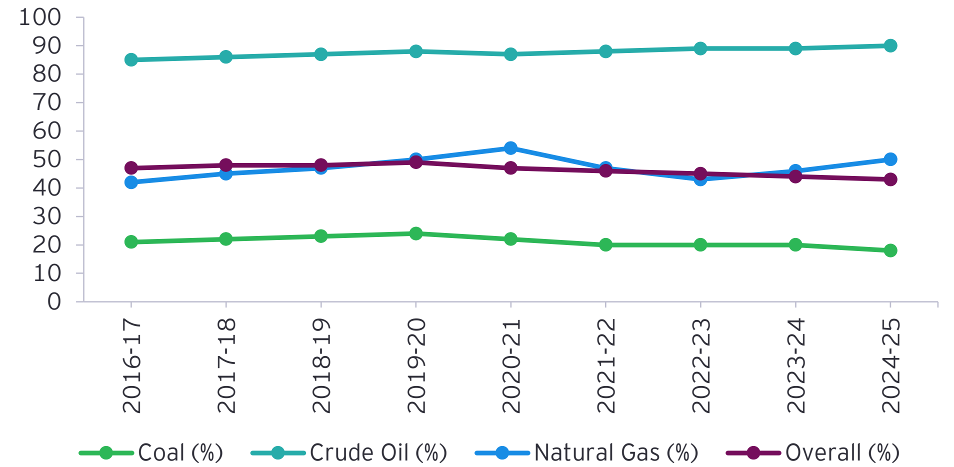
Average annual intensity reduction



ote: GJ/capita = gigajoule/capita; C&S America = Central and South America. Total final consumption excludes the traditional use of solid biomass. Energy intensity is the ratio of total final consumption per unit of GDP, excluding the traditional use of biomass.

India's energy transition continues to be anchored by imported fuels

India's import dependency on primary fuel supply



The composition of total final consumption (TFC) provides a complementary perspective on India's evolving energy mix. Oil products remain the largest contributor to final energy consumption, accounting for nearly 39% of TFC and reflecting their continued importance in transport and industry. Electricity's share has steadily increased to around 23%, driven by growing electrification across residential, commercial and industrial sectors, while the shares of coal and natural gas have remained broadly stable. These trends indicate that India's transition is being driven by gradual diversification and electrification rather than rapid substitution of conventional fuels.

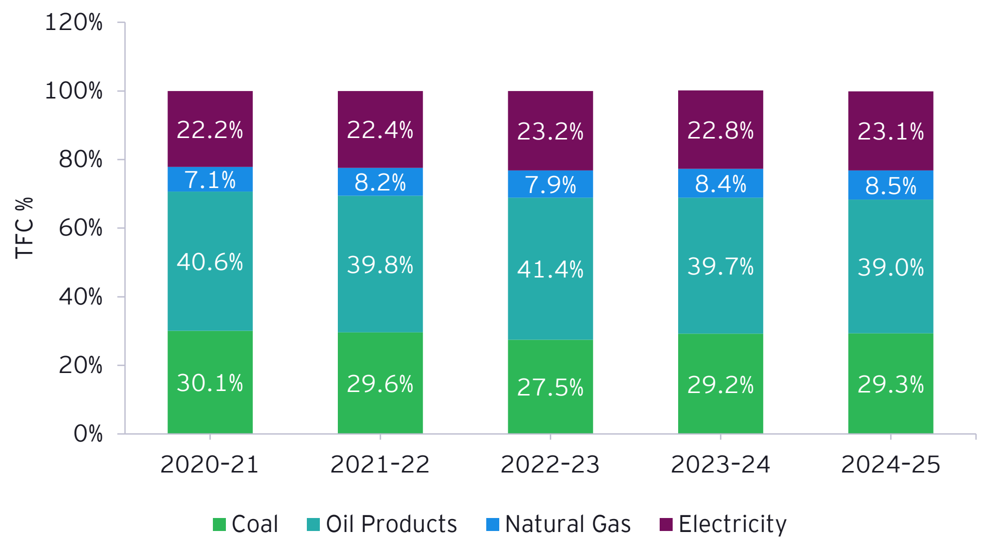
Taken together, these trends illustrate the dual nature of India's energy transition. While electricity is steadily expanding its role in the economy, imported fossil fuels remain indispensable for sectors where viable alternatives are still limited. Strengthening long-term energy security will therefore require a balanced strategy that accelerates renewable energy deployment and electrification while reducing strategic import vulnerabilities through greater domestic production, diversified supply chains and a more resilient energy system.

Source: https://iea.blob.core.windows.net/assets/9753df19-0a71-422a-b725-012c555763b3/WorldEnergyOutlook2025.pdf
https://beeindia.gov.in/WriteReadData/L45218/4600785880366907.pdf

India's energy transition is progressively reshaping the country's energy landscape, with electricity playing an increasingly important role in final energy consumption. Rapid growth in renewable energy capacity, expansion of electricity infrastructure and increasing electrification across sectors are gradually changing the composition of energy demand. However, this transition is unfolding alongside continued reliance on imported fossil fuels, highlighting that strengthening energy security will depend not only on expanding clean energy capacity but also on reducing structural import dependence across the energy value chain.

Import dependence on the primary energy supply remains one of the defining characteristics of India's energy system. Crude oil continues to be the largest component of India's energy import requirement, with imports meeting around 90% of domestic demand in 2024-25. Natural gas import dependence has also increased to around 50%, reflecting demand growth that has outpaced domestic production growth. In contrast, coal import dependence has declined to approximately 18%, supported by higher domestic production. Consequently, overall primary energy import dependence has reduced modestly from 47% to around 42% between FY17 and FY25, indicating gradual diversification of the energy system despite persistent dependence on imported oil.

Fuel wise share in total final energy consumption (TFC)



Source: https://beeindia.gov.in/WriteReadData/L45218/4600785880366907.pdf
DGFT Import Export data bank

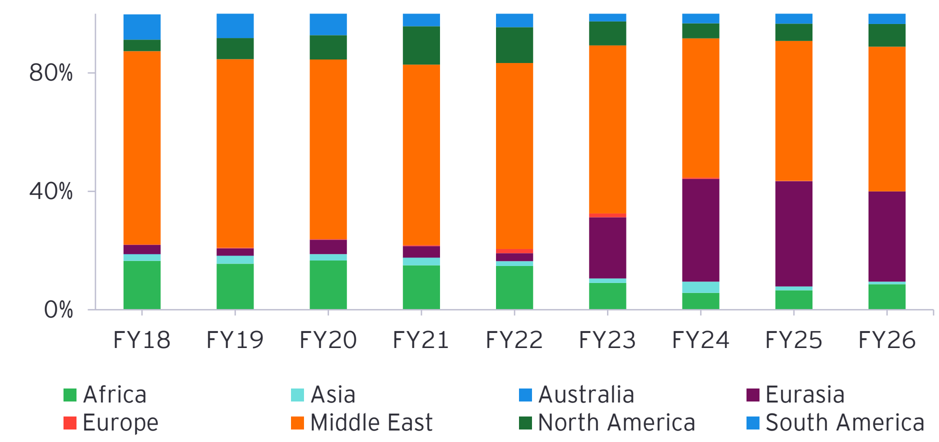
The Middle East remains central to India's energy security

India's energy security remains closely linked to developments in the Middle East, even as the country has diversified its hydrocarbon sourcing in recent years. Historically, the Middle East supplied **61% to 65% of India's crude oil imports between FY18 and FY22,** making it the dominant source of crude supply. Following the Russia-Ukraine conflict and the subsequent reshaping of global energy trade flows, India significantly increased imports from Eurasia, primarily Russian crude. Eurasia's share of crude imports rose from **2.8% in FY22 to 20.6% in FY23 and further to 35.7% in FY25,** while the Middle East's share declined from **62.8% to around 47% to 49%** over the same period. This diversification has improved procurement flexibility and reduced dependence on a single region; however, the Middle East continues to account for nearly half of India's crude oil imports and remains the country's largest source of supply.

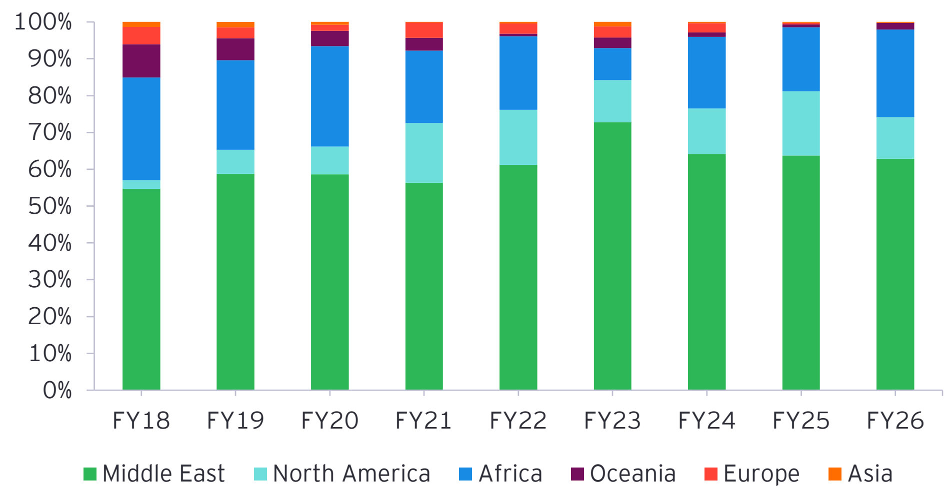
Natural gas imports exhibit a relatively higher degree of regional concentration compared with crude oil. Throughout the period under review, the Middle East accounted for between **55% and 73% of India's LNG imports,** supplying **62.9% of total LNG imports in FY26.** Although imports from North America increased from **2.3% in FY18 to over 11% in FY26,** and African suppliers continue to play an important role, diversification has progressed more gradually than in the crude oil market. This sourcing pattern reflects the structure of global LNG trade, where long-term contracts, infrastructure linkages and market dynamics often shape procurement options.

While supplier diversification has strengthened India's ability to navigate changing market conditions, regional concentration remains an important consideration in long-term energy security planning. A substantial share of India's crude oil and LNG imports continues to originate from the Middle East, which remains a key pillar of global energy supply. As India's energy demand continues to grow, further diversification of energy sources, suppliers and technologies can enhance supply resilience and procurement flexibility. Consequently, alongside supplier diversification, continued progress in energy efficiency, domestic energy development, electrification and broader fuel diversification will further strengthen India's long-term energy security and resilience.

Region-wise share of crude oil import in India



Region-wise share in import of natural gas in India



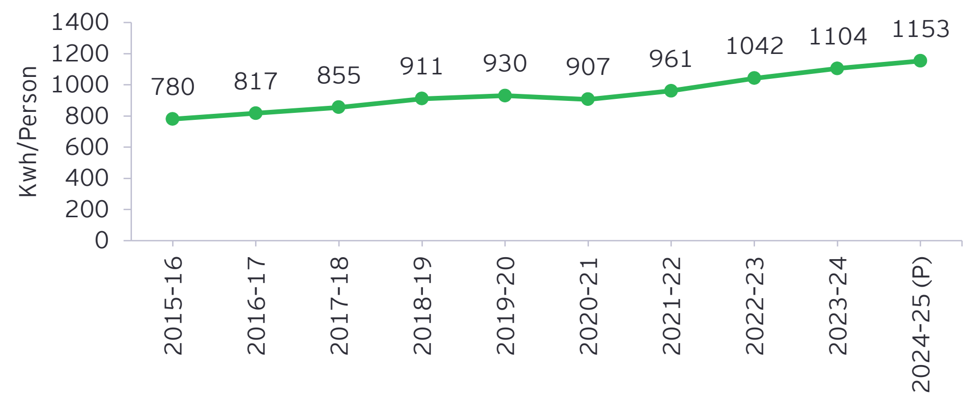
Electricity demand growth will define India's long-term energy security

As economic development accelerates, electricity is expected to become the primary carrier of energy across industry, transport, buildings, and emerging clean energy applications, making sustained growth in electricity consumption both inevitable and essential.

India's per capita electricity consumption has increased steadily over the past decade, rising from **780 kWh in 2015–16 to 1,153 kWh in 2024–25**, representing an increase of nearly **48%.** Despite temporary moderation during the pandemic period, electricity demand has resumed a strong upward trajectory, reflecting continued industrial expansion, increasing household electrification, rising cooling demand, digitalization and improvements in standards of living. The sustained year-on-year increase demonstrates that electricity demand is becoming increasingly decoupled from basic access and is now being driven by structural changes in the economy.

However, India's electricity consumption remains significantly below the levels observed in most major economies. In 2024, per capita electricity demand was approximately **1.15 MWh,** compared with around **6 MWh in China, 8 MWh in the European Union** and more than **12 MWh in North America**. Even the global average remains several times higher than India's current level. These differences highlight the substantial headroom that exists for future demand growth as India continues its journey towards becoming a developed economy.

India electricity consumption per capita (in Kwh)



Source: DGFT Import Export data bank
https://www.mospi.gov.in/publications-reports/innerpage/2817 , https://iea.blob.core.windows.net/assets/9753df19-0a71-422a-b725-012c555763b3/WorldEnergyOutlook2025.pdf

Looking ahead to 2035, electricity demand is projected to increase across all major regions, with India's growth expected to be among the fastest. This reflects the combined impact of rising incomes, rapid urbanization, expansion of manufacturing under initiatives such as Make in India, increasing adoption of electric mobility, wider deployment of electric appliances and the gradual electrification of industrial processes. As sectors that have traditionally depended on fossil fuels increasingly transition towards electricity, the role of the power sector will continue to expand across the broader economy.

The implications for energy security are significant. Rising electricity demand implies not only substantial additions in generation capacity but also corresponding investments in storage, transmission and distribution networks to ensure that electricity remains reliable, affordable and resilient. As renewable energy assumes a larger share of the generation mix, the ability of the power system to integrate variable resources, maintain grid stability and respond to changing demand patterns will become equally important as expanding generation itself.

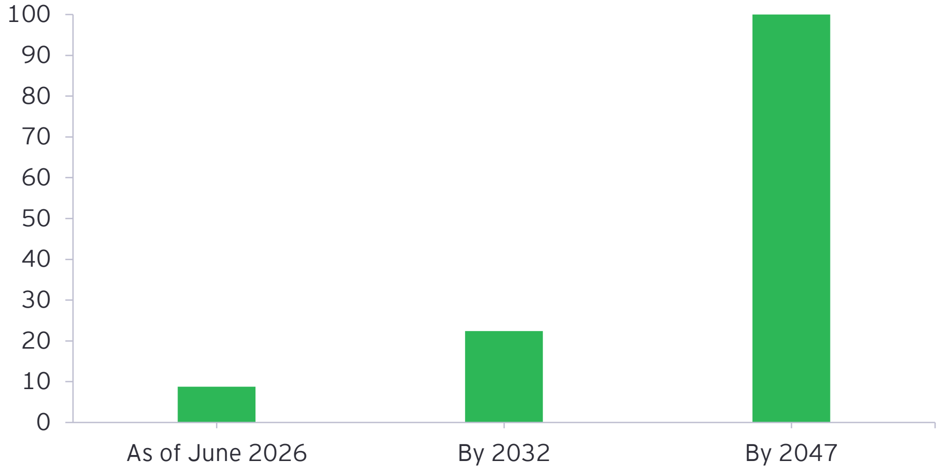
Taken together, these trends reinforce that India's energy transition is fundamentally an electrification-led transition. The country's relatively low level of per capita electricity consumption represents both a development opportunity and an infrastructure challenge. Meeting future demand securely will depend on sustained investment across the entire electricity value chain, enabling India to support economic growth while advancing its objectives of energy independence, efficiency and long-term system resilience.

Electricity demand MWh per capita

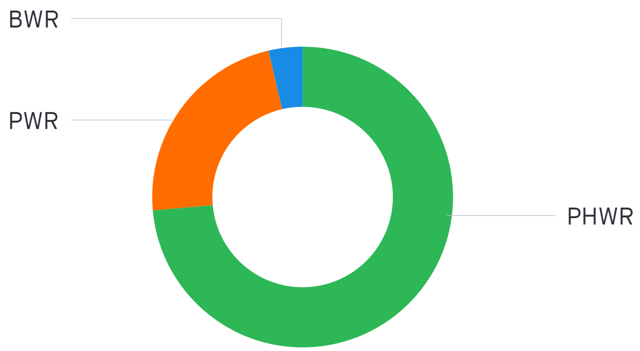
Source: https://www.mospi.gov.in/publications-reports/innerpage/2817 , https://iea.blob.core.windows.net/assets/9753df19-0a71-422a-b725-012c555763b3/WorldEnergyOutlook2025.pdf

Nuclear power: A critical enabler of India's energy transition

India's nuclear installed capacity trajectory (GW)



Nuclear installed capacity in India (MW) as of FY26



As India's electricity demand continues to grow, ensuring a secure, reliable and low-carbon power system will depend on a balanced portfolio of generation technologies. While renewable energy will remain the primary driver of capacity additions, its increasing share also raises the need for dependable, round-the-clock sources of clean electricity that are not dependent on weather conditions. In this context, nuclear energy assumes strategic importance by providing firm, low-carbon baseload generation capable of supporting a highly renewable electricity system.

India's nuclear program is entering a period of significant expansion. Installed nuclear capacity currently stands at around **8.78 GW**, with projects under construction expected to increase capacity to approximately **22.38 GW** by the early 2030s. Beyond this, the planned deployment of additional reactors—including Pressurized Heavy Water Reactors (PHWRs), **Pressurized Water Reactors (PWRs), Fast Breeder Reactors (FBRs), Bharat Small Reactors (BSRs)** and **Bharat Small Modular Reactors (BSMRs)**—envisions total installed capacity reaching **about 100 GW by 2047**, in line with India's long-term energy and climate ambitions.

The roadmap also reflects an important technological diversification of India's nuclear fleet. While PHWRs remain the backbone of the program, future expansion increasingly incorporates advanced reactor technologies and small modular designs that offer greater flexibility, improved safety features and broader deployment opportunities. This diversified approach is expected to strengthen domestic manufacturing capabilities, support technology development and reduce dependence on imported fossil fuels over the long term.

Expanding nuclear power delivers benefits that extend beyond electricity generation. Unlike variable renewable resources, nuclear plants provide continuous power with high-capacity factors, contribute to grid stability, reduce exposure to volatile international fuel markets and help limit carbon emissions. As electricity demand rises and sectors such as transport, industry and green hydrogen become increasingly electrified, the availability of reliable baseload generation will become progressively more important.

Taken together, the planned expansion illustrates that nuclear energy is not intended to replace renewable energy, but to complement it. A power system dominated by renewable generation will increasingly require firm, dispatchable and low-carbon sources to maintain reliability. In that context, nuclear power is expected to become one of the key pillars of India's strategy for building an independent, efficient and resilient electricity system capable of supporting sustained economic growth through 2047 and beyond.

Source: : https://www.pib.gov.in/FactsheetDetails.aspx?Id=150617&lang=1&reg=3#:~:text=Installed%20Capacity%3A%20India's%20current%20nuclear,of%20India's%20total%20electricity%20generation. , Home:Nuclear Power Corporation of India Limited

Supply chain independence will define the next phase of energy security

India's energy transition is no longer defined solely by the availability of fuels such as coal, oil and natural gas. As the power system becomes increasingly electrified and clean energy technologies are deployed at scale, energy security is progressively shifting towards the availability of critical minerals, advanced manufacturing capabilities and resilient supply chains. In the coming decades, the ability to secure these strategic inputs will be as important as ensuring access to conventional energy resources.

The scale of this challenge is evident from India's projected mineral requirements. Between **2025 and 2070**, demand for critical minerals is expected to increase substantially to support renewable energy, battery storage, electric mobility, nuclear energy and modern electricity infrastructure. Copper alone is projected to require over **66 million tons**, followed by graphite **(46 million tons),** silicon **(19.5 million tons),** phosphorus **(16.7 million tons)** and nickel **(11.5 million tons).** These minerals form the backbone of solar PV modules, batteries, transmission networks, electric motors, power electronics and other technologies essential for a low-carbon economy.

While India possesses meaningful domestic resources for a few minerals such as copper, graphite, titanium and phosphorus, the country remains highly dependent on imports for many strategically important materials. India currently sources several critical minerals, including **lithium, nickel, cobalt, silicon, rare earth elements, molybdenum, tin, selenium, indium, gallium, tungsten, niobium, germanium and platinum group elements,** primarily through international supply chains. Even where domestic resources exist, commercially exploitable reserves are often limited or remain underdeveloped, creating vulnerabilities across the clean energy supply chain.

These dependencies introduce a new dimension to energy security. Unlike conventional fuels, where risks are associated primarily with production and transportation, critical mineral supply chains are concentrated across a limited number of countries involved in mining, refining, processing and manufacturing. Geopolitical tensions, export restrictions, processing bottlenecks, or disruptions in global logistics can therefore have significant implications for the pace, cost and resilience of India's energy transition.

Strengthening long-term energy security will therefore require a comprehensive supply chain strategy extending beyond mineral extraction. Accelerating domestic exploration, expanding mineral processing and refining capacity, developing indigenous manufacturing ecosystems, promoting recycling and circular economy approaches, and securing international partnerships for critical minerals will all be essential. As India transitions towards a more electrified economy, energy security will increasingly be determined not only by the energy it produces but also by its ability to secure the materials and technologies that power the transition.

India's comparison of CETM demand with remaining resources, reserves and import dependence

S. No.	Mineral	Demand (2025-2070) (kt)	Resources (kt)	Reserves (kt)	Import Dependence (%)
1	Copper	66,069	14,96,979	1,63,891	57
2	Graphite	46,489	2,03,060	8,563	28
3	Silicon	19,538	-	-	100
4	Phosphorous	16,689	2,80,377	30,876	85
5	Nickel	11,543	1,89,000	-	100
6	Lithium	5,468	-	-	100
7	Cobalt	1,454	45,000	-	100
8	Vanadium	783	24,633	-	46
9	Rare Earth Elements (REE)	668	459	-	100
10	Molybdenum	273	27,203	-	100
11	Titanium	124	4,11,108	15,998	0
12	Tin	118	102	0.97	100
13	Tellurium	52	-	-	-
14	Cadmium	50.45	5.69	-	-
15	Zirconium	47.79	1,674	669	78
16	Selenium	37.34	-	-	100
17	Indium	20.64	-	-	100
18	Gallium	4.27	-	-	100
19	Tungsten	4.04	144	-	100
20	Niobium	1.87	-	-	100
21	Germanium	1.85	-	-	100
22	Platinum Group Elements (PGE)	0.3	0.02	-	100
23	Strontium	0.004	-	-	100

Source: : https://niti.gov.in/sites/default/files/2026-02/Scenarios-Towards-Viksit-Bharat-and-Net-Zero-Critical-Mineral-Assessment-Demand-and-Supply.pdf

Transforming India's power sector, which requires unprecedented capital investment

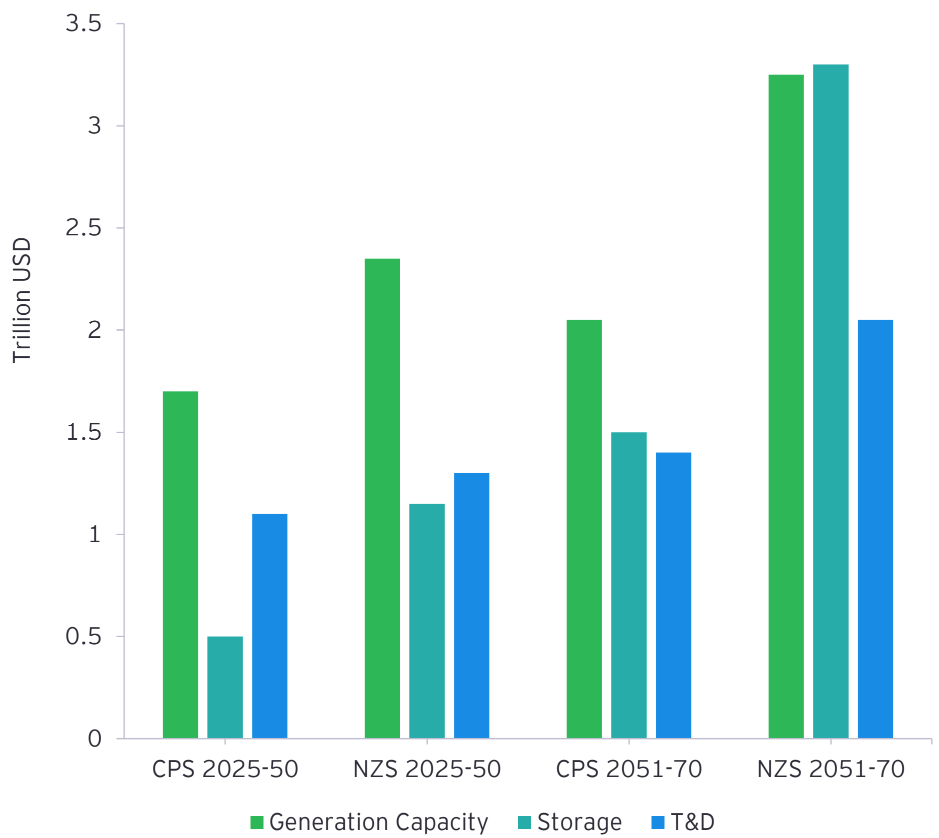
Meeting India's rapidly growing electricity demand while strengthening energy security and advancing decarbonization will involve unprecedented investment across the entire power value chain – not only in generation capacity but also in energy storage and transmission infrastructure. As renewable energy assumes a larger share of the electricity mix, the supporting systems required to integrate, transmit and manage electricity will become equally critical in ensuring reliability, flexibility and resilience.

NITI Aayog and CEA scenario analysis highlight the scale and changing composition of these investment requirements. Under the Current Policies Scenario (CPS), generation remains the dominant investment area during 2025–2050, requiring around US$1.7 trillion, while storage accounts for a comparatively modest US$0.5 trillion, reflecting continued reliance on conventional sources of system flexibility. In contrast, the Net Zero Scenario (NZS) requires substantially higher investments across all segments, with storage emerging as one of the fastest-growing components. Investment in energy storage more than doubles to approximately US$1.15 trillion during 2025–2050 and rises further to around US$3.3 trillion during 2051–2070, eventually exceeding investment in generation capacity. This underscores the increasingly important role of storage in balancing variable renewable generation, enhancing grid flexibility and enabling round-the-clock clean power supply.

The long-term investment profile also demonstrates that capital requirements remain elevated even after large-scale deployment of renewable energy technologies. Transmission and distribution infrastructure requires sustained investment, increasing from around US$1.1 trillion in the near term to more than US$2 trillion over subsequent decades. As electricity demand grows and the power system becomes more decentralized and renewable-intensive, modern grid infrastructure will be central to integrating diverse energy resources, maintaining system stability and improving operational resilience.

Taken together, these trends demonstrate that India's energy transition is fundamentally an infrastructure transformation rather than simply a generation expansion program. While new renewable generation remains indispensable, the growing importance of storage and grid investments highlights that long-term energy security will increasingly depend on the country's ability to build a flexible, interconnected, and digitally enabled electricity system capable of reliably supporting future economic growth.

Investment required in power sector (Trillion US$)



Source: : Scenarios-Towards-Viksit-Bharat-and-Net-Zero-Sectoral-Insights-Power, Niti Aayog Report, CEA

As

India's power system evolves,

investment priorities gradually shift from expanding generation capacity towards strengthening storage and grid infrastructure to support a more flexible and resilient electricity system.

2 The legacy dependence: India’s oil and gas import exposure

Growing energy demand continues to outpace domestic oil and gas production

India's energy transition is unfolding alongside a growing dependence on imported hydrocarbons to meet rising energy demand. Despite the rapid expansion of renewable energy capacity and increasing electrification across several sectors, crude oil and natural gas continue to play a critical role in transportation, industry, petrochemicals and other hard-to-abate applications. As a result, the balance between domestic production and imports remains a key determinant of India's energy security.

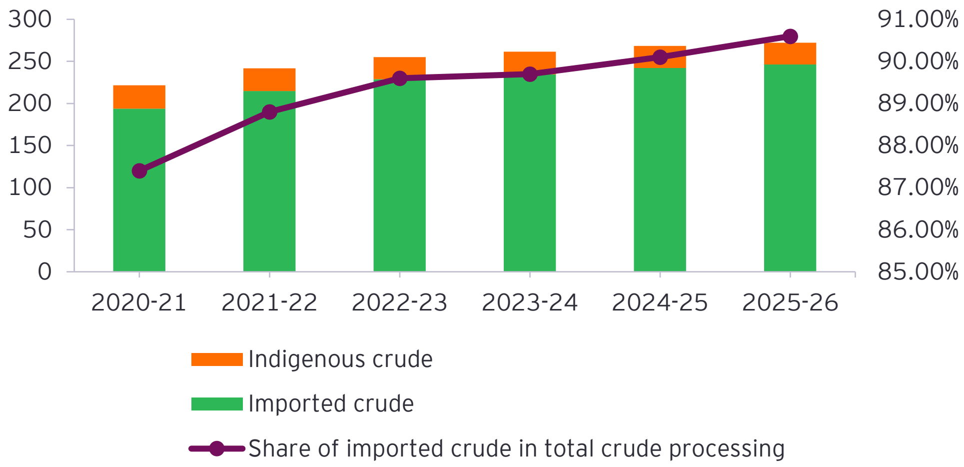
In the case of crude oil, domestic production has remained largely stagnant over recent years, declining marginally from 28.0 MT in FY21 to 25.7 MT in FY26. Over the same period, imported crude increased from 193.8 MT to 246.4 MT as refinery throughput and petroleum demand continued to grow. Consequently, the share of imported crude in total crude processing increased from 87.4% in FY21 to 90.6% in FY26, indicating that nine out of every ten barrels of crude processed in India are now sourced from international markets. The trend highlights the growing importance of secure and diversified crude procurement strategies in maintaining supply security and supporting economic growth.

Natural gas presents a somewhat different picture. Domestic production increased from 27.8 BCM in FY21 to a peak of 35.7 BCM in FY24, before moderating to 34.3 BCM in FY26. However, increasing demand from city gas distribution, industry and fertilizer sectors has continued to require substantial LNG imports. Although LNG import dependence fell from 54.4% in FY21 to 43.9% in FY23 owing to higher global LNG prices and stronger domestic production, it subsequently increased to around 50% in FY25 and FY26 as demand recovered. As a result, approximately one out of every two units of natural gas consumed in India continues to be sourced from international markets.

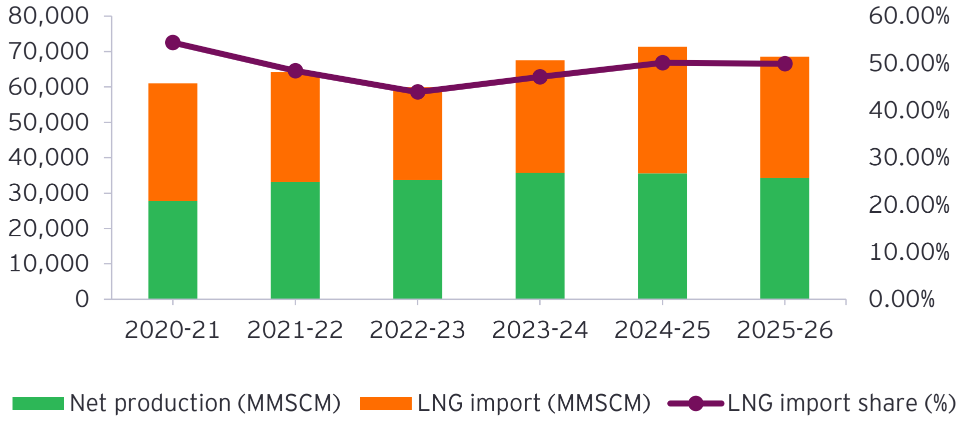
These trends underscore the growing gap between domestic hydrocarbon production and India's expanding energy requirements. While natural gas production has shown modest growth and crude oil output has remained broadly stable at lower levels, demand growth continues to outpace domestic supply additions. Consequently, imported crude oil and LNG remain indispensable to meeting India's energy needs, increasing the country's exposure to international market dynamics, geopolitical developments and global price volatility. This structural dependence reinforces the importance of diversifying import sources, strengthening supply resilience and expanding domestic energy alternatives as India seeks to enhance its long-term energy security.

Source: : https://ppac.gov.in/

India imported crude and indigenous crude oil processing (MMT)



India imported LNG and domestic net production (MMSCM)



Source: : https://ppac.gov.in/
https://iea.blob.core.windows.net/assets/9753df19-0a71-422a-b725-012c555763b3/WorldEnergyOutlook2025.pdf

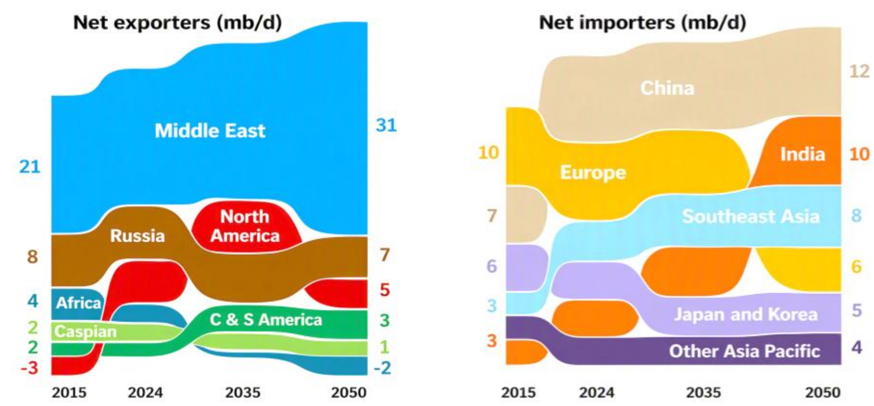
The Middle East will continue to anchor global oil supply as India's import requirement grows

India's long-term energy security will continue to be shaped by structural trends in global oil trade. While the geography of oil demand is expected to shift steadily towards Asia, the Middle East is projected to remain the world's largest net oil exporting region through 2050, supplying an increasing share of internationally traded crude oil. This sustained concentration of export capacity reinforces the region's central role in global energy markets despite the ongoing expansion of renewable energy and electrification.

At the same time, India is projected to emerge as the world's second-largest net oil importer by 2050, with net imports approaching 10 million barrels per day, surpassed only by China. Unlike several advanced economies where oil demand is expected to plateau or decline, India's growing economy, expanding industrial base, rising mobility demand and continued reliance on liquid fuels in hard-to-abate sectors are expected to sustain significant crude oil import requirements over the coming decades.

Viewed together, these projections illustrate a defining characteristic of India's long-term energy security landscape. As the center of global oil demand shifts towards Asia while export capacity remains concentrated in the Middle East, India's energy security will continue to be closely influenced by developments in international oil markets, geopolitical stability and global supply chains. These structural trends provide the broader context for understanding the country's continued focus on energy independence, efficiency and resilience as its energy transition accelerates.

Net oil trade for exporters and importers in the CPS to 2050



India's hydrocarbon imports are becoming more diversified, but concentration risks persist

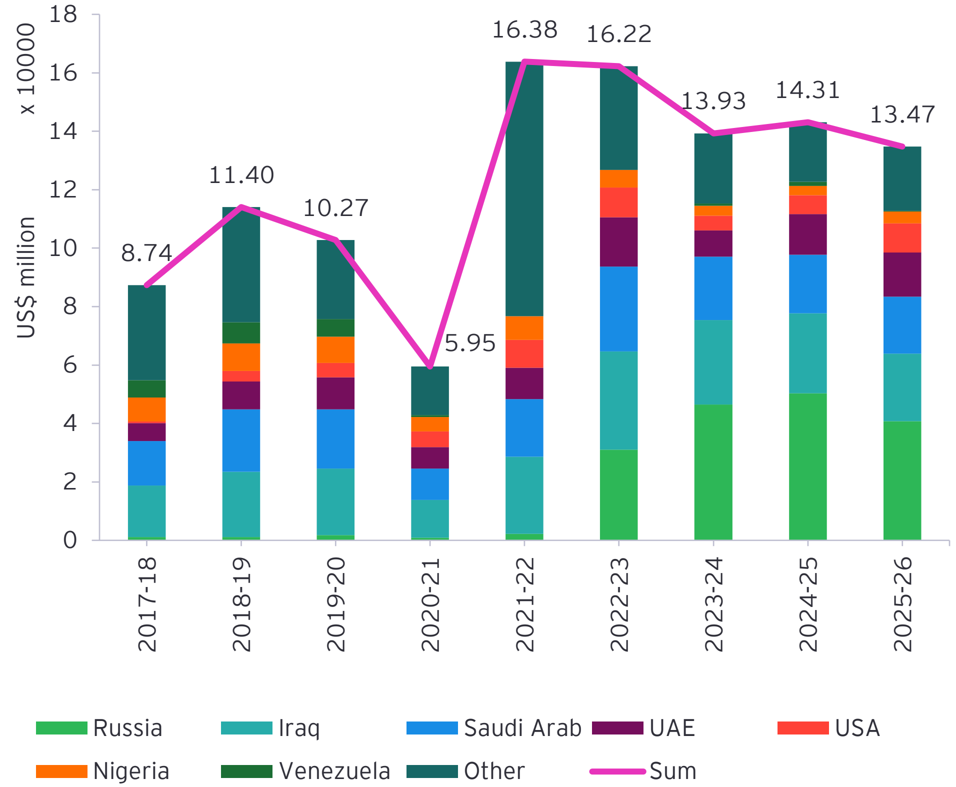
India's hydrocarbon procurement strategy has evolved significantly over the past decade, reflecting changing global energy markets, geopolitical developments and a deliberate effort to diversify import sources. While overall crude oil and LNG import volumes have increased in line with growing domestic demand, India's supplier portfolio has become considerably more dynamic, enhancing procurement flexibility and reducing reliance on any single exporting country.

The transformation has been particularly pronounced in crude oil imports. During FY18-FY22, India's crude imports were predominantly sourced from traditional Middle Eastern suppliers, with Iraq, Saudi Arabia and the UAE together accounting for the majority of imports. However, following the Russia-Ukraine conflict and the subsequent reconfiguration of global oil trade flows, India rapidly expanded purchases of discounted Russian crude. Russia's share of India's crude imports increased from less than 2% in FY22 to nearly 19% in FY23, 33% in FY24 and approximately 35% in FY25, making it India's largest crude supplier. At the same time, imports continued to be sourced from Iraq, Saudi Arabia, the UAE, the United States, Nigeria and several other producing countries, creating a significantly more diversified supplier mix than existed prior to FY23. The changing composition demonstrates India's ability to adapt procurement strategies in response to evolving market conditions while balancing cost, supply security and geopolitical considerations.

A similar, albeit less dramatic, diversification trend is evident in LNG imports. While Qatar has consistently remained India's largest LNG supplier, its share of total LNG imports has moderated over time as supplies from the United States, UAE, Oman, Angola and Nigeria have expanded. Qatar accounted for roughly 40% to 50% of LNG imports across most years, but the growth of alternative suppliers has broadened India's sourcing options and reduced dependence on a single exporter. The increasing contribution of the United States and Middle Eastern suppliers outside Qatar reflects India's efforts to develop a more geographically diversified LNG procurement portfolio. Nevertheless, LNG sourcing remains more concentrated than crude oil imports, reflecting the influence of long-term contracts, infrastructure constraints and the relatively lower liquidity of global LNG markets.

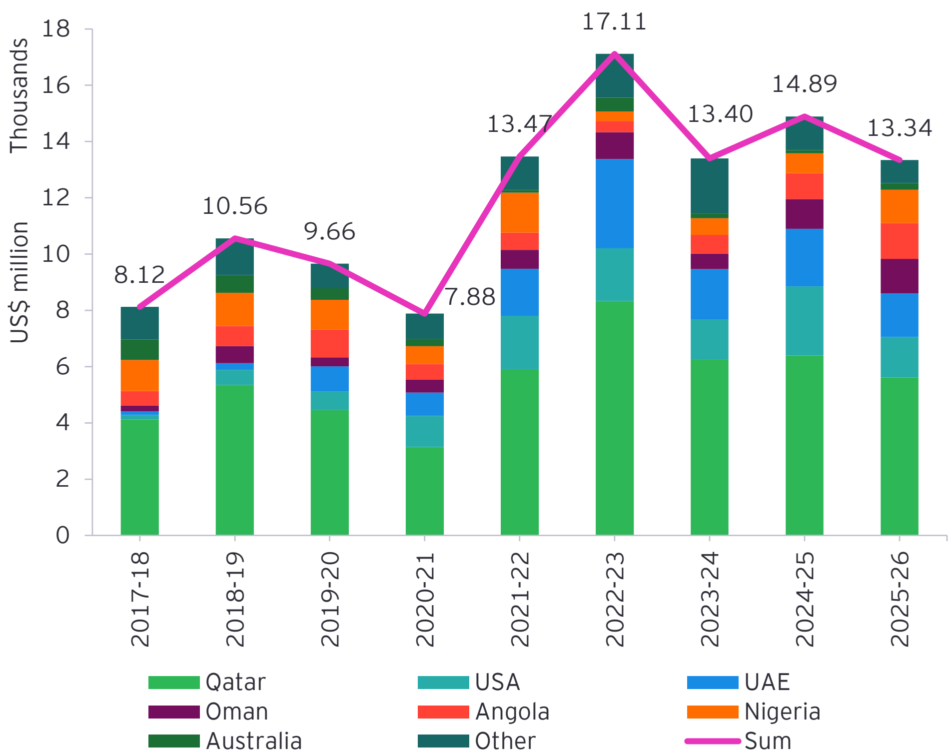
Overall, India's hydrocarbon import profile has become substantially more diversified at the supplier level over the past decade. The emergence of Russia as a major crude supplier and the gradual broadening of LNG sourcing beyond Qatar have strengthened procurement flexibility and enhanced India's ability to respond to changing market conditions. While a significant share of India's crude oil and LNG imports continues to originate from key producing regions, particularly the Middle East, ongoing diversification of suppliers has contributed to a more balanced import portfolio. As India's energy system continues to evolve, further diversification of supply sources, together with energy efficiency, domestic energy development, electrification and strategic reserves, will continue to strengthen long-term energy security and supply resilience.

Petroleum crude import trend in India



Source: : https://tradestat.commerce.gov.in/eidb/commodity_wise_all_countries_import

LNG import trend in India



Strategic Petroleum Reserves strengthen India's energy security architecture

Strategic Petroleum Reserves (SPR) form an important component of India's energy security architecture by providing a dedicated emergency stock of crude oil that can be deployed during periods of supply disruption, geopolitical crises or extreme price volatility. Unlike commercial inventories maintained for operational requirements, strategic reserves are designed to strengthen national preparedness against unforeseen external shocks affecting global crude oil markets. The Strategic Petroleum Reserve complements India's broader oil security framework, which also includes diversification of crude import sources, long-term procurement arrangements, commercial inventories maintained by oil marketing companies, and institutional mechanisms for emergency response. Operational preparedness is maintained through regular testing and circulation of crude oil within the storage caverns, while emergency deployment decisions are undertaken through an Inter-Ministerial Empowered Committee. India also participates in international emergency response exercises that assess preparedness under simulated global supply disruption scenarios.

International comparison illustrates that strategic petroleum reserve programs vary considerably across major economies, reflecting differences in energy demand, import requirements, policy priorities and historical approaches to energy security. Countries such as Japan, South Korea, Germany, France and China have developed strategic reserve systems of varying scale and coverage over time. In India, the Strategic Petroleum Reserve program forms an important component of the country's broader energy security architecture and has expanded progressively over the past decade, with additional capacity approved to further strengthen preparedness and supply resilience. As India's petroleum consumption increases and crude oil imports continue to account for a significant share of domestic demand, strategic petroleum reserves provide an additional layer of security by enhancing the country's ability to manage short-term supply disruptions while supporting continuity of refinery operations and fuel availability.

India's current SPR capacity

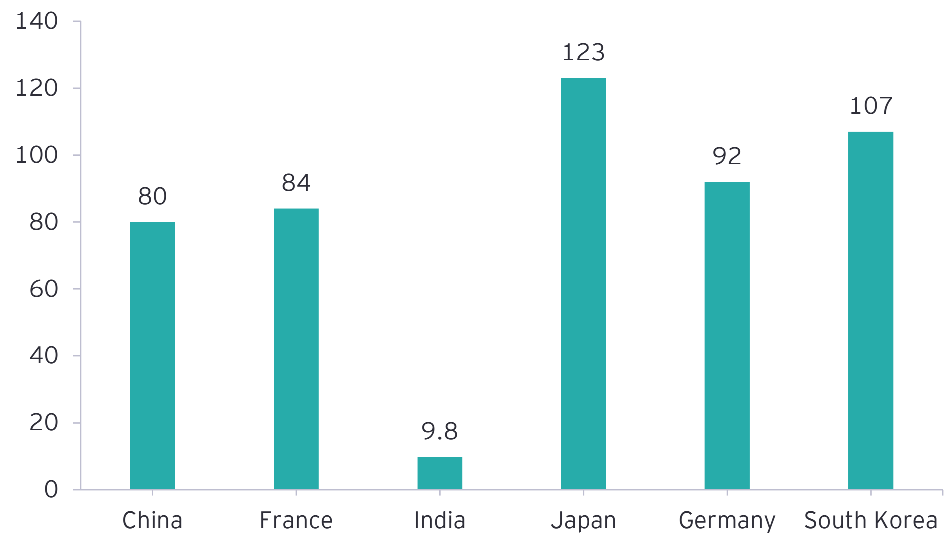
5.33 MMT

Approved additional SPR capacity

6.5 MMT

Source: https://tradestat.commerce.gov.in/eidb/commodity_wise_all_countries_import
IEA https://www.iea.org/data-and-statistics/data-tools/oil-stocks-of-iea-countries?__cf_chl_f_tk=gfzsWmz1v7kk4vH.sD7PJG3f9BN4EVK10dMaNylqMSw-1783354894-1.0.1.1-rTNUzEDqbV.8s0LXs4WPlg9Jbco7TKdvMxBrb6ueH6o, , https://www.iosrjournals.org/iosr-jhss/papers/Vol.31-Issue5/Ser-1/G3105017579.pdf

SPR of major economies (no. of days)



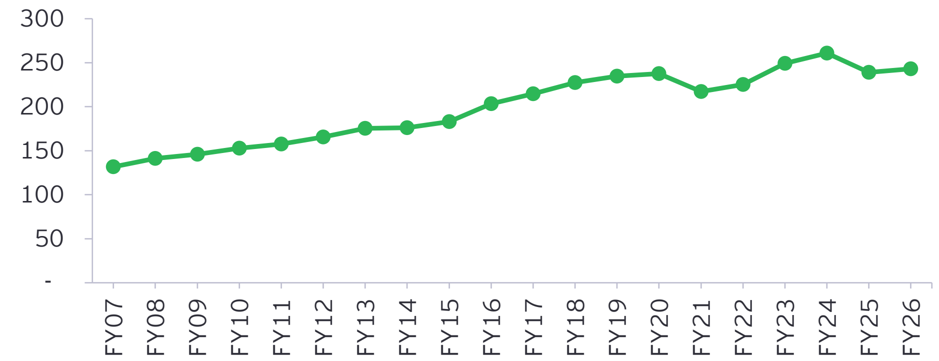
Petroleum products remain indispensable across India's economy

India's energy transition is unfolding along with sustained growth in petroleum consumption, underscoring the continued importance of liquid fuels across transport, industry, petrochemicals and other economic activities. While renewable energy deployment and electrification are accelerating across multiple sectors, petroleum products remain essential for applications where commercially viable alternatives are either limited or yet to be deployed at scale. As a result, oil demand has continued to expand even as India's energy mix becomes progressively more diversified.

Source: IEA https://www.iea.org/data-and-statistics/data-tools/oil-stocks-of-iea-countries?__cf_chl_f_tk=gfzsWmz1v7kk4vH.sD7PJG3f9BN4EVK10dMaNyIqMSw-1783354894-1.0.1.1-rTNUzEDqbV.8s0LXs4WPlg9Jbco7TKdvMxBrb6ueH6o, , https://www.iosrjournals.org/iosr-jhss/papers/Vol.31-Issue5/Ser-1/G3105017579.pdf
https://ppac.gov.in/, ICED Dashboard by NITI Aayog

Total petroleum product consumption increased from approximately **123 MMT in FY07** to **243 MMT in FY26**, nearly doubling over the past two decades. Growth has been largely underpinned by rising economic activity, increasing freight movement, expanding vehicle ownership, growth in aviation demand and continued industrialization. Petroleum consumption rose steadily from 123 MMT in FY06 to 238 MMT in FY20 before temporarily declining to 217 MMT in FY21 during the COVID-19 pandemic. Demand subsequently recovered strongly, reaching a record **261 MMT in FY24**, before moderating to **239 MMT in FY25** and recovering to 243 MMT in FY26. Despite short-term fluctuations, the long-term trajectory remains firmly upward, reflecting the continued role of petroleum products in supporting India's economic growth and development.

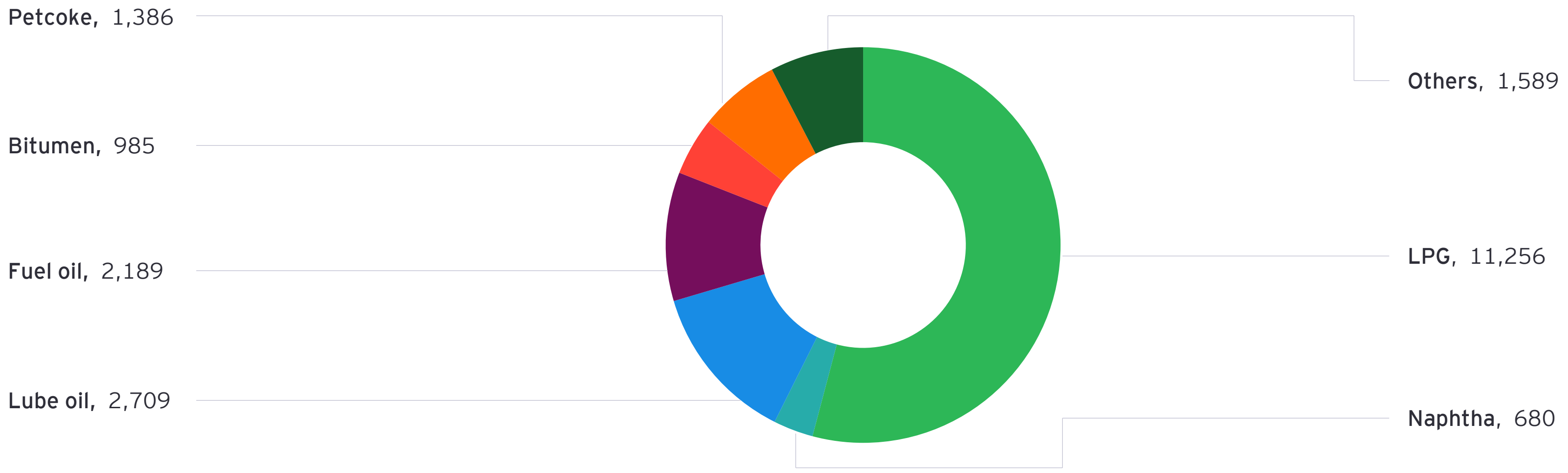
Trend of total consumption of petroleum products in India (MMT)

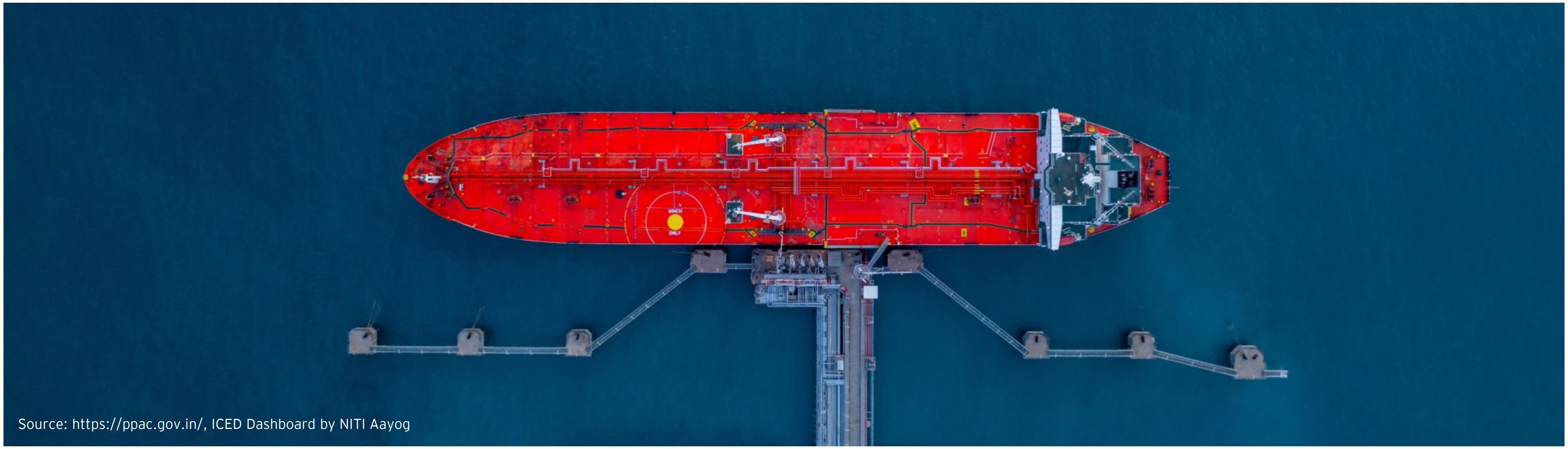


The composition of petroleum product imports further illustrates the sectors driving import dependence. In FY26, **LPG accounted for approximately 54% of petroleum product imports by value**, making it by far the largest imported petroleum product. This was followed by **lube oil (13%), fuel oil (11%), other petroleum products (8%), petcoke (7%), bitumen (5%) and naphtha (3%).** The predominance of LPG imports reflects strong demand from households and commercial consumers, while imports of fuel oil, petcoke and lubricants underscore the continued reliance of industrial and infrastructure sectors on petroleum-based products.

Taken together, these trends indicate that India's dependence on imported petroleum extends well beyond transportation fuels. Growing demand from the residential, commercial, industrial and infrastructure sectors continues to support petroleum consumption despite rapid progress in renewable energy and electrification. As India's economy expands and energy demand rises, petroleum products are expected to remain integral to several end-use applications, reinforcing their strategic importance within the country's broader energy security framework.

Share of petroleum products imports in India (in terms of value) in FY26

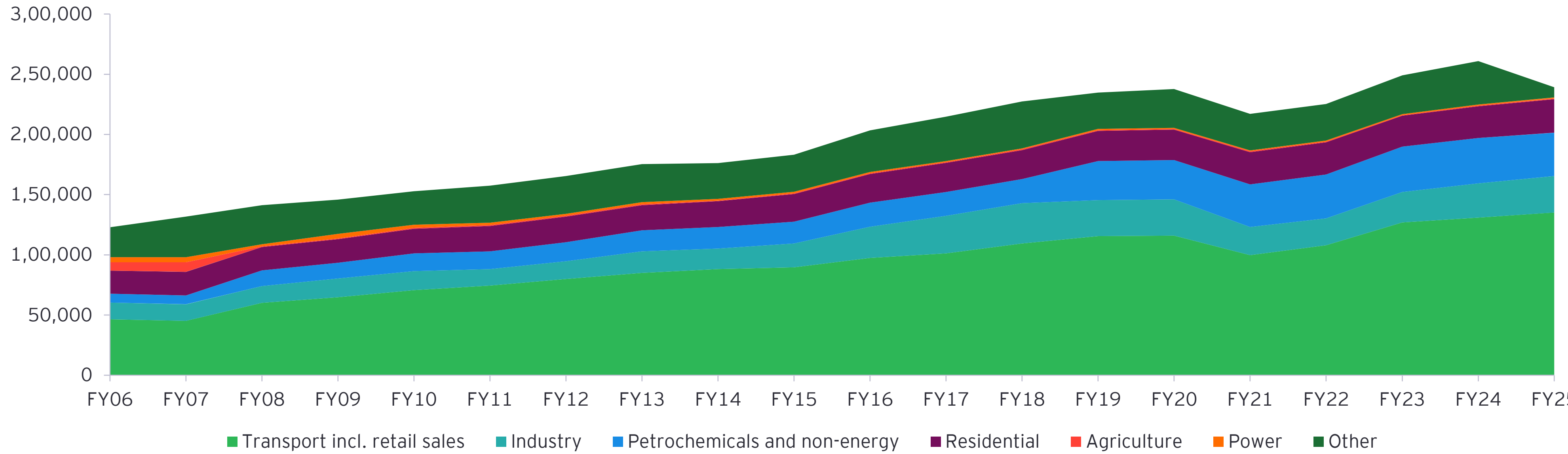




Source: https://ppac.gov.in/, ICED Dashboard by NITI Aayog

Transport and industry sector continues to drive petroleum consumption

Historical trend of sector-wise petroleum product consumption ('000 tons)



Agriculture and power generation now represents only a small proportion of total petroleum demand

India's petroleum consumption profile reflects both the enduring importance of oil in the economy and the changing nature of energy demand as electrification advances. While petroleum products remain critical across several end-use segments, their role is increasingly concentrated in sectors where commercially viable alternatives are either limited or still emerging. The evolution of sectoral consumption patterns therefore provides an important lens through which to understand India's broader energy transition.

Transport remains the dominant consumer of petroleum products, accounting for approximately 57% of total petroleum consumption in FY25. Growing freight movement, rising passenger mobility and expanding vehicle ownership continue to drive demand for transport fuels, making mobility the single largest source of petroleum consumption. Alongside transport, petrochemical and non-energy applications (15%) and industrial uses (13%) constitute major demand centres, reflecting the continued importance of petroleum as both an energy source and a feedstock for chemicals, plastics, synthetic

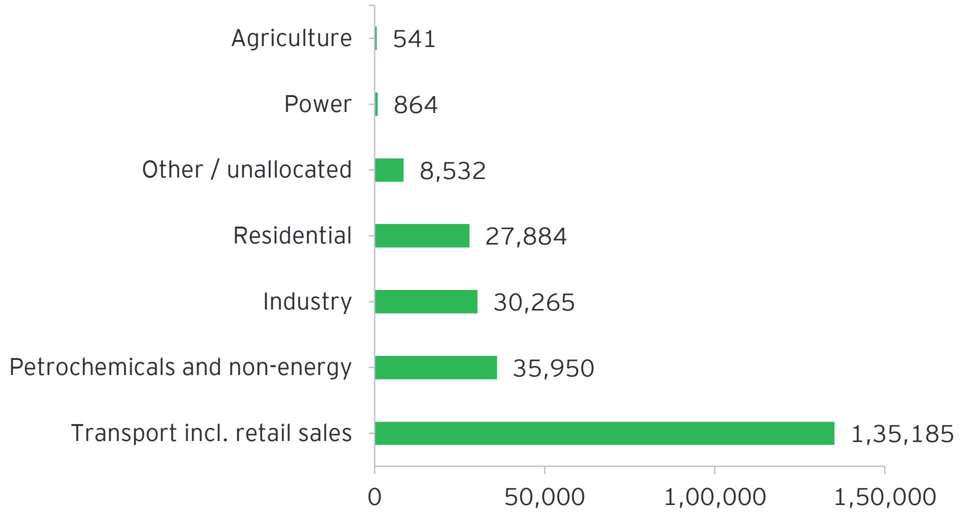
Source: ICED dashboard by NITI Aayog

fibres and numerous industrial products. Residential consumption also remains significant, supported primarily by the widespread use of LPG.

In contrast, the role of petroleum in agriculture and power generation has declined substantially over time and now accounts for less than 1% of total consumption. The reduction reflects the growing penetration of electric irrigation pumps, expansion of grid connectivity, increased availability of reliable electricity supply and the rapid growth of renewable energy-based power generation. As electricity has become more accessible and cost-effective, these sectors have progressively reduced their dependence on petroleum products.

This shift illustrates a broader trend already underway in India's energy system: electrification is displacing petroleum demand in sectors where alternatives are readily available, while oil consumption is increasingly concentrated in transport, industry and petrochemical applications where substitution remains more challenging. Understanding this divergence is critical to assessing India's future energy pathway and highlights why electricity is expected to play an increasingly central role in the country's long-term decarbonisation and energy security strategy.

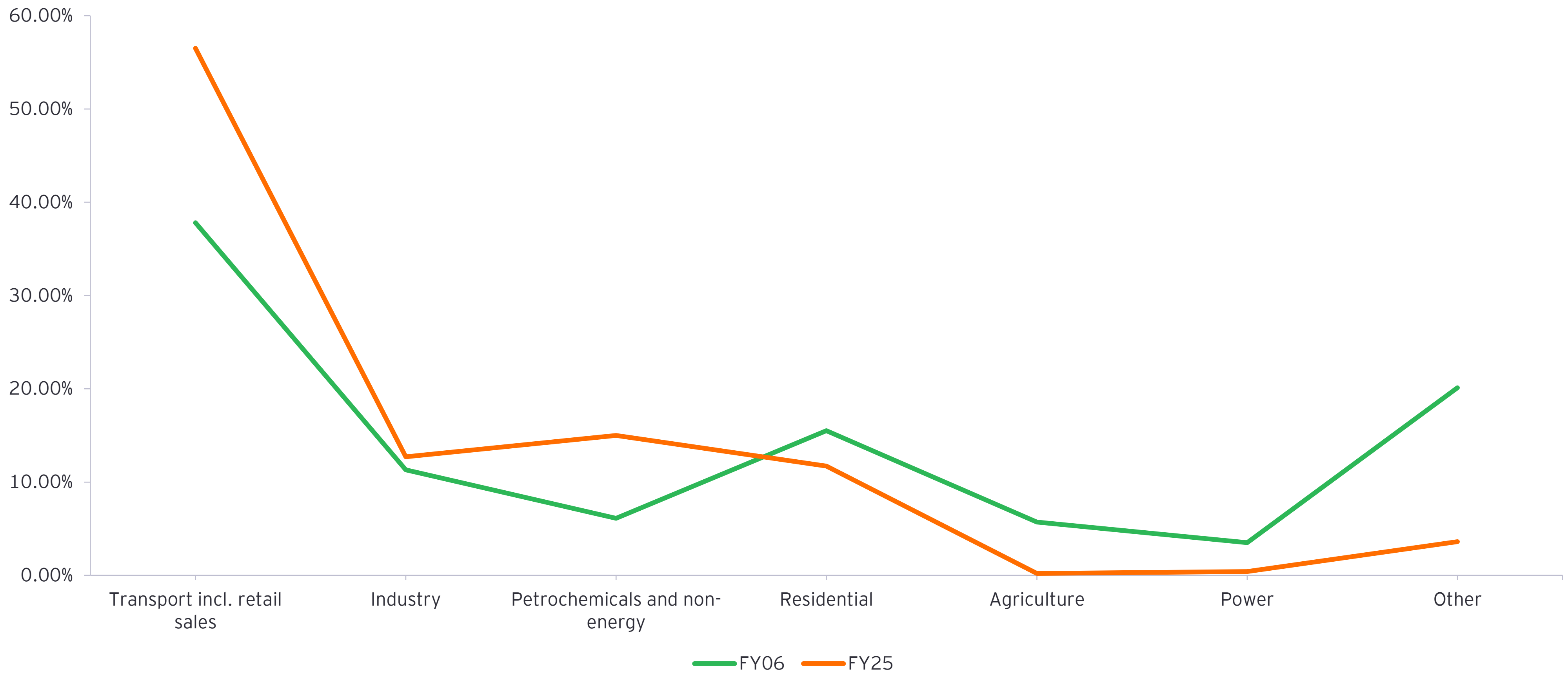
Total consumption of petroleum products in India (in '000 tons) in FY25



Source: ICED dashboard by NITI Aayog

Petroleum products remain indispensable across India's economy

Growth analysis of petroleum product end-use consumption



Source: ICED dashboard by NITI Aayog

Electrification is reshaping end-use petroleum consumption

The analysis presented in this chapter highlights an important characteristic of India's evolving energy landscape. While petroleum products continue to play a significant role in meeting the country's energy requirements, the composition of demand is gradually changing. Petroleum consumption is increasingly concentrated in transport, industrial and petrochemical applications, while its role in sectors such as agriculture and power generation has declined significantly as electricity has become more accessible, reliable and cost-effective.

This trend illustrates the growing contribution of electrification in sectors where commercially viable alternatives are available. Between FY06 and FY25, the combined share of agriculture and power generation in petroleum consumption declined from nearly 9% to less than 1%, reflecting the impact of grid expansion, rural electrification, improved power supply and increasing renewable energy deployment. These sectors demonstrate how sustained investment in electricity infrastructure can support the diversification of energy use across the economy.

At the same time, India's energy landscape continues to evolve along with changing global energy markets, expanding domestic energy alternatives and ongoing efforts to strengthen supply security. As the economy grows and energy demand increases, continued progress in electrification, energy efficiency, domestic energy development, strategic reserves and supply diversification will further enhance the resilience and flexibility of the energy system.

Viewed together, these trends suggest that the next phase of India's energy transition will be increasingly shaped by the expanding role of electricity across end-use sectors. The ability of the power sector to provide affordable, reliable and increasingly clean electricity will play an important role in supporting energy security, economic competitiveness and long-term decarbonization objectives.

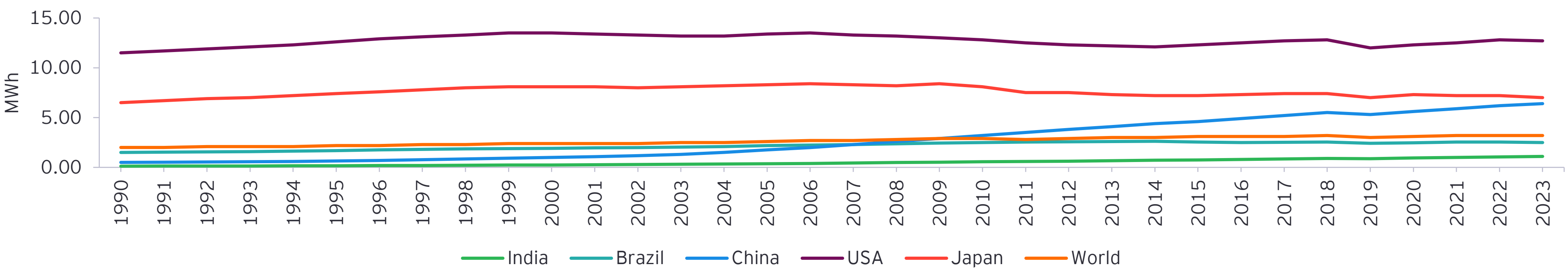
Source: ICED dashboard by NITI Aayog

3

From molecules to electrons: Demand growth and the grid build-out

Strong economic growth has driven rising electricity demand, yet India's per capita electricity consumption remains below the world average

Annual electricity consumption per capita (MWh/capita)



Source: https://www.mospi.gov.in/publications-reports/innerpage/2817

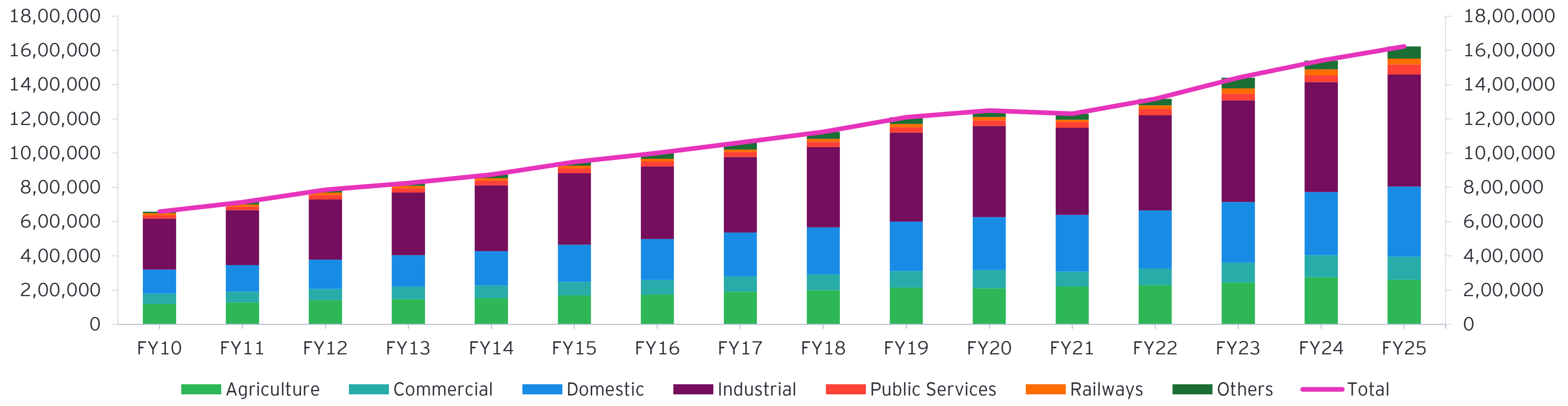
Electricity consumption per capita provides an important indicator of the level of economic development, industrialization and electrification across economies. Despite becoming the world's third-largest electricity producer and consumer in absolute terms, India's annual per capita electricity consumption remains significantly lower than that of major developed and emerging economies. In 2023, India's electricity consumption stood at approximately 1.15 MWh per capita, compared with around 6.4 MWh in China, 6.9 MWh in Japan, 12.7 MWh in the US, and a global average of nearly 3.1 MWh per capita.

Over the past three decades, India's per capita electricity consumption has increased steadily, reflecting expanding electricity access, economic growth and rising household demand. However, the pace of growth has remained considerably lower than that observed in rapidly industrializing economies such as China. The large gap between India and other major economies indicates substantial headroom for future growth in electricity demand as industrial production expands, urbanization accelerates, living standards improve and end-use sectors such as transport, cooking and industry become increasingly electrified.

This widening electrification pathway has important implications for India's energy transition. As electricity assumes a larger share of final energy consumption, the scale, reliability and flexibility of the power system will become increasingly important. Rising electricity demand will therefore require continued expansion of generation capacity, transmission infrastructure, storage systems and firm low-carbon power sources to ensure that increasing demand can be met while maintaining system reliability and supporting long-term energy security.

Electricity demand has more than doubled across India's economy since FY10

Electricity consumption trend in India (MU)



Source: https://www.mospi.gov.in/publications-reports/innerpage/2817
IECD Dashboard by NITI Aayog

India's electricity demand has grown 2.5× in 15 years, driven by economy-wide electrification

India's electricity consumption has increased significantly over the past 15 years, rising from approximately 658 TWh in FY09-10 to over 1,623 TWh in FY24-25—an increase of nearly 2.5 times. This sustained growth reflects expanding economic activity, rising electricity access, increasing urbanization and the progressive electrification of households, industry, transport and public infrastructure. Despite a temporary slowdown during the COVID-19 pandemic, electricity demand recovered rapidly and continued its long-term upward trajectory.

Industrial consumers remain the largest users of electricity, with consumption increasing from around 298 TWh to 656 TWh over the period, highlighting the continued importance of electricity in supporting manufacturing, mining and other energy-intensive industries. Domestic electricity demand has also expanded substantially, increasing from approximately 142 TWh to 409 TWh, driven by higher household electrification, rising incomes, increased appliance ownership and improvements in quality of life. Agricultural and commercial electricity consumption have also recorded sustained growth, reflecting expanding irrigation demand, commercial activity and broader economic development.

Electricity demand has also increased across public services and the railway sector, illustrating the growing role of electrification beyond traditional end-use sectors. Railway electricity consumption has nearly tripled over the period, reflecting the continued electrification of India's rail network and the gradual transition away from diesel-based traction. Together, these trends indicate that electricity is becoming the preferred energy carrier across an increasingly diverse range of economic activities.

The broad-based increase in electricity demand demonstrates that electrification is no longer confined to the power sector—it is transforming the wider economy. As electricity progressively replaces petroleum in sectors where technically and economically viable alternatives exist, the capacity of the power system to reliably transmit and deliver electricity becomes increasingly important. This growing dependence on electricity underscores the strategic importance of transmission infrastructure, which forms the backbone of India's future energy security, efficiency and resilience.

Source: IECD dashboard by NITI Aayog

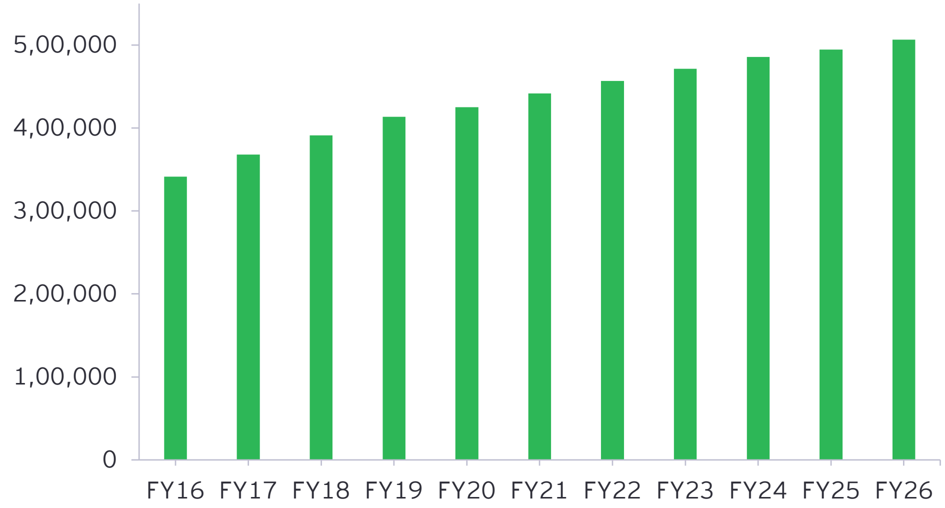
India's transmission network is expanding in scale and capacity

India's transmission infrastructure has expanded significantly over the past decade, strengthening the foundation required to support rising electricity demand and the rapid integration of renewable energy. Between FY15–16 and FY26–27, the national transmission network increased from approximately 342,000 circuit kilometers (ckm) to over 509,000 ckm, representing an expansion of nearly 50%. Over the same period, substation transformation capacity more than doubled, increasing from around 659 GVA to nearly 1,469 GVA, reflecting substantial strengthening of the country's power transmission capability.

The significantly faster growth in substation capacity relative to transmission line length indicates that India's power network is not only expanding geographically but is also becoming capable of transferring much larger volumes of electricity. This strengthening is central to integrating utility-scale renewable energy projects, facilitating long-distance power transfers between resource-rich and demand-intensive regions, and maintaining system reliability as electricity demand continues to increase across the economy.

The simultaneous expansion of transmission lines and transformation capacity demonstrates the evolving role of the transmission system in enabling India's energy transition. As electricity increasingly replaces fossil fuels across transport, industry and buildings, a stronger and more interconnected transmission network becomes critical for delivering reliable power, improving operational flexibility and supporting the continued electrification of the economy. These trends position transmission infrastructure as one of the key enablers of India's long-term energy security, efficiency and resilience.

Transmission line length (Ckm)



Substation capacity (MVA)

Source: IECD dashboard by NITI Aayog

India has built one of the world's youngest transmission networks

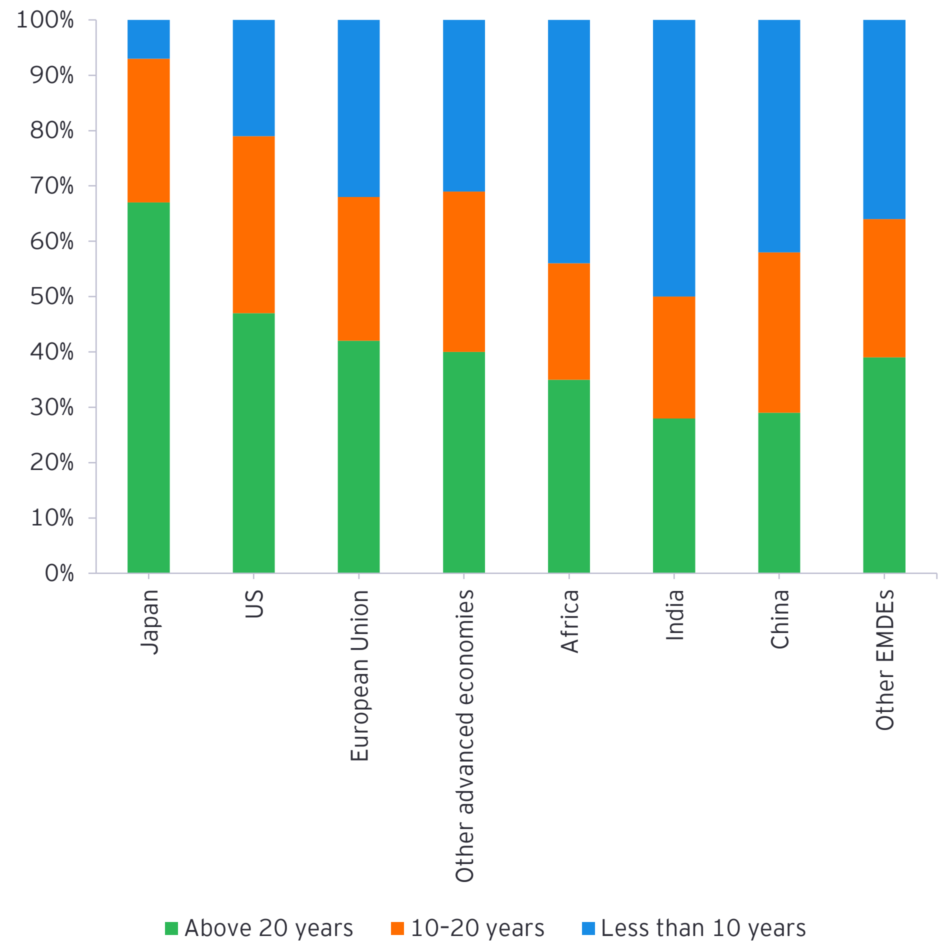
Electricity transmission infrastructure forms the backbone of a reliable and resilient power system, enabling efficient transfer of electricity from generation centers to demand hubs while supporting the integration of renewable energy resources. As electricity demand grows and renewable energy deployment accelerates, the expansion and modernization of transmission networks become increasingly important for maintaining system reliability, reducing congestion and improving operational flexibility. The age profile of transmission assets provides a useful indicator of the pace at which countries are investing in and upgrading their electricity networks to meet evolving energy requirements.

India has significantly expanded its transmission infrastructure over the past decade, resulting in one of the youngest transmission networks among major economies. Around 50% of India's transmission lines are less than 10 years old, while only 28% are more than 20 years old. This compares favorably with several advanced economies where a substantially larger share of transmission assets was commissioned more than two decades ago. For example, nearly 67% of Japan's transmission network, 47% of the US network and 42% of the European Union's network are more than 20 years old. The relatively younger age profile of India's grid reflects sustained investment in expanding and strengthening the national transmission system to accommodate rising electricity demand and the rapid growth of renewable energy capacity.

The continued expansion of India's transmission network is also reflected in the growth of total transmission line length, which increased from approximately 341,500 ckm in FY15-16 to over 508,500 ckm by FY26-27, representing an increase of nearly 49% in just over a decade. This expansion has supported improved inter-regional power transfer capability, strengthened grid connectivity across states and facilitated the evacuation of renewable energy from resource-rich regions to major demand centers. The development of Green Energy Corridors, high-capacity interstate transmission systems and renewable energy evacuation infrastructure has further enhanced the flexibility and resilience of the national grid.

The comparatively young transmission asset base positions India favorably to support the next phase of electricity demand growth and large-scale electrification. As transport, industry and buildings increasingly shift towards electricity, the role of transmission infrastructure will become even more critical in ensuring reliable and efficient power delivery. Continued expansion of the transmission network, combined with investments in digital grid technologies, storage systems and advanced grid management solutions, is expected to play a central role in supporting India's long-term energy transition while strengthening the resilience and flexibility of the electricity system.

Share of transmission length by age, 2023



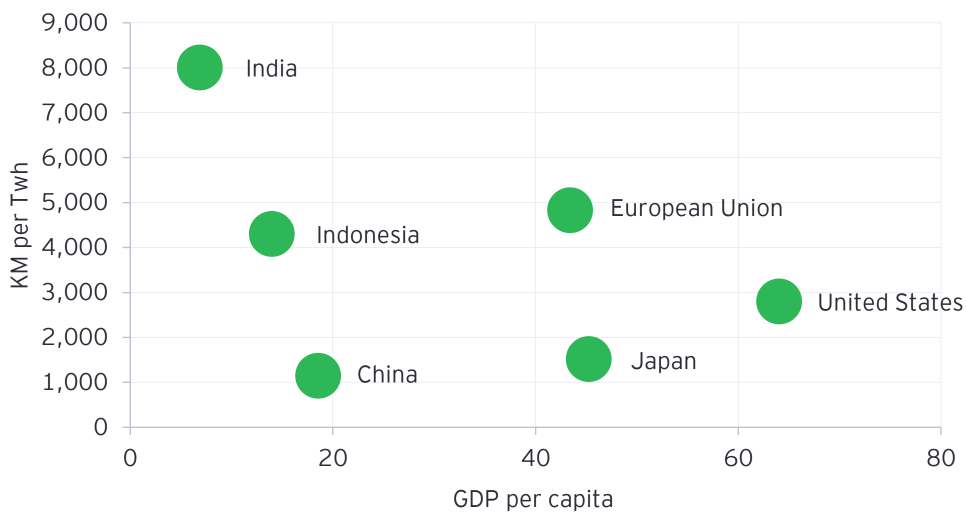
Source: https://iea.blob.core.windows.net/assets/ea2ff609-8180-4312-8de9-494bcf21696d/ElectricityGridsandSecureEnergyTransitions.pdf

India's transmission network reflects its stage of economic development

The relationship between electricity network infrastructure and economic development shows a clear global pattern. Emerging economies generally require more extensive transmission and distribution networks relative to the volume of electricity supplied as they expand electricity access, industrial activity and renewable energy integration. As economies mature and electricity consumption per capita increases, network utilization typically improves, reducing the amount of network infrastructure required per unit of electricity delivered.

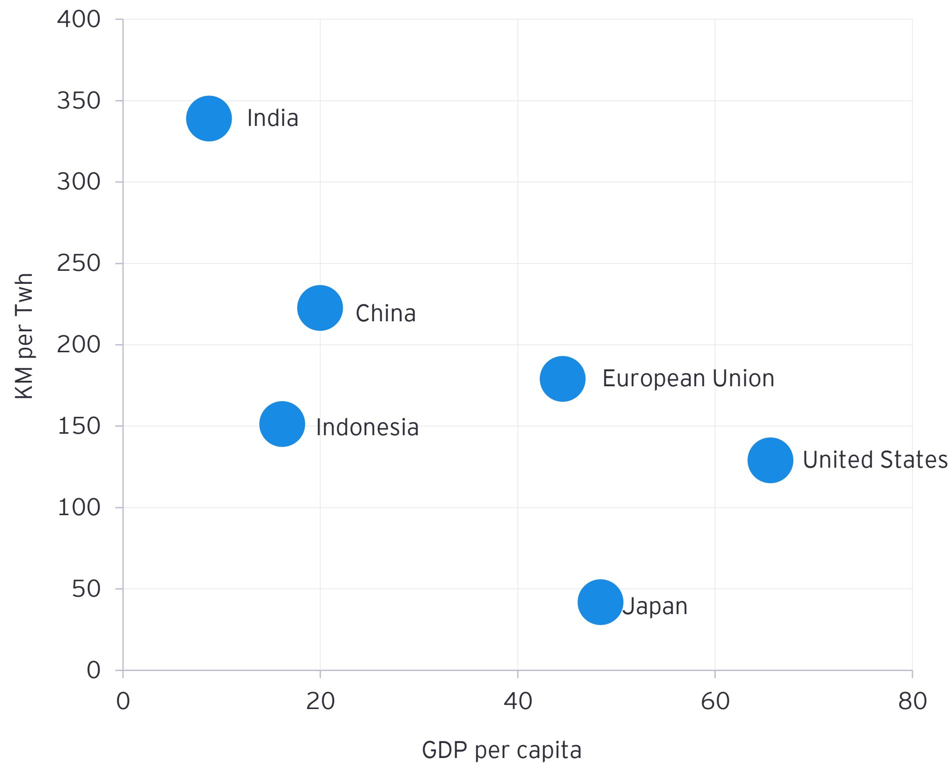
India's transmission and distribution network intensity is broadly aligned with this global trend. The country's position close to the global trendline indicates that its network development is consistent with its current stage of economic growth and electrification. Compared with advanced economies, India maintains a relatively larger network per TWh of electricity supplied, reflecting ongoing grid expansion to support rising demand and connect new load centers.

Distribution



As electricity consumption continues to increase, there is significant potential to improve utilization of existing transmission and distribution assets. Continued investments in grid modernization, digital technologies, advanced system operations and renewable energy integration are expected to enhance network efficiency while supporting India's long-term electrification and energy transition objectives.

Transmission



Source: https://iea.blob.core.windows.net/assets/ea2ff609-8180-4312-8de9-494bcf21696d/ElectricityGridsandSecureEnergyTransitions.pdf

Transmission infrastructure: Powering India's electrification pathway

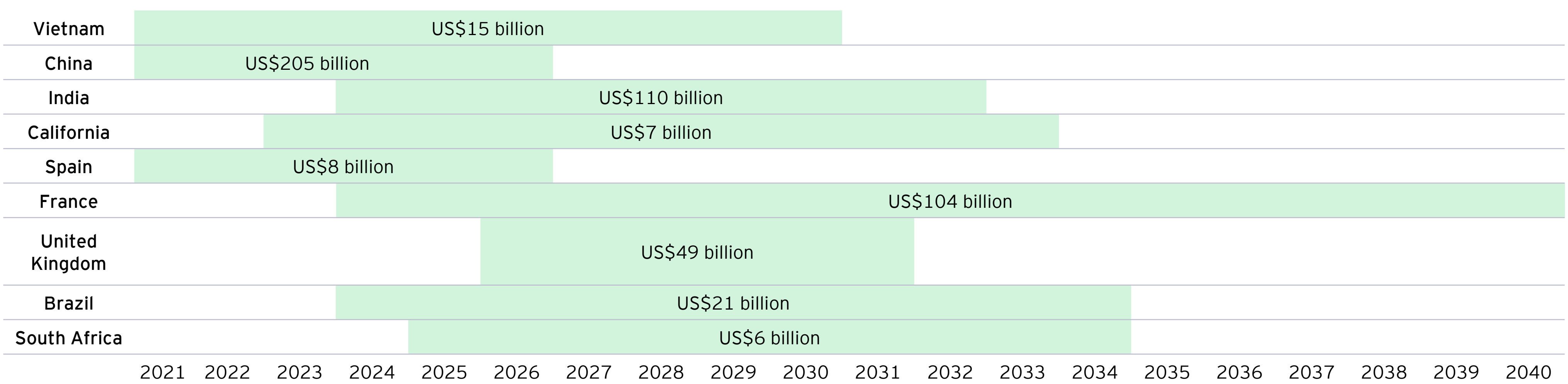
India has announced one of the world's largest transmission investment programs, with planned investments of approximately US$110 billion, reflecting the scale of grid infrastructure required to support rapid electrification and renewable energy integration. Global energy transition scenarios project India's transmission network to expand from around 0.5 million ckm today to approximately 1.7 million ckm by 2050 – a 3.4-fold increase over the period. This projected expansion exceeds the global average of 2.4 times and is significantly higher than the growth projected for the US (2.0×), the European Union (1.8×) and Japan (1.3×), highlighting the scale of transmission infrastructure required to support India's evolving electricity system.

China presents an important international comparison. While China's transmission investment program of around US$205 billion is roughly twice that of India, it aims to expand its transmission network from 2.4 million ckm in 2030 to 3.7 million ckm by 2050, with a substantial portion of the network already planned and under development by 2030. In contrast, India's transmission expansion is distributed over a longer implementation horizon, with much of the planned network addition extending beyond 2030.

The comparison highlights that, along with the scale of investment, the sequencing and timely development of transmission infrastructure play an important role in supporting renewable energy integration, interregional power transfer and economy-wide electrification. International experience demonstrates that sustained investments in transmission networks can enhance grid flexibility and support the evolving needs of a rapidly growing power system. India's planned transmission expansion program is among the largest globally and reflects the scale of infrastructure required to support rising electricity demand, increasing renewable energy deployment and long-term electrification goals.

As electricity demand continues to grow over the coming decades, continued expansion and modernization of transmission infrastructure will support the efficient integration of generation capacity, renewable energy resources and emerging demand centres. The experience of major power systems worldwide highlights the value of aligning grid development with evolving energy system requirements, helping strengthen reliability, operational flexibility and long-term energy resilience.

Planned transmission investments



Source: https://iea.blob.core.windows.net/assets/ea2ff609-8180-4312-8de9-494bcf21696d/ElectricityGridsandSecureEnergyTransitions.pdf

International experience demonstrates that

Large-scale Transmission Investment,

aligned with timely implementation, can support renewable energy integration, electrification and long-term system development.

Transmission supply chains: Emerging as a critical determinant of grid expansion

The global acceleration of electrification, renewable energy deployment and grid modernization has significantly increased demand for transmission infrastructure. Countries across the world are simultaneously expanding transmission networks to integrate renewable energy, strengthen grid resilience and support rising electricity demand. This unprecedented scale of investment has shifted transmission equipment from being a routine engineering procurement item to a strategic supply chain, with manufacturing capacity increasingly determining the pace of grid expansion. As a result, lead times for critical equipment such as large power transformers, high-voltage cables, conductors and switchgear have increased considerably, creating bottlenecks that are delaying transmission projects across multiple regions.

A defining characteristic of the global transmission equipment market is the high concentration of manufacturing capacity. China has developed an integrated manufacturing ecosystem spanning the entire transmission value chain—from grain-oriented electrical steel and transformer cores to high-voltage transformers, HVDC equipment, conductors, cables, insulators and digital grid components. Supported by decades of sustained domestic grid investment and large-scale manufacturing, Chinese companies have established significant production capacity across most critical transmission technologies. This industrial ecosystem has enabled China not only to meet its rapidly growing domestic requirements but also to become one of the world's largest suppliers of transmission equipment to international markets.

The concentration of manufacturing capacity has important implications for countries undertaking large-scale transmission expansion. Unlike previous infrastructure cycles where financing and project execution were the primary constraints, the availability of critical equipment has emerged as an equally important determinant of project timelines. As multiple economies pursue ambitious grid expansion programs simultaneously, competition for manufacturing capacity is expected to remain elevated, particularly for transformers, electrical steel and high-voltage transmission equipment. Consequently, transmission infrastructure development is increasingly influenced by global industrial supply chains alongside domestic investment and execution capability.

These developments are particularly relevant for India, which has announced one of the world's largest transmission expansion programs over the coming decades. Delivering this scale of infrastructure will depend on the timely availability of transmission equipment across the value chain, in addition to financial investment and project execution capabilities. The international experience highlights that grid expansion is no longer determined solely by the availability of capital or engineering expertise; resilient and diversified supply chains for critical transmission equipment have become equally important in sustaining the pace of infrastructure development. As India accelerates electrification and renewable energy integration, strengthening domestic manufacturing capabilities and supply chain resilience for transmission equipment will increasingly influence the country's ability to deliver large-scale grid expansion within planned timelines.

Transmission has emerged as a strategic manufacturing challenge as much as an infrastructure challenge. Countries with integrated manufacturing ecosystems and robust transmission supply chains are better positioned to deliver grid expansion at scale and pace.

Source: https://iea.blob.core.windows.net/assets/ea2ff609-8180-4312-8de9-494bcf21696d/ElectricityGridsandSecureEnergyTransitions.pdf

4 The renewables surge: Generation capacity and the integration frontier

Solar has become the primary driver of India's capacity expansion

India's installed power generation capacity has undergone a significant transformation over the past decade, with renewable energy emerging as the primary source of new capacity additions. Between FY15 and FY27, installed solar capacity expanded from 3.7 GW to over 150 GW, representing more than a 40-fold increase, while wind capacity doubled from 23 GW to nearly 57 GW. During the same period, hydro capacity increased steadily to around 52 GW, taking the country's total non-fossil installed capacity to historically high levels.

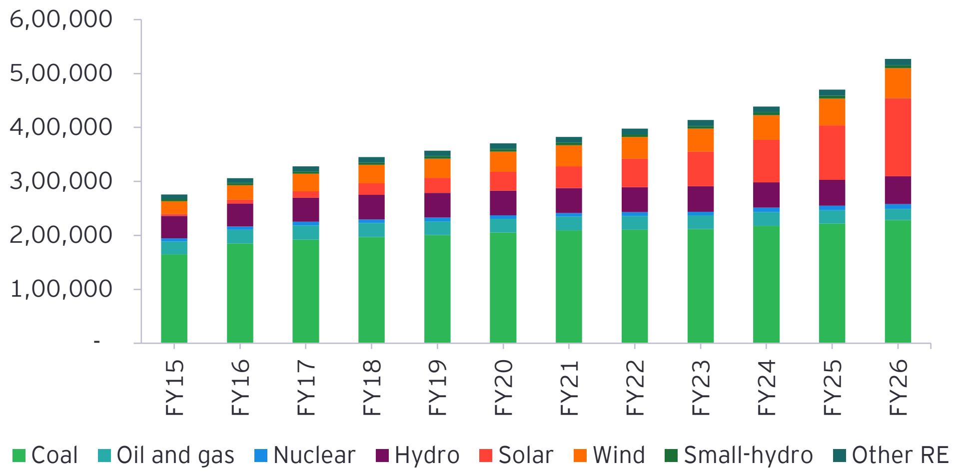
The expansion of renewable energy has substantially altered the composition of India's power sector. While coal continues to account for the largest installed capacity at around 230 GW, its contribution to incremental capacity additions has declined as solar has become the fastest-growing technology. The rapid scale-up of renewable energy reflects sustained policy support, declining technology costs and increasing private sector investment, positioning India among the world's fastest-growing renewable energy markets.

The changing capacity mix also presents new operational challenges for the power system. Unlike conventional generation, solar and wind output varies with weather conditions and time of day, requiring greater flexibility from the electricity network. As renewable penetration increases, transmission infrastructure, energy storage, flexible generation and advanced grid management systems will play an increasingly important role in maintaining grid stability and ensuring reliable electricity supply.

India's renewable energy expansion therefore marks the beginning of the next phase of the energy transition. The focus is progressively shifting from adding renewable capacity to integrating it efficiently into the grid. Continued investment in transmission corridors, Battery Energy Storage Systems (BESS), pumped storage, forecasting tools, and digital grid technologies will determine how effectively the growing renewable fleet can be utilized while maintaining system resilience and supporting rising electricity demand.

Source: ICED Dashboard by NITI Aayog

Electricity installed capacity in India (MW)



India's generation mix highlights the next challenge in the energy transition

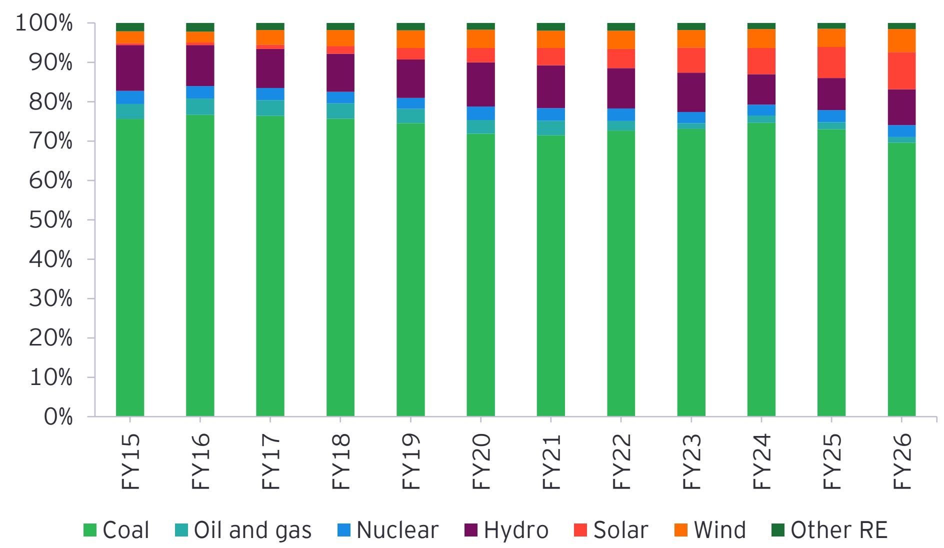
India's electricity sector has witnessed a significant transformation over the past decade, with renewable energy becoming the dominant source of new capacity additions. Installed solar capacity increased from 4 GW in FY15 to over 150 GW by FY27, while wind capacity more than doubled during the same period. This rapid expansion has fundamentally altered the country's installed capacity mix, positioning renewable energy as a major pillar of India's long-term energy transition.

The evolution of electricity generation, however, presents a different perspective. Despite the rapid growth in renewable capacity, coal remains the backbone of India's electricity supply, with annual generation increasing from approximately 835 BU in FY15 to over 1,280 BU in FY26. During the same period, solar generation increased from 4.6 BU to nearly 175 BU, while wind generation grew from 34 BU to around 107 BU. Renewable generation has therefore expanded rapidly, but conventional generation continues to provide the majority of electricity required to meet growing demand and ensure reliable system operation.

The differing trajectories of installed capacity and electricity generation reflect the complementary roles of various technologies within the power system. Solar and wind have lower capacity utilization due to their dependence on weather conditions and daylight availability, whereas coal, hydro and nuclear continue to provide dispatchable and firm generation that supports system adequacy. As renewable energy penetration increases, ensuring that the growing renewable capacity translates into higher clean electricity generation will depend on the availability of transmission infrastructure, energy storage, forecasting systems and flexible grid operations.

India's energy transition is therefore entering a new phase. The focus is gradually shifting from adding renewable capacity to maximizing its effective utilization within the electricity system. Strengthening transmission networks, expanding Battery Energy Storage Systems (BESS) and pumped storage capacity, improving forecasting accuracy, and deploying advanced grid management technologies will be critical to integrating larger volumes of renewable energy while maintaining grid reliability and supporting sustained growth in electricity demand.

Source-wise share of electricity generation in India



Source: ICED Dashboard by NITI Aayog

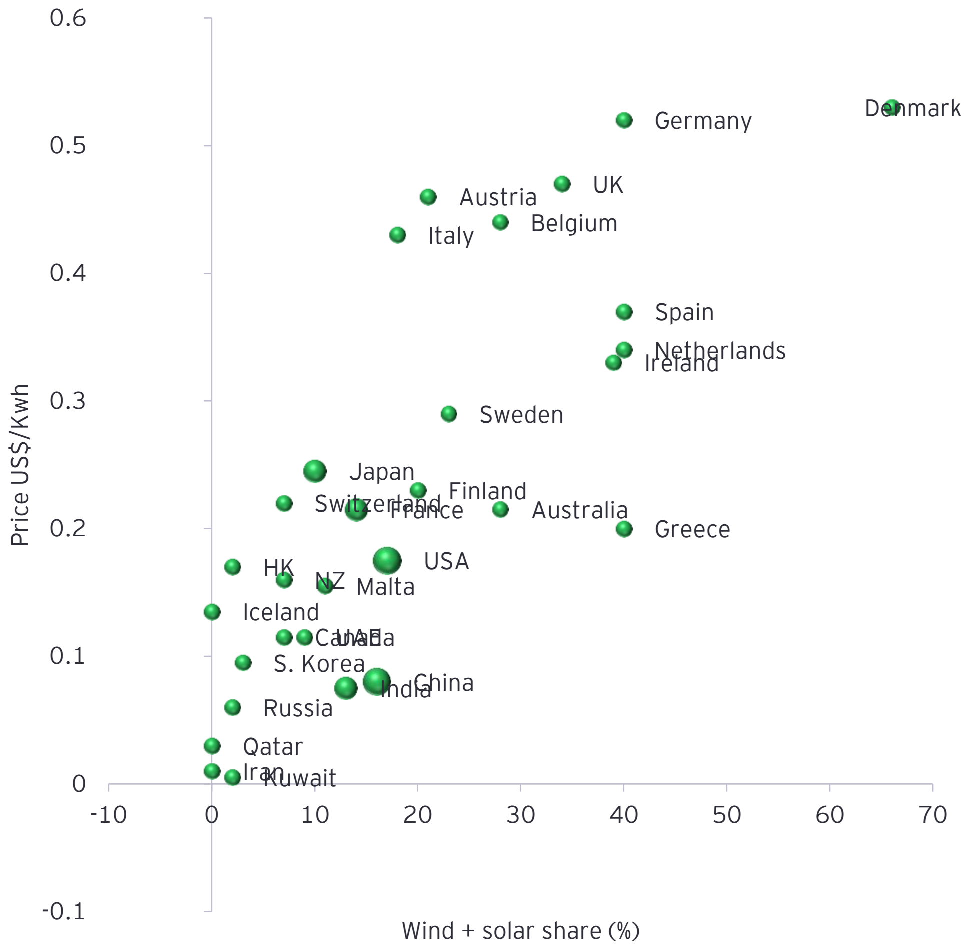
India has successfully accelerated

Renewable Capacity Addition

The next phase of the energy transition will depend on converting this capacity into a larger share of electricity generation through enhanced transmission, storage and grid flexibility.

Higher renewable penetration brings new system integration challenges

Snapshot of RE share and retail prices in major economies



Source: https://www.cis.org.au/publication/the-renewable-energy-honeymoon-starting-is-easy-the-rest-is-hard/

India's renewable energy transition has achieved remarkable progress over the past decade, driven by rapid additions of solar and wind capacity and some of the world's most competitive renewable energy tariffs. During the initial phase of renewable deployment, electricity systems are generally able to absorb increasing shares of variable renewable energy with relatively limited changes to grid operations. This phase is often referred to as the "renewable honeymoon period," where renewable capacity can be integrated without significant investments in flexibility or system balancing.

As renewable penetration continues to increase, however, the characteristics of the power system begin to change. Beyond a certain level of variable renewable generation, maintaining reliability requires proportionately greater investments in transmission infrastructure, energy storage, forecasting systems, ancillary services and flexible generation. Consequently, the overall cost of the electricity system is increasingly influenced not only by the cost of renewable generation itself but also by the investments required to reliably integrate larger volumes of intermittent generation into the grid.

The international comparison illustrates this evolving system as dynamic. Countries with relatively modest shares of wind and solar generation generally exhibit a wider range of electricity prices, with renewable generation costs playing a dominant role. As renewable penetration increases beyond 20% to 30% of annual electricity generation, system-level considerations such as storage, transmission expansion, balancing services, and market design become progressively more important in determining overall electricity costs. While these costs vary across countries depending on resource availability, market structure and regulatory design, international experience demonstrates that renewable integration is not a linear progression, and system requirements increase as renewable penetration deepens.

India is now entering in this next phase of the energy transition. Having successfully scaled renewable energy deployment, the focus is progressively shifting towards the efficient integration of renewable resources into the electricity system. Continued investments in transmission networks, Battery Energy Storage Systems (BESS), pumped hydro storage, flexible generation, digital grid technologies and advanced system operations will largely determine the ability to maximize renewable energy utilization while maintaining affordability, reliability and grid resilience.

Energy storage is emerging as a critical enabler of India's renewable energy transition

India's rapid renewable energy expansion has been accompanied by an increasing focus on energy storage as a key enabler of grid flexibility and renewable integration. As solar and wind penetration increases, storage is becoming essential for balancing supply and demand, reducing renewable curtailment and supporting reliable power system operations.

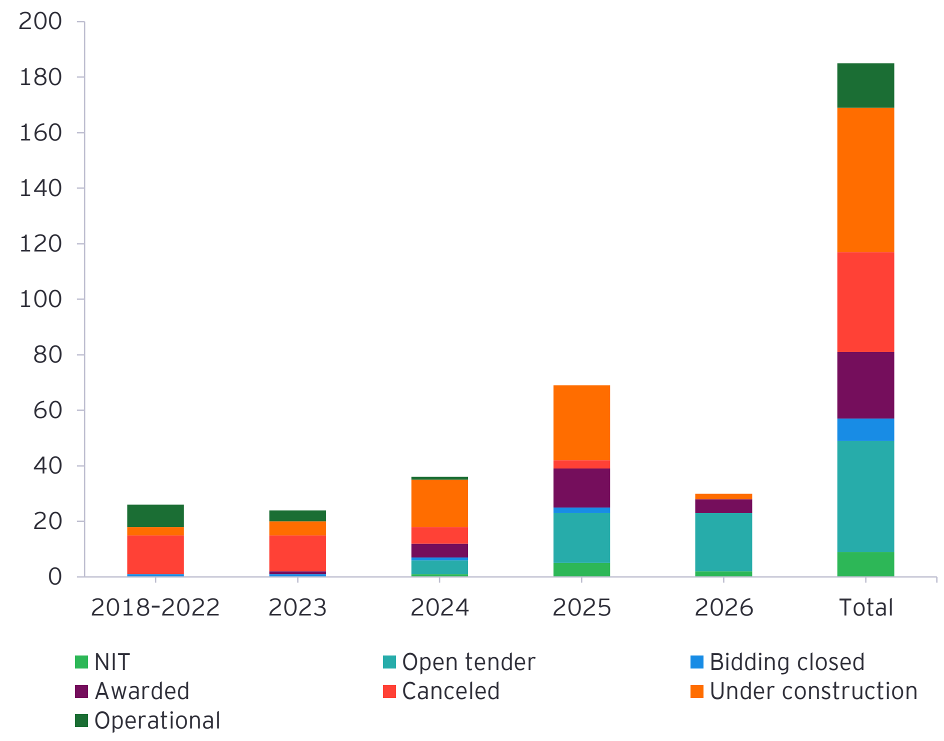
This growing emphasis is reflected in the storage project pipeline. Between 2018 and June 2026, 183 storage-linked tenders covering 275 GWh of Energy Storage Systems (ESS) have been issued, comprising 142 GWh of Pumped Storage Projects (PSP) and 133 GWh of Battery Energy Storage Systems (BESS). Tender activity has accelerated significantly, with 2025 recording the highest number of storage tenders (69), indicating that storage has become an integral part of renewable energy procurement.

The market is now transitioning from planning to implementation. Around 94 GWh (35%) of the announced ESS capacity is under construction, while 7.5 GWh of BESS capacity is already operational. As renewable energy penetration continues to rise, timely deployment of storage infrastructure will be increasingly important for improving renewable energy utilization, enhancing grid flexibility and strengthening power system resilience.

Energy storage-linked tenders in India till 2026

Stage	No. of tenders	RE capacity (GW)	ESS capacity (GWh)	PSP capacity (GWh)	BESS capacity (GWh)
NIT	9	1.47	2.50	2.00	0.50
Open tender	39	4.99	90.43	54.25	36.18
Bidding closed	8	1.22	14.40	12.00	2.40
Canceled	36	12.43	49.36	34.63	14.73
Awarded	23	11.64	17.27	-	17.27
Under construction	51	23.30	94.30	39.45	54.85
Operational	17	1.05	7.52	0.00	7.52
Total	183	56.00	275.00	142.00	133.00

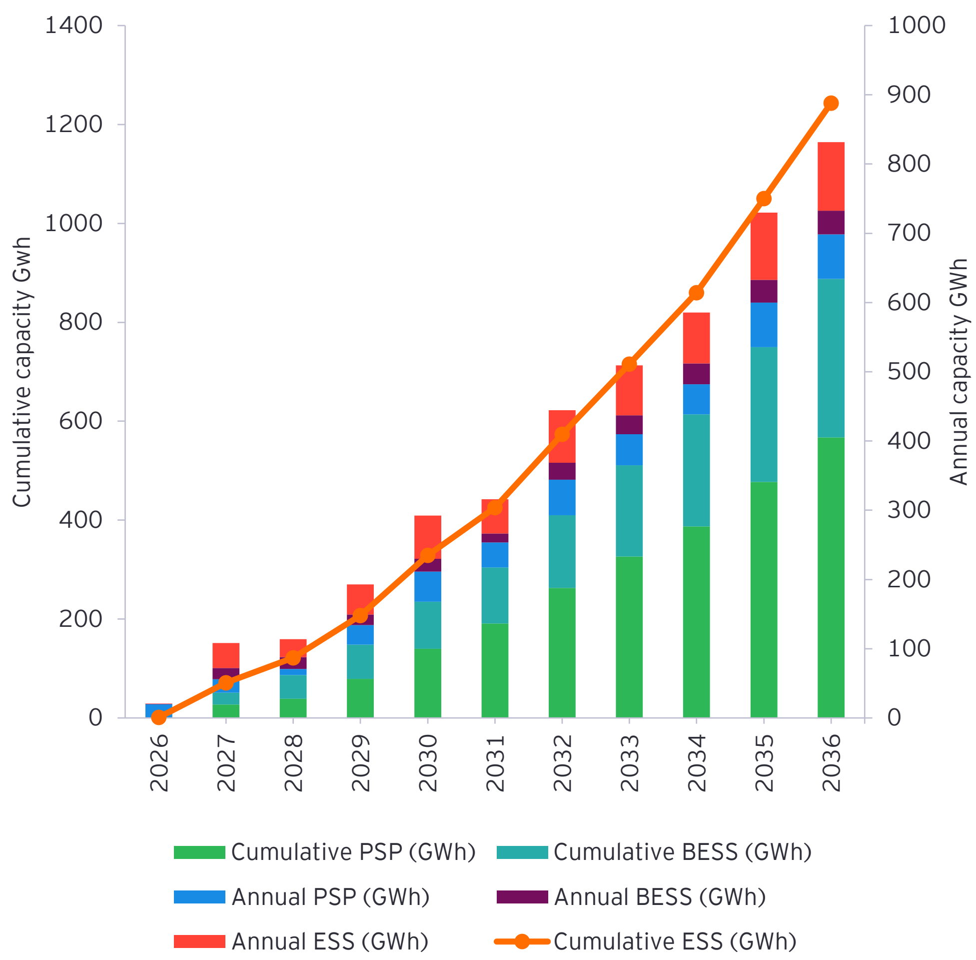
Energy storage-linked tenders in India till 2026



Source: India Energy Storage Market Update- May 2026, IESA report

India's energy storage requirement is set to expand rapidly over the next decade

Annual BESS capacity addition projection 2026-2036



India's energy storage requirement is projected to increase significantly over the next decade as renewable energy deployment accelerates and electricity demand continues to grow. Current projections indicate that cumulative Energy Storage System (ESS) capacity could reach approximately 888 GWh by 2035-36, comprising around 567 GWh of Pumped Storage Projects (PSP) and 321 GWh of Battery Energy Storage Systems (BESS). This represents a substantial increase from the current operational storage capacity, highlighting the scale of infrastructure required to support a renewable-dominated power system.

The projected growth also reflects the complementary roles of different storage technologies. While PSP is expected to account for nearly two-thirds of the cumulative storage capacity, BESS is projected to witness rapid deployment owing to its modularity, faster construction timelines and suitability for grid balancing and renewable energy integration. Together, these technologies will enhance system flexibility, support peak demand management and improve the utilization of variable renewable energy.

Achieving this scale of storage deployment implies sustained project execution over the coming decade. Annual ESS additions are projected to increase steadily, reaching 138 GWh in 2036, illustrating the scale of continued investment, timely project implementation and expansion of the domestic storage ecosystem. As India moves towards higher renewable energy penetration, energy storage will play an increasingly important role in maintaining grid reliability, reducing renewable curtailment and strengthening overall power system resilience.

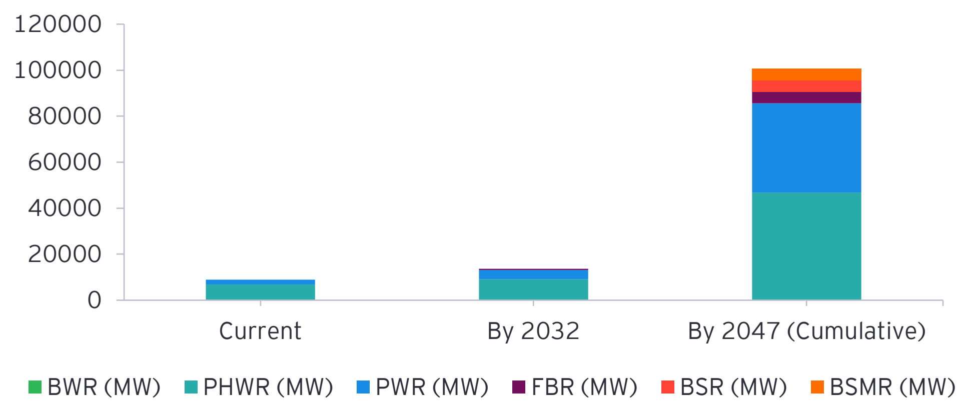
Source: India Energy Storage Market Update- May 2026, IESA report

5

Nuclear at the core of a renewable-heavy grid

India plans to increase nuclear capacity from around 8 GW to 100 GW by 2047

India's nuclear capacity roadmap (MW)



Source: CEA Roadmap for achieving 100GW Nuclear capacity by 2047, 2025
https://world-nuclear.org/our-association/publications/world-nuclear-outlook-report/india---world-nuclear-outlook-report,
https://www.pib.gov.in/FactsheetDetails.aspx?Id=150617&reg=5&lang=1#:~:text=Installed%20Capacity%3A%20India's%20current%20nuclear,of%20India's%20total%20electricity%20generation.

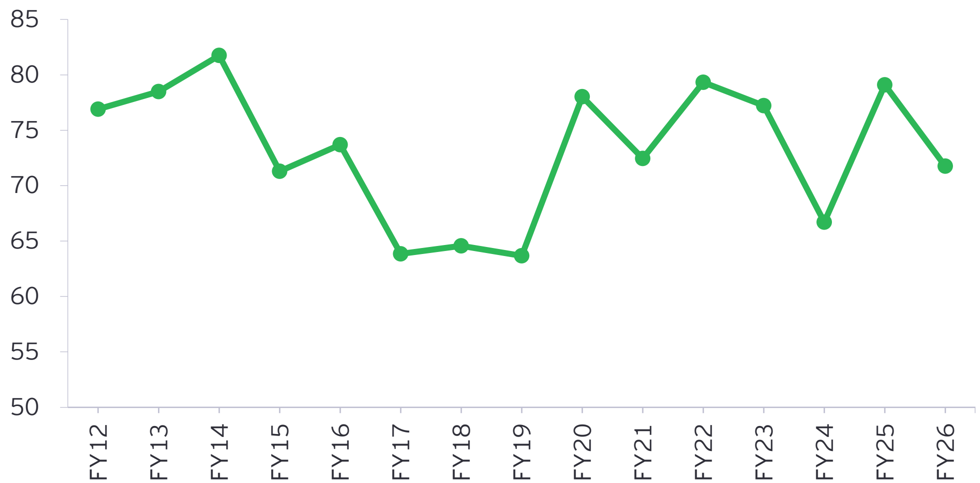
Nuclear energy can provide the firm capacity required for a renewable-dominated grid

India has outlined one of the world's most ambitious nuclear expansion programs, targeting 100 GW of installed nuclear capacity by 2047 as part of its long-term energy transition strategy. The projected capacity mix indicates a diversified deployment pathway, comprising indigenous Pressurized Heavy Water Reactors (PHWRs), Pressurized Water Reactors (PWRs), Fast Breeder Reactors (FBRs) and emerging Small Modular Reactors (SMRs). This expansion represents a significant increase from the current installed capacity and reflects the growing role envisaged for nuclear energy within India's future electricity system.

The importance of nuclear power extends beyond installed capacity to the reliability of electricity generation. Over the past 15 years, India's nuclear power plants have generally operated at Plant Load Factors (PLFs) in the 70% to 80% range, with several years recording utilization above 75% and occasional dips to the mid-60s (FY17-19 and FY24). Despite periodic maintenance outages and fuel availability constraints, nuclear generation has remained one of the country's most dependable sources of low-carbon electricity, providing continuous baseload generation largely independent of weather conditions or seasonal variability. This high operational reliability distinguishes nuclear power from variable renewable energy sources and enables it to provide stable electricity throughout the year.

As the share of solar and wind generation continues to increase, the characteristics of the electricity system are expected to evolve. While renewable energy is projected to contribute an increasing share of electricity generation, its variable nature will require complementary sources of firm and dispatchable generation to maintain grid stability, frequency control and adequacy during periods of low renewable output. In this evolving generation mix, nuclear power can complement renewable energy by providing continuous low-carbon baseload generation, reducing dependence on fossil-fuel-based balancing resources and supporting higher levels of renewable energy integration.

Average PLF of nuclear plants in India



International experience increasingly demonstrates that electricity systems with high renewable energy penetration require a balanced portfolio comprising variable renewables, storage, flexible grid infrastructure and firm low-carbon generation. India's planned nuclear expansion therefore represents not only an increase in installed capacity but also a strengthening of the country's long-term firm power capability. As electricity demand continues to rise and the power system becomes increasingly renewable-intensive, the availability of reliable, high-utilization nuclear generation will play an important role in supporting grid resilience, energy security and uninterrupted electricity supply.

India's nuclear expansion aligns with global growth while leveraging cost-competitive indigenous technology

The global nuclear sector is witnessing renewed momentum as countries increasingly recognize the role of firm, low-carbon generation in supporting energy security and electricity system reliability. Global capacity addition scenarios indicate a steady increase in annual nuclear deployments through 2040, driven by growing electricity demand, decarbonization commitments and the need for reliable generation to complement variable renewable energy. China is expected to account for the largest share of future nuclear additions, while India also emerges as one of the major contributors to global capacity expansion, reflecting the country's long-term commitment to scaling nuclear power.

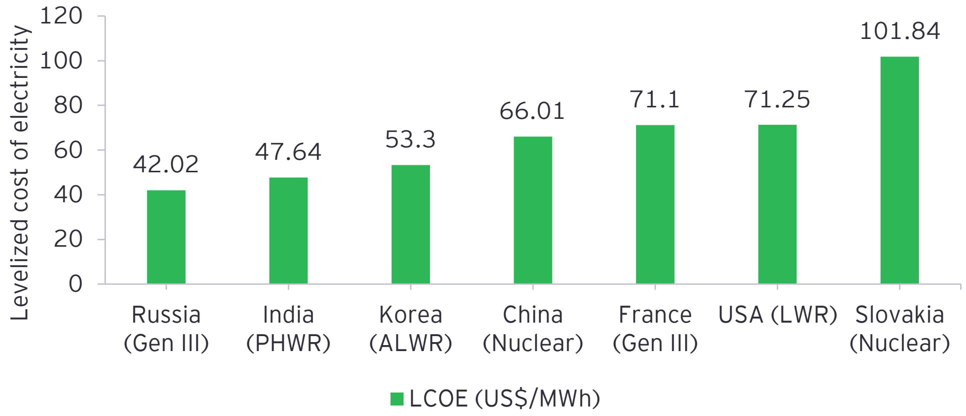
India's nuclear expansion strategy is supported by a strong domestic technology base centered on Pressurized Heavy Water Reactors (PHWRs). International comparisons indicate that India's indigenous PHWR technology is among the most cost-competitive nuclear technologies globally, with an estimated levelized cost of electricity (LCOE) of around US$48/MWh. This is lower than comparable technologies deployed in countries such as China (US$66/MWh), France (US$71/MWh) and the United States (US$71/MWh), while remaining comparable with some of the world's lowest-cost nuclear programs. The relatively lower cost reflects decades of indigenous technology development, standardized reactor designs and accumulated construction and operational experience.

The combination of cost competitiveness and planned capacity expansion positions nuclear energy as an increasingly important component of India's future electricity mix. As the share of solar and wind generation continues to increase, electricity systems will require reliable sources of firm, low-carbon generation capable of operating independently of weather conditions. Nuclear power complements renewable energy by providing continuous baseload generation, supporting system adequacy and reducing dependence on fossil-fuel-based balancing resources during periods of low renewable output.

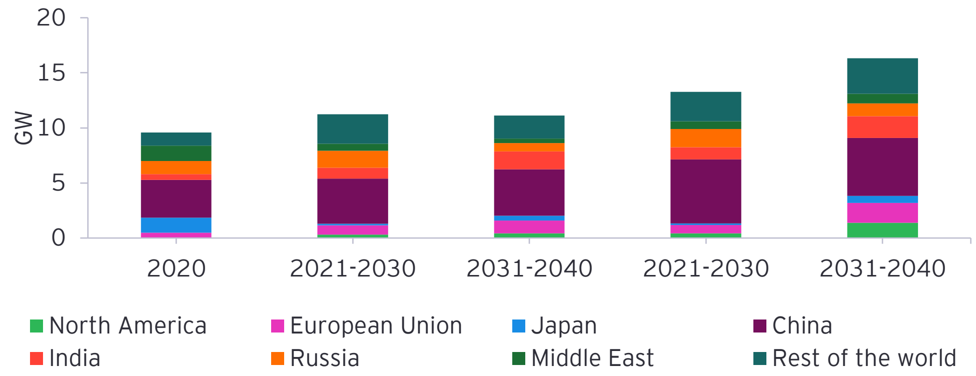
India's long-term nuclear roadmap therefore reflects both domestic priorities and broader global trends. While countries worldwide are accelerating investments in firm low-carbon generation, India's expansion strategy is distinguished by the availability of an indigenous, comparatively cost-competitive reactor technology alongside an ambitious capacity addition program. Together, these factors strengthen nuclear energy's role in supporting India's long-term energy security, grid resilience and transition towards a more diversified and reliable electricity system.

Source: https://world-nuclear.org/our-association/publications/world-nuclear-outlook-report/india---world-nuclear-outlook-report, https://www.pib.gov.in/FactsheetDetails.aspx?Id=150617&reg=5&lang=1#:~:text=Installed%20Capacity%3A%20India's%20current%20nuclear,of%20India's%20total%20electricity%20generation. https://iea.blob.core.windows.net/assets/9753df19-0a71-422a-b725-012c555763b3/WorldEnergyOutlook2025.pdf, https://www.iea.org/data-and-statistics/charts/nuclear-capacity-in-operation-and-under-construction-in-selected-regions-2025?__cf_chl_f_tk=f8OEY_J.LfKZJbh5dqY5vl_fnmfr7etfd9pE0I7xITc-1782755843-1.0.1.1-PsI.G0NMccyVCz2PxEHm0WaVS8fAxgrfKpiGCscOk6s, https://www.iea.org/data-and-statistics/charts/nuclear-capacity-in-operation-and-under-construction-in-selected-regions-2025 , Indias-Nuclear-Energy.pdf, NPCIL

Indicative cost comparison of nuclear generation



Average annual capacity additions from nuclear power by scenario, 2020-2040



India's three-stage nuclear power program

850,000 tons

World's largest thorium reserves

11.93 million tons

Monazite reserves along the coasts of Andhra Pradesh, Kerala, Tamil Nadu and Odisha

April 2026

PFBR's first criticality at Kalpakkam – Stage 2 opens

Stage one – PHWRs (now)

Natural uranium (UO_2) fuel produces electricity plus plutonium as a by-product. Around 8.78 GW is operational and fueled by domestic mines and international purchases. The plutonium produced feeds to Stage 2.

Stage two – fast breeders (now entering)

The PFBR burns plutonium inside a thorium blanket and breeds more fissile U-233 than it consumes. It achieved first criticality in April 2026 – the gateway that multiplies India's fissile resources.

Stage three – thorium reactors (future)

U-233 bred in Stage 2 fuels thorium-based reactors, turning India's vast thorium reserves into a primary energy source independent of imported fuel.

Source: https://iea.blob.core.windows.net/assets/9753df19-0a71-422a-b725-012c555763b3/WorldEnergyOutlook2025.pdf, https://www.iea.org/data-and-statistics/charts/nuclear-capacity-in-operation-and-under-construction-in-selected-regions-2025?__cf_chl_f_tk=f8OEY_J.LfKZJbh5dqY5vl_fnmfr7etfd9pE0I7xITc-1782755843-1.0.1.1-PsI.G0NMccyVCz2PxEHm0WaVS8fAxgrfKpiGCscOk6s, https://www.iea.org/data-and-statistics/charts/nuclear-capacity-in-operation-and-under-construction-in-selected-regions-2025 , Indias-Nuclear-Energy.pdf, NPCIL

India holds ~850,000 tons of thorium in coastal monazite sands. The April 2026 PFBR criticality is the measured, physical entry into stage 2 of the three-stage program – the pathway by which nuclear fuel itself ceases to be an import dependency.

Why thorium cannot be used directly

India's monazite reserves — an immense latent resource — require an intermediate nuclear transformation before they can power reactors.

The core constraint

Thorium-232 (Th-232) is fertile, not fissile.

Fissile: absorbs a slow neutron and splits immediately, sustaining a chain reaction (e.g. U-235, Pu-239, U-233).

Fertile: absorbs a neutron and transmutes into a fissile isotope – but cannot itself initiate or sustain a chain reaction.

Th-232 falls firmly in the fertile category. Loading thorium into a reactor without a fissile 'driver' fuel simply produces no sustained reaction.

No critical mass

Pure Th-232 has no critical configuration – it cannot achieve the neutron multiplication factor (k-effective ≥1) needed for a self-sustaining chain reaction.

Requires external neutron source

Th-232 must be bombarded with neutrons from an external fissile source (U-235, Pu-239) or from an accelerator-driven system (ADS) to begin the conversion sequence.

Intermediate decay needed

Even after neutron capture, Th-232 does not directly become fissile. It transitions via Th-233 → Pa-233 (half-life 27 days) → U-233. The physical decay time means thorium fuel cycles are inherently slower to initiate.

High radiation handling

Th-232 and its daughter products emit significant gamma radiation during processing, demanding robust remote-handling facilities for both irradiation and reprocessing – a capital-intensive requirement.

India's three-stage strategy is precisely the engineering solution to this constraint: use PHWRs to produce Pu-239, use Pu-239 to drive FBRs that breed U-233 from thorium, then use U-233 as the self-sustaining fissile driver for stage three thorium reactors.

Source: https://www.pib.gov.in/FactsheetDetails.aspx?Id=150617 ; https://www.pib.gov.in/newsite/PrintRelease.aspx?relid=138056 ; https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-thorium.pdf, EY Analysis

Stage one: Pressurized Heavy Water Reactors (PHWRs) – building the plutonium bank

India's existing fleet | natural uranium fuel | heavy water moderated | continuous Pu-239 production

Key nuclear reaction

$^{238}U + n \rightarrow {}^{239}U \rightarrow {}^{239}Np \rightarrow {}^{239}Pu$

Natural uranium (^{235}U ~0.7%) undergoes fission in heavy water, releasing neutrons that are absorbed by the far more abundant ^{238}U atoms. Beta decay chain converts $^{238}U \rightarrow {}^{239}Pu$ (Plutonium-239) – the fissile fuel for stage two.

Why natural uranium?

India lacks domestic uranium enrichment capacity at scale. PHWRs are uniquely capable of running on unenriched natural uranium, reducing import dependency and leveraging modest domestic reserves from Jharkhand, Rajasthan and Andhra Pradesh.

Strategic output: Plutonium-239

Spent PHWR fuel, though classified as waste in most programs, is India's strategic asset. The ^{239}Pu produced is reprocessed and stockpiled exclusively to fuel the stage two fast breeder fleet.

Current status

India operates ~20 PHWRs (including 700 MWe PHWR at Kakrapar and Rawatbhata) with ~8.78 GWe installed capacity. Reprocessing plants at BARC and IGCAR extract Pu-239 from spent fuel for stage two.

↓ Pu-239 feeds stage two

- **DAE established**
- **First PHWR (RAPS-1, 220 MWe)**
- **Reprocessing scaled up**
- **700 MWe PHWRs operational**

Source: EY analysis based on DAE Annual Report 2023-24 – https://dae.gov.in/writereaddata/AnnualReport2324.pdf | NPCIL Fleet Data – https://www.npcil.nic.in/main/AllProjectOperationDisplay.aspx | WNA India Profile – https://world-nuclear.org/information-library/country-profiles/countries-g-h/india.aspx

Stage two: Fast Breeder Reactors (FBRs) – multiplying fissile inventory and breeding U-233

Pu-MOX core fuel | liquid sodium coolant | thorium blanket for U-233 breeding | prototype FBR achieved criticality at Kalpakkam

Core reaction: Fission of Pu-239	$^{239}\mathrm{Pu} + n \rightarrow$ fission products + 2-3 neutrons + energy The surplus fast neutrons (unmoderated) are the engine of the FBR. Each fission event produces more neutrons than are consumed, enabling both energy generation and the simultaneous breeding of fresh fissile material.
Blanket reaction: Breeding U-233 from Th-232	$^{232}\mathrm{Th} + n \rightarrow {}^{233}\mathrm{Th} \rightarrow {}^{233}\mathrm{Pa} \rightarrow {}^{233}\mathrm{U}$ Thorium-232 rods surround the core as a 'blanket'. Fast neutron capture by Th-232, followed by two successive beta decays (via Pa-233, half-life 27 days), converts fertile Th-232 into fissile Uranium-233 – the fuel for stage three.

Self-sustaining fuel cycle

The FBR breeds at least as much fissile material as it consumes (breeding ratio ≥ 1). Over time, the Pu inventory grows, enabling the deployment of more reactors without proportional import of fresh fuel.

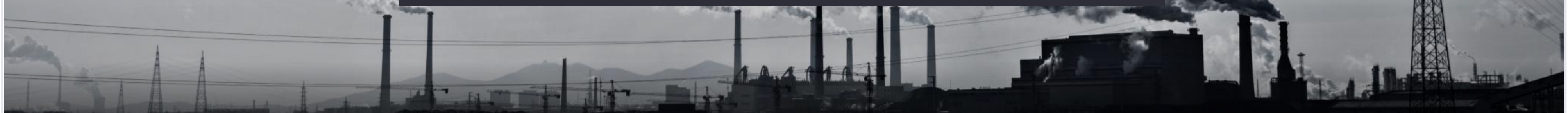
Closing the fuel loop

Spent fuel from FBRs is reprocessed to extract bred Pu-239 and U-233. This circular fuel cycle radically reduces waste volumes relative to once-through thermal reactor models.

India's progress

PFBR (500 MWe) at Kalpakkam, built by BHAVINI, was declared achieved criticality in April 2026.

⬇ U-233 extracted from thorium blanket → fuels stage three



Source: EY analysis based on DAE Annual Report 2023-24 – https://dae.gov.in/writereaddata/AnnualReport2324.pdf | NPCIL Fleet Data – https://www.npcil.nic.in/main/AllProjectOperationDisplay.aspx | WNA India Profile – https://world-nuclear.org/information-library/country-profiles/countries-g-h/india.aspx

Stage three: Thorium-uranium-233 reactors – the long-term endgame

U-233 / Th-232 fuel cycle | Advanced Heavy Water Reactors (AHWR) | Accelerator Driven Systems (ADS) | Self-sustaining thorium economy

Core reaction: U-233/ Th-232 cycle

$^{233}U + n \rightarrow$ fission products + ~2.5 neutrons + energy

One neutron sustains the chain reaction; the remaining ~1.5 neutrons are captured by the Th-232 surrounding the core, breeding fresh U-233. A near-unity breeding ratio means the reactor generates almost as much new fissile U-233 as it consumes, approaching a closed fuel cycle entirely within the thorium system.

In ADS configurations, a proton accelerator drives a spallation target that produces additional neutrons, allowing sub-critical operation and enhanced safety margins.

Vast domestic fuel base

With substantial thorium resources, stage 3 has the potential to provide a long-term indigenous fuel base for India's nuclear program, supporting greater energy security and reducing reliance on external fuel supplies over time.

Lower long-lived waste

Th-232/U-233 cycles produce significantly lower quantities of minor actinides (Np, Am, Cm) compared to uranium cycles, reducing the geological disposal burden and radiotoxicity of spent fuel.

Proliferation resistance

U-233 is always co-produced with U-232, whose decay daughters emit intense gamma radiation, making diversion or weaponization technically difficult and detectable, enhancing non-proliferation credentials.

AHWR design

BARC's Advanced Heavy Water Reactor (AHWR-300-LEU) is designed to run on thorium + low-enriched uranium, with passive safety systems. It represents India's near-term pathway to commercial stage three deployment.

Current status

Stage three remains under advanced research and technology development, with ongoing efforts focused on enabling the long-term utilization of India's thorium resources. BARC continues to advance AHWR and ADS concepts, while the PFBR's thorium blanket experiments are generating valuable U-233 irradiation data to support future fuel qualification activities. As technology development and Fast Breeder Reactor deployment progresses over the coming decades, stage three is expected to play an increasingly important role in India's long-term nuclear energy roadmap.

Source: EY Analysis on BARC AHWR – https://www.barc.gov.in/technologies/reactor-technology/ahwr.html | IAEA Thorium Fuel Cycle – https://www.iaea.org/publications/7192/thorium-fuel-cycle | IAEA Thorium Reserves – https://www.iaea.org/newscenter/news/thorium-resources

Three indigenous SMR designs advance under India's INR20,000 crore nuclear mission

	BSMR-200	SMR-55	HTGCR
Capacity	220 MWe	55 MWe × 2 units	Up to 5 MWth
Cost outlay	INR5,960 crore	INR7,000 crore	INR320 crore
Status	In-principle approval; AEC-cleared for submission to the Cabinet Committee	In-principle approval received	In-principle approval; DPR prepared; siting consent + environmental ToR received
Lead-unit side	Tarapur APS, Maharashtra	Tarapur APS, Maharashtra	BARC Vizag, Andhra Pradesh

INR20,000 crore
SMR provision – nuclear energy mission (Budget 2025-26)

60 months -72 months
BSMR construction time from administrative and financial approval

Indigenized
ApuRVA reactor-vessel alloy + in-house control-rod-drive mechanism

Recognizing the growing importance of nuclear energy in ensuring long-term energy security and providing reliable low-carbon baseload power, the Government of India has significantly strengthened support for the domestic nuclear ecosystem. The Union Budget 2025-26 announced a INR20,000 crore nuclear energy mission to accelerate the development and deployment of indigenous Small Modular Reactors (SMRs).

India's SMR program is progressing across multiple reactor technologies. The 220 MWe Bharat Small Modular Reactor (BSMR-200) and the 55 MWe SMR-55 have received in-principle approvals, while the High Temperature Gas Cooled Reactor (HTGR) has secured key project clearances. The program is supported by indigenous technology development, including domestically developed reactor vessel materials and control rod mechanisms, reinforcing India's emphasis on building a self-reliant nuclear manufacturing ecosystem.

Together, these developments indicate that nuclear energy is being positioned as an important component of India's future electricity system, complementing renewable energy by providing firm, low-carbon power while strengthening long-term energy independence and energy security.

Source: EY Analysis based on https://www.pib.gov.in/PressReleasePage.aspx?PRID=2238907&reg=48&lang=2

The intelligence layer: AI for energy, energy for AI

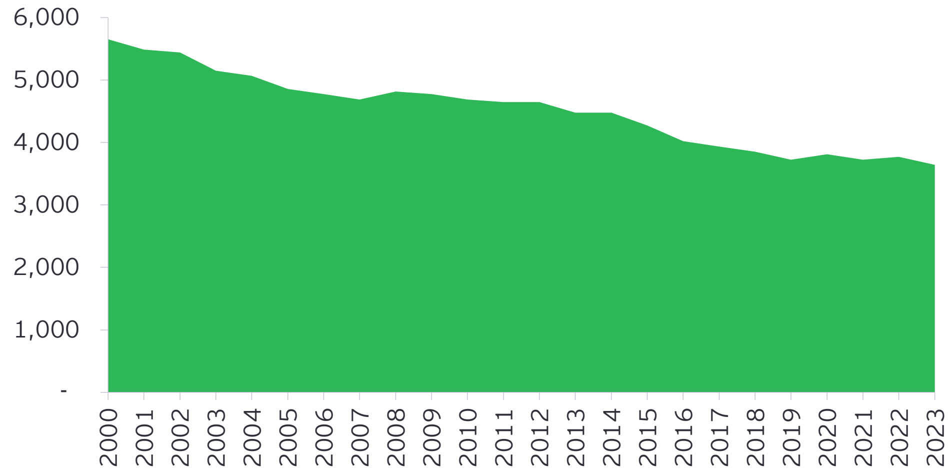
India's energy intensity has declined steadily over two decades

India has made significant progress in improving the energy efficiency of its economy over the past two decades. The country's total energy supply required to generate one unit of economic output declined from approximately 5,650 MJ per US dollar (PPP) in 2000 to around 3,640 MJ per US dollar (PPP) in 2023, representing an improvement of nearly 36%. This steady decline indicates that economic growth has become progressively less energy-intensive, reflecting improvements in technology, industrial processes, energy efficiency programs and structural changes across the economy.

The reduction in energy intensity demonstrates that India's economy has continued to expand while requiring comparatively less energy to produce each unit of GDP. Improvements in industrial efficiency, expansion of modern infrastructure, adoption of energy-efficient technologies, and policy initiatives such as the Perform, Achieve and Trade (PAT) scheme, appliance efficiency standards and energy conservation measures have collectively contributed to this long-term trend.

Although the overall trajectory has been consistently positive, the data also indicate that improvements in recent years have become more gradual. As India's economy becomes increasingly electrified and energy demand continues to grow, achieving further reductions in energy intensity will increasingly depend on efficiency improvements beyond conventional technologies. Digitalization, artificial intelligence, smart energy management systems and real-time optimization are expected to play an increasingly important role in enhancing efficiency across generation, transmission, distribution and end-use sectors.

Total energy supply (MJ) per unit of GDP(US$) (PPP), India



Source: https://www.iea.org/countries/india/efficiency-demand

India's energy efficiency programs have delivered significant economic and environmental benefits

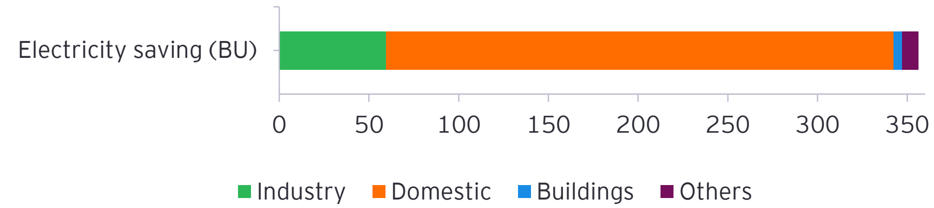
Energy efficiency has emerged as one of the most cost-effective approaches to strengthening India's energy security while supporting sustainable economic growth. Over the past decade, the government has implemented a comprehensive portfolio of energy efficiency initiatives across industry, households, buildings, transport and municipal infrastructure. Programs such as the Perform, Achieve and Trade (PAT) scheme, Standards & Labeling (S&L), UJALA, Street Lighting National Programme (SLNP) and Corporate Average Fuel Efficiency (CAFÉ) standards have collectively improved energy productivity across multiple sectors of the economy.

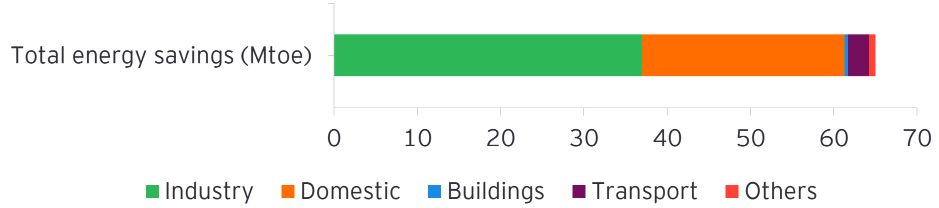
The cumulative impact of these initiatives has been substantial. Collectively, they have delivered 356.1 BU of electricity savings, 65.03 MTOE of total energy savings, 365.76 million tons of avoided CO_2 emissions, and approximately INR2.82 lakh crore in avoided energy costs. These outcomes demonstrate that energy efficiency is not only an environmental initiative but also a significant contributor to reducing energy demand, improving economic competitiveness and lowering the overall cost of energy consumption across the economy.

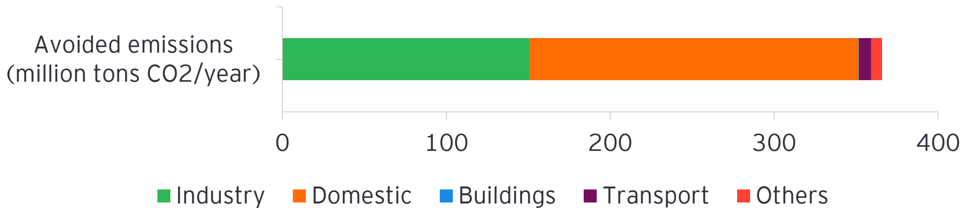
The benefits have been distributed across multiple sectors, each reflecting different pathways to improved energy performance. The industrial sector, driven primarily by successive PAT cycles, has cumulatively delivered 37.01 MTOE of energy savings, accounting for the largest share of total energy savings, while avoiding 150.49 $MtCO_2$ emissions and generating nearly INR83,754 crore in avoided energy costs. Meanwhile, the domestic sector, led by initiatives such as UJALA and Standards & Labeling, has emerged as the largest contributor to electricity savings, accounting for 282.9 BU of cumulative electricity savings, 200.86 $MtCO_2$ of avoided emissions and nearly INR1.84 lakh crore in avoided consumer expenditure. Additional contributions from buildings, transport and municipal lighting programs further demonstrate that energy efficiency opportunities extend across the entire economy.

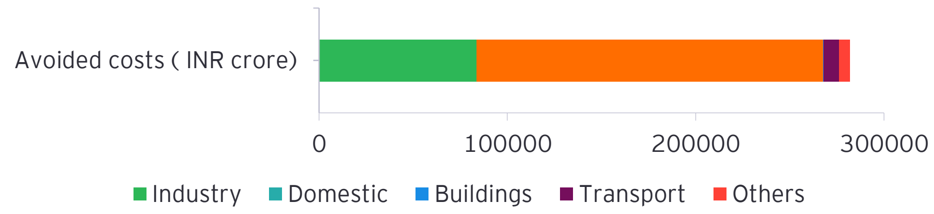
The cumulative achievements of these programs underline the important role of demand-side measures in India's energy transition. As conventional energy efficiency measures mature, future improvements are expected to increasingly depend on digitalization, advanced analytics and artificial intelligence. AI-enabled energy management, predictive maintenance, intelligent demand response, smart buildings and real-time optimization of industrial and power system operations have the potential to unlock the next generation of efficiency gains, complementing the strong foundation established through existing national energy efficiency programs.

Sector-wise energy saving summary, 2024-25









Source: https://beeindia.gov.in/WriteReadData/L45218/4600785880366907.pdf

AI applications span the entire electricity value chain making systems more efficient

India's next phase of energy efficiency will increasingly be driven by digitalization and AI. Unlike traditional energy efficiency measures that improve the performance of individual assets, AI enables continuous optimization of the entire electricity value chain through real-time analysis of operational data and predictive decision-making. Across generation, transmission, distribution and consumer applications, AI can improve renewable energy forecasting, optimize network utilization, reduce technical losses, enhance asset reliability and support demand-side flexibility. As the electricity system becomes more complex with higher renewable penetration, AI has the potential to significantly improve both operational efficiency and grid resilience. Internationally, AI techniques are also being applied upstream of operations – in long-term system planning, renewable resource assessment, network expansion studies and the design, scheduling and monitoring of infrastructure construction – extending digital optimization across the full project lifecycle.

Generation

- RE output forecasting (solar/wind)
- Predictive maintenance of plants and turbines
- Thermal ramp-rate optimization

Efficiency linkage

Lower forecast error → less balancing and curtailment

Transmission

- Dynamic line rating
- Congestion and margin prediction
- Fault detection/self-healing

Efficiency linkage

Higher utilization of existing lines

Distribution

- Distribution load forecasting
- Loss and theft detection
- Predictive asset maintenance

Efficiency linkage

Targets India's ~15% AT&C losses

Consumption and DER

- Smart-meter analytics
- Demand response/ToD optimization
- VPP and DER aggregation

Efficiency linkage

Flattens peak load

India anchor

RE forecasting is already mandated under CERC's Forecasting, Scheduling and Deviation Settlement framework – making forecast accuracy a measurable, penalized metric, not an optional capability.

Source: EY Analysis, ICED Dashboard by NITI Aayog

Forecasting: The highest-value AI capability already mandated

Small accuracy gains carry outsized, quantified value across India's generation fleet.

80%-90%

Forecast accuracy achieved by AI/deep-learning models versus conventional statistical methods

Already mandated in India

Under CERC's Forecasting and Scheduling regulations, wind and solar generators must forecast output; deviations are penalized through the Deviation Settlement Mechanism (DSM). Forecast accuracy therefore carries a direct rupee value.

1%→0.1%-0.3%

1% cut in load-forecast error (MAPE) with a 3%-5% production-side impact and by 0.1%-0.3% lower generation costs

Way forward

As renewable energy penetration increases, further strengthening of real-time data integration and communication between renewable energy generators and system operators can enhance forecasting accuracy, system balancing and overall grid efficiency.

Source: EY Analysis, IEEE (load-forecasting MAPE-cost relationship); CERC Forecasting, Scheduling & DSM regulations; NITI Aayog / S. Sharma (Spain ensemble forecasting).

The demand side carries the biggest measurable loss and peak-load gaps — and leads into the data-center surge.

15.04%

All-India AT&C losses, FY25

Down from 15.97% in FY24 (PFC / Ministry of Power). The single largest efficiency baseline AI loss-detection and predictive maintenance can act on

Loss and theft detection

Analytics on smart-meter and feeder data to localize technical and commercial losses.

Predictive asset maintenance

Transformer/ feeder health monitoring to cut outages during demand peaks.

Smart-meter analytics

Consumption-pattern insight enabling time-of-day tariffs and demand shifting.

Demand response

Automated load-shifting to flatten peaks and absorb midday solar.

VPP and DER aggregation

Pooling rooftop solar, storage and EV load into dispatchable capacity.

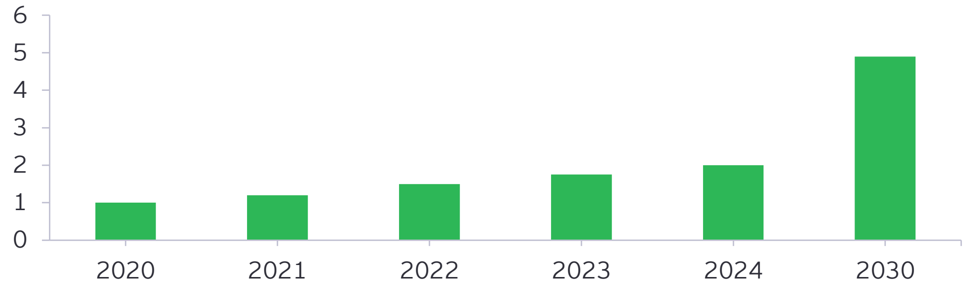
The pivot to demand

the same AI that optimizes the electricity value chain is itself becoming one of its fastest-growing loads – next, the data-center demand surge.

Source: PFC / Ministry of Power, 14th Integrated Rating & Ranking Report (AT&C losses, FY25); EY analysis.

India’s digital ecosystem is accelerating AI adoption across the power sector

India’s data center capacity (GW)



Metric	Global	India
Internet penetration	~67% of population (2024)	>55% of population (2024)
5G / 6G deployment	USA and China exploring 6G; ~6.3 billion global 5G subscriptions by 2030	5G still deploying; India's 5G penetration likely doubled in 2024 vs 2023
Mobile data/smartphone/ month	~19 GB (2024); ~13% CAGR to 2030	~30 GB (2024); ~13% CAGR to 2030
Technology and communications share in service exports	14.6% (2023)	48.2% (2023)
AI market size	US$180 billion - US$200 billion; ~28% CAGR next 5-6 years	US$ >9 billion; 25%–35% CAGR next 2-3 years

The adoption of AI in the power sector is closely linked to the rapid evolution of India's digital ecosystem. Rising internet penetration, widespread smartphone adoption, expanding broadband connectivity and the nationwide rollout of 5G networks are generating unprecedented volumes of digital data, creating the foundation for large-scale AI deployment. These developments enable utilities and system operators to leverage real-time information from smart meters, SCADA systems, sensors, weather stations and distributed energy resources to optimize power system operations and improve overall energy efficiency.

India is also emerging as one of the world's fastest-growing digital economies, supported by strong growth in AI investments, cloud computing and digital infrastructure. Mobile data consumption has increased to around 30 GB per user per month, significantly above the global average, while the domestic AI market is expected to grow at 25%–35% annually over the next few years. At the same time, the technology and communications sector accounts for nearly half of India's services exports, highlighting the country's growing role in the global digital economy and its favorable ecosystem for AI innovation.

These digital advancements provide a strong platform for accelerating AI adoption across the electricity value chain. AI-powered forecasting, predictive maintenance, intelligent asset management and demand-side optimization have the potential to improve system efficiency, reduce technical losses, enhance renewable energy integration and optimize the utilization of existing infrastructure. As the electricity system becomes increasingly complex with higher renewable penetration and greater electrification, AI is expected to play a progressively larger role in improving both operational efficiency and grid resilience.

However, the rapid expansion of AI also introduces a new dimension to energy planning. The growth of AI applications is driving substantial investments in hyperscale data centers and cloud infrastructure, creating a rapidly growing source of electricity demand. Consequently, AI is emerging both as an enabler of a more efficient power system and as a driver of future electricity consumption, making efficient and reliable power infrastructure increasingly critical for sustaining India's digital economy.

Source: https://iea.blob.core.windows.net/assets/de9dea13-b07d-42c5-a398-d1b3ae17d866/EnergyandAI.pdf , The digital backbone: Data center growth prospects in India, May 2025 - https://www.colliers.com/en-in/research/the-digital-backbone-data-center-growth-prospects-in-india

Growing data center capacity reinforces the need for reliable power infrastructure

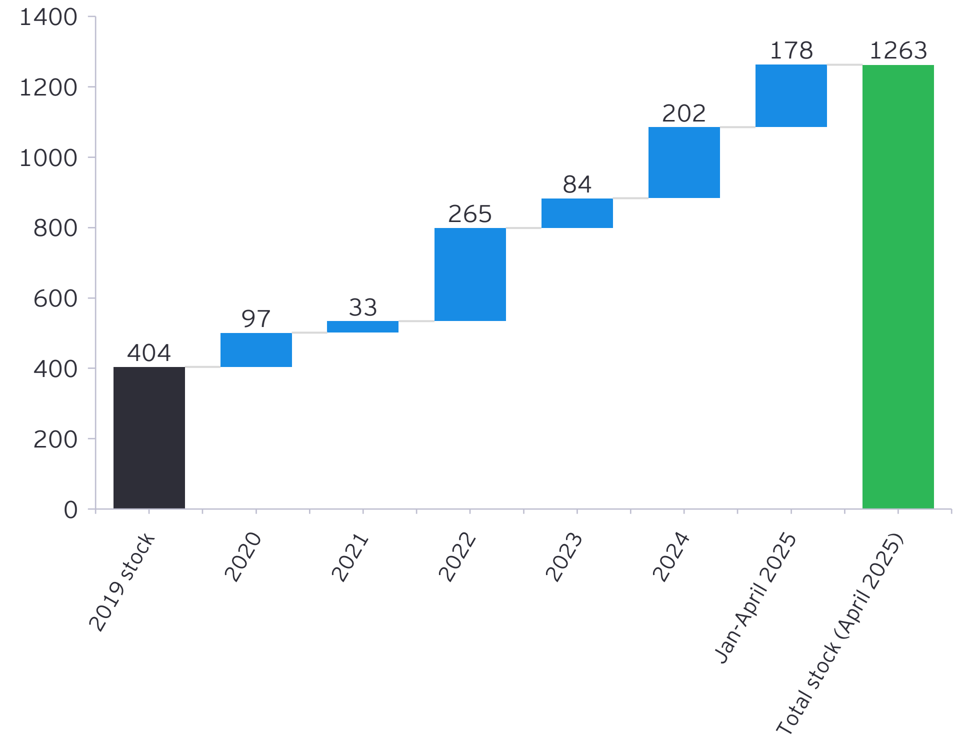
India's rapid digitalization and accelerating adoption of AI are driving unprecedented investments in data center infrastructure. As businesses, cloud service providers, and AI developers increasingly rely on high-performance computing and data-intensive applications, data centers are emerging as one of the fastest-growing sources of electricity demand. Between 2019 and April 2025, the installed data center capacity of India's seven largest markets increased from approximately 404 MW to 1,263 MW, representing more than a three-fold expansion in just six years.

The pace of capacity addition has accelerated significantly in recent years, reflecting strong growth in cloud computing, AI workloads, digital services and enterprise data requirements. The largest annual additions were recorded during 2022 (265 MW) and 2024 (202 MW), while a further 178 MW was added in the first four months of 2025 alone. This sustained growth indicates that India's data center market is transitioning from an emerging segment to a critical component of the country's digital infrastructure.

Unlike conventional commercial buildings, data centers require a continuous, high-quality electricity supply and place substantial demands on transmission and distribution infrastructure. In addition to increasing electricity consumption, AI-enabled computing significantly raises cooling requirements, making power availability, reliability and energy efficiency key factors in determining future data center locations and operating costs.

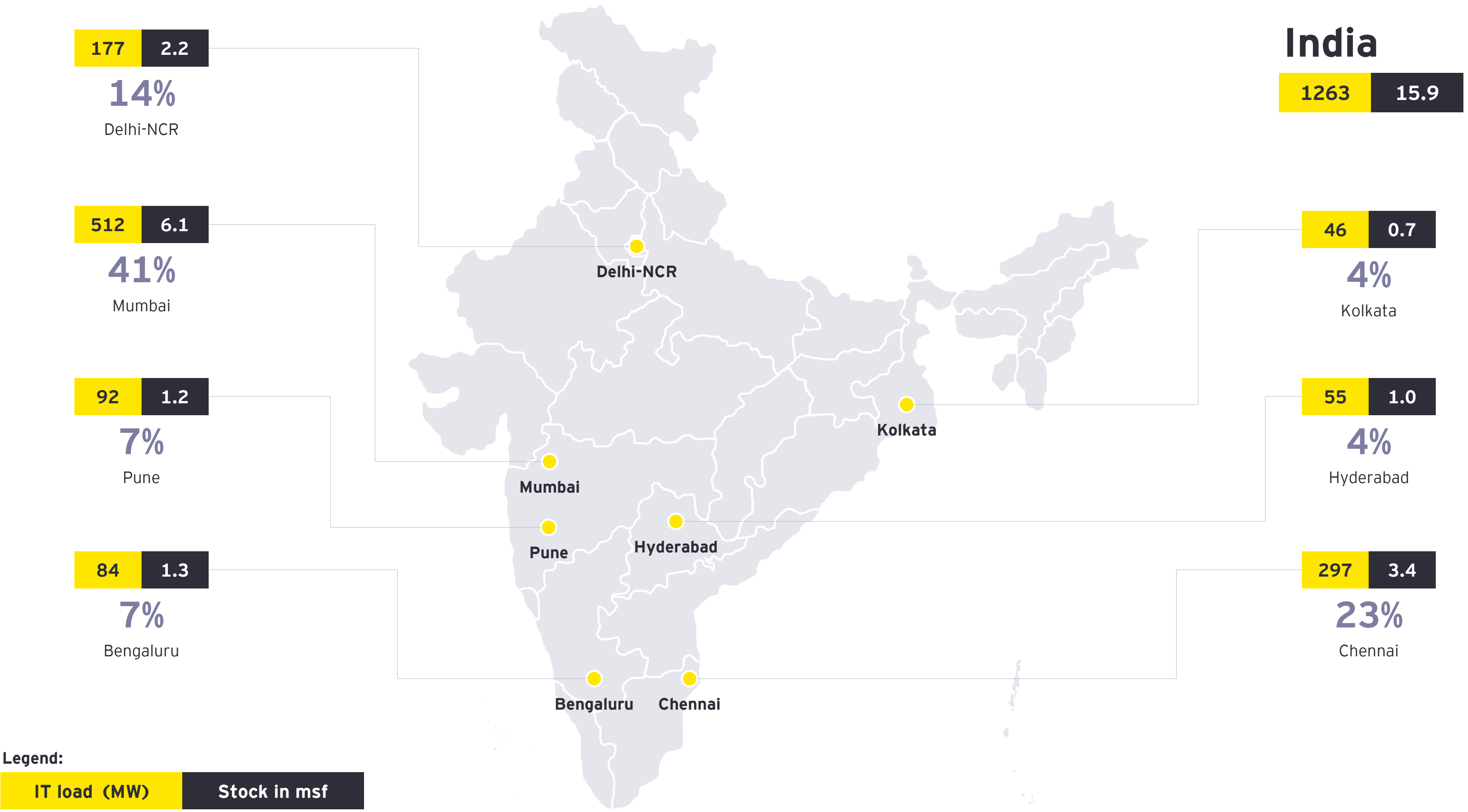
As India's AI ecosystem continues to expand, ensuring that the growing demand from data centers is met through reliable, efficient and increasingly low-carbon electricity will become an important aspect of long-term energy planning. This presents both an opportunity and a challenge—while AI can significantly improve the efficiency of the electricity system, the infrastructure supporting AI is itself becoming a major driver of future electricity demand.

Trends in DC capacity/supply addition in MW across top seven Indian cities



Source: The digital backbone: Data center growth prospects in India, May 2025 - https://www.colliers.com/en-in/research/the-digital-backbone-data-center-growth-prospects-in-india

India's data center capacity is concentrated in a few strategic digital hubs



XX% indicates the share of the respective city in the overall DC capacity of India (top seven cities)

Source: The digital backbone: Data center growth prospects in India, May 2025 - https://www.colliers.com/en-in/research/the-digital-backbone-data-center-growth-prospects-in-india

Geographic concentration of data centers calls for targeted power infrastructure planning

India's data center ecosystem is highly concentrated, with the majority of capacity located in a few major metropolitan regions that offer strong digital connectivity, reliable power infrastructure and access to large enterprise customers. As of April 2025, the country's seven largest data center markets account for 1,263 MW of installed IT load and approximately 15.9 million sq. ft. of operational data center space.

Mumbai remains the dominant data center hub, accounting for 41% of the country's installed IT load (512 MW), followed by Chennai (23%; 297 MW) and Delhi NCR (14%; 177 MW). Together, these three regions account for nearly 78% of India's total operational data center capacity, highlighting the strong geographic concentration of digital infrastructure. Bengaluru and Pune contribute 7% each, while Hyderabad and Kolkata currently account for about 4% each.

The concentration of data centers in a handful of cities presents both opportunities and challenges for the power sector. These facilities require uninterrupted, high-quality electricity and are increasingly procuring renewable energy to meet sustainability commitments. Consequently, utilities serving these regions face growing requirements to strengthen transmission and distribution networks, improve power quality, and ensure adequate firm capacity to support rapidly growing digital infrastructure.

As AI adoption accelerates, data center expansion is expected to extend beyond traditional hubs into emerging markets. As India's digital economy continues to expand, ongoing development of generation, transmission and distribution infrastructure will play an important role in supporting growing electricity demand while maintaining reliability, efficiency and system resilience.

Source: The digital backbone: Data center growth prospects in India, May 2025 - https://www.colliers.com/en-in/research/the-digital-backbone-data-center-growth-prospects-in-india

7

The new dependence: Critical minerals and the geography of supply

Critical minerals and the future of energy security

For decades, India's energy security has been defined by its dependence on imported crude oil, with around 90% of domestic crude oil demand met through imports. Consequently, reducing oil import dependence has remained a central objective of India's energy policy, driving efforts to diversify energy sources, improve efficiency and accelerate electrification.

As the global energy transition gathers pace, however, the nature of India's energy security challenge is evolving. Clean energy technologies – including solar PV, wind turbines, battery energy storage systems, electric vehicles and modern transmission infrastructure—are significantly more mineral-intensive than conventional energy systems. This is creating a new strategic dependency on critical energy transition minerals (CETMs) that underpin the technologies of the future.

The analysis indicates that India currently sources several critical minerals, including lithium, nickel, cobalt, rare earth elements and other technology materials, primarily through international supply chains. These minerals are expected to play an increasingly important role in supporting renewable energy, battery storage, electric mobility and modern power infrastructure. As the energy transition advances, the focus of energy security is broadening from conventional fuels to include critical minerals, clean energy technologies and resilient supply chains that support long-term economic growth and energy resilience.

India's long-term energy independence is therefore evolving from a focus on fuel security to a broader objective of supply-chain sovereignty, encompassing mineral availability, domestic processing, manufacturing and recycling. As clean energy technologies continue to expand, securing resilient critical mineral supply chains will become an increasingly important pillar of India's future energy security.

~90% of crude oil is imported – India's defining fuel-era dependency

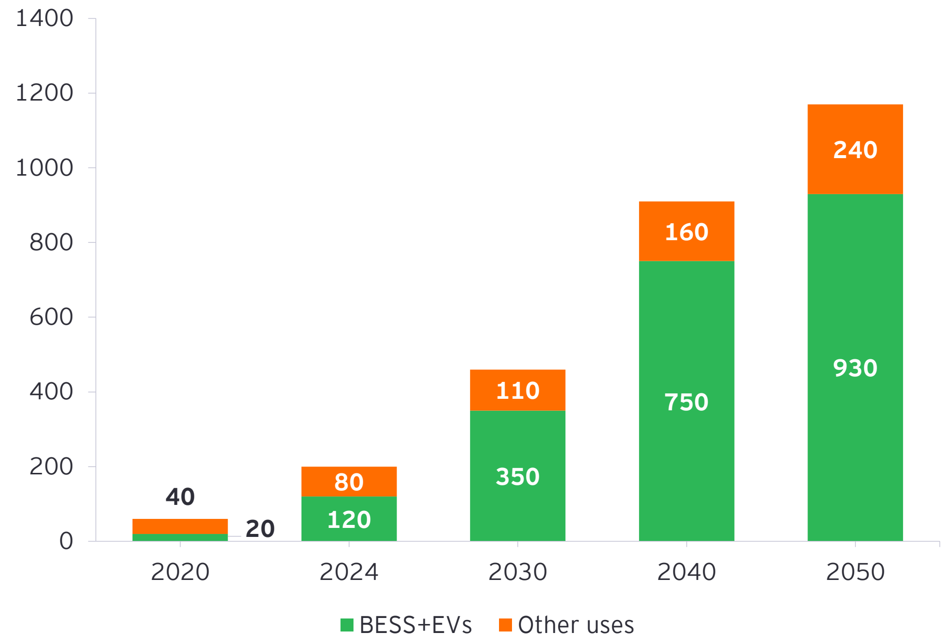
100% import dependence for 15 tracked critical minerals – the transition-era equivalent

Source: NITI Aayog Critical Mineral Assessment; PPAC (crude import dependence). EY analysis.

As India's dependence on imported crude oil gradually declines through electrification, a new strategic dependency is emerging on critical minerals that are indispensable for clean energy technologies, advanced manufacturing and future electricity infrastructure.

The energy transition is first a minerals transition

Global lithium demand by sector (KT)



The global energy transition is expected to drive an unprecedented increase in demand for critical minerals, with lithium emerging as one of the most strategically important resources. As the adoption of electric vehicles and battery energy storage systems (BESS) accelerates, lithium demand is projected to increase several-fold over the coming decades, fundamentally reshaping global mineral supply chains.

The chart illustrates that battery applications will account for the overwhelming majority of future lithium demand. Combined demand from electric vehicles and battery energy storage systems is projected to increase from around 20 kt in 2020 to approximately 930 kt by 2050, accounting for nearly 80% of total global lithium consumption. Demand from other applications is also expected to rise, increasing from 40 kt to around 240 kt over the same period, although at a comparatively slower pace.

This shift reflects the central role of lithium-ion batteries in supporting transport electrification, renewable energy integration and grid flexibility. As countries deploy larger volumes of electric vehicles and storage systems to strengthen energy security and decarbonize their economies, access to lithium and other battery minerals will become increasingly important for sustaining clean energy deployment.

For India, where lithium demand is expected to rise alongside ambitious electric mobility, renewable energy and battery storage targets, the rapid growth in global demand highlights the strategic importance of securing resilient mineral supply chains. The projected increase in battery-driven demand highlights the strategic significance of domestic capabilities across mineral sourcing, processing, recycling and advanced battery manufacturing as part of India's broader energy transition.

Source: EY Analysis on IEA Global Critical Mineral Outlook, 2025

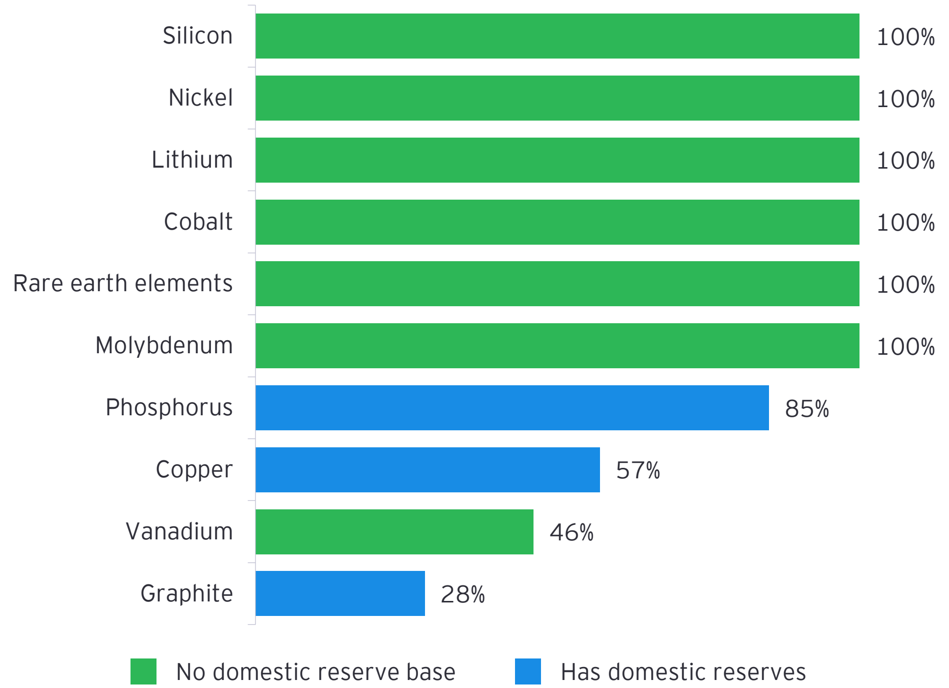
Critical minerals: Expanding domestic capabilities and supply security

India's transition towards a clean energy economy will require a substantial increase in the use of critical energy transition minerals (CETMs) that underpin renewable energy technologies, battery storage, electric mobility, power transmission and advanced manufacturing. An assessment of projected demand, domestic resources, reserves and current sourcing patterns highlights the growing importance of critical minerals in supporting India's energy transition. As clean energy deployment accelerates, strengthening domestic capabilities across exploration, processing, manufacturing and recycling will become increasingly important for enhancing long-term supply-chain resilience.

Of the 23 critical energy transition minerals assessed, 15 minerals are currently sourced primarily through international supply chains, including lithium, nickel, cobalt, silicon, rare earth elements (REEs), molybdenum, tin, selenium, indium, gallium, tungsten, niobium, germanium, platinum group elements (PGEs) and strontium. These minerals play a vital role in the manufacture of lithium-ion batteries, permanent magnets, semiconductors, photovoltaic modules, advanced electronics, hydrogen technologies and high-efficiency transmission equipment. As demand for these technologies grows, continued efforts to diversify supply sources, expand domestic capabilities and strengthen international partnerships will support long-term supply security and supply-chain resilience.

Even among minerals where domestic resources exist, import dependence remains significant. Phosphorous (85%), zirconium (78%), copper (57%) and vanadium (46%) continue to rely heavily on international supply chains despite the presence of identified resources. In several cases, the gap between estimated resources and economically recoverable reserves highlights the challenge of converting geological potential into commercially viable production. As demand accelerates between 2025 and 2070, this imbalance between projected consumption and domestic supply capability is expected to become increasingly pronounced.

Import dependence (%)

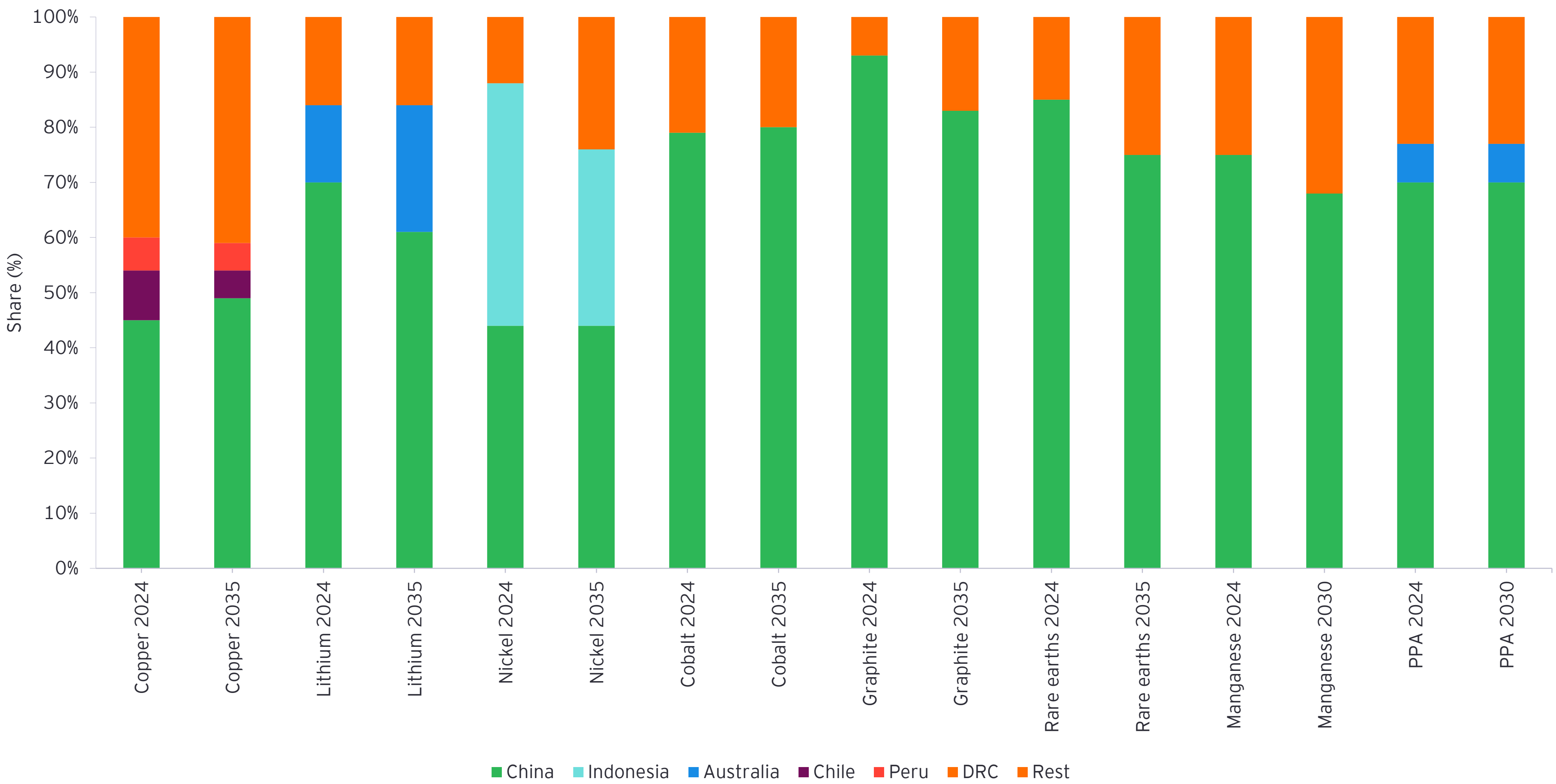


The analysis also illustrates that resource availability alone does not guarantee mineral security. Several minerals exhibit sizeable geological resources but relatively limited proven reserves or domestic refining capacity, indicating that mining, processing and downstream manufacturing remain equally important components of supply-chain resilience. Consequently, the transition to clean energy is shifting India's strategic dependence from imported hydrocarbons to imported minerals and mineral processing ecosystems.

Source: NITI Aayog Critical Mineral Assessment; PPAC (crude import dependence). EY analysis.

From ore to cell: India imports the finished product

Geographical distribution of refined material production – base case



Source: IEA Global Critical Mineral Outlook, 2025

Processing and refining capacity are emerging as key determinants of mineral security

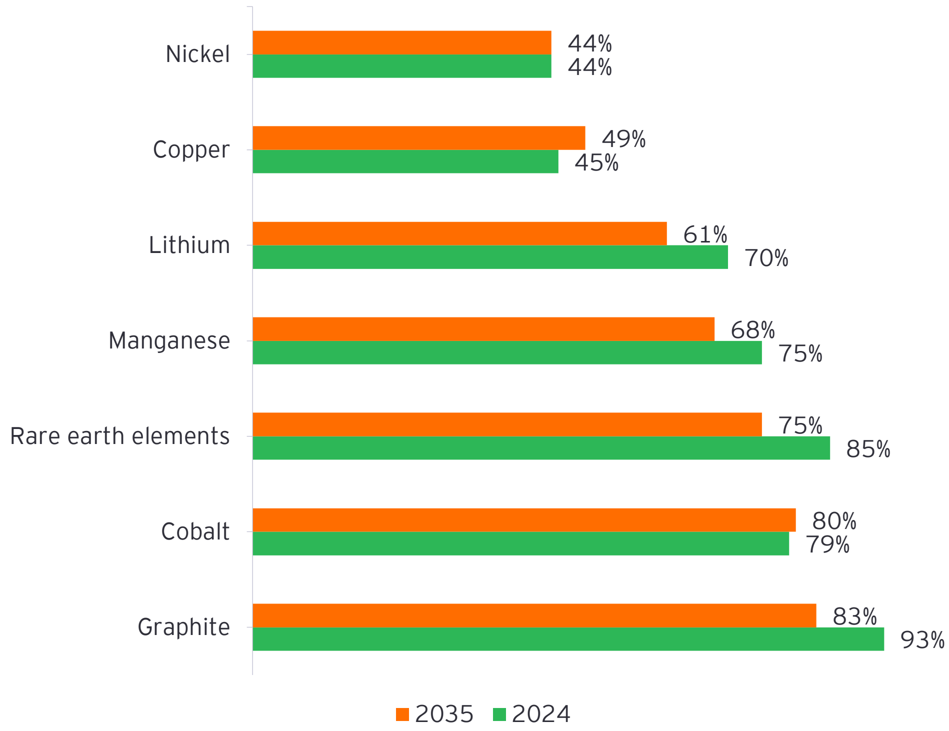
While critical minerals are geographically distributed across multiple countries, the processing and refining of these minerals remain highly concentrated, with China emerging as the dominant global hub across several strategic mineral value chains. This concentration extends beyond mining and gives China a pivotal role in supplying refined materials required for batteries, electric vehicles, renewable energy technologies, advanced electronics and modern power infrastructure.

The analysis shows that China accounts for nearly 93% of global graphite refining, 85% of rare earth processing, around 79% of cobalt refining, 75% of manganese processing, 70% of lithium refining, 45% of copper refining and 44% of nickel refining in 2024. Although China's share is projected to moderate marginally by 2035 for certain minerals as new refining capacity emerges globally, it is expected to remain the dominant producer across most critical mineral supply chains.

The geographical distribution of refining capacity also highlights varying levels of concentration across minerals. While countries such as Indonesia have established a significant position in nickel processing, Australia contributes meaningfully to lithium refining, and Chile and Peru remain important in copper processing, these capacities remain considerably smaller than China's across most mineral value chains. Consequently, a large proportion of globally mined critical minerals continue to be processed and refined in China before entering international clean energy manufacturing supply chains.

For India, this concentration represents an important dimension of future energy security. As demand for batteries, electric vehicles, renewable energy systems and transmission infrastructure increases, dependence on imported critical minerals is increasingly accompanied by dependence on overseas processing and refining capacity. The evolving energy transition therefore extends beyond securing access to raw minerals and increasingly requires resilient and diversified value chains across refining, processing, manufacturing and recycling.

China's share of global refined-material production (%)



44%–93% of refining concentrated in one country

Source: NITI Aayog Critical Mineral Assessment; PPAC (crude import dependence). EY analysis.

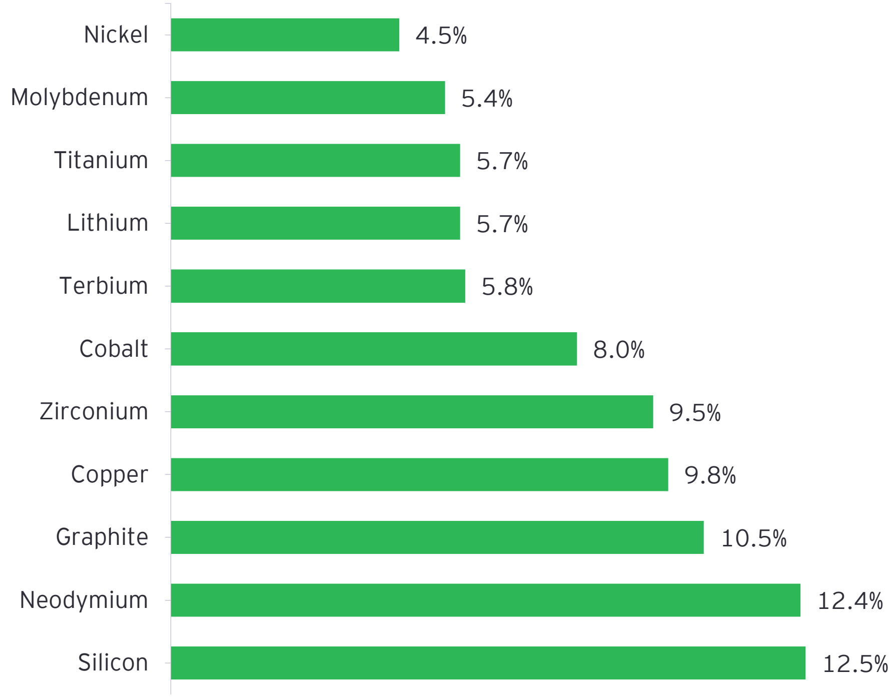
India’s role in evolving global critical mineral markets

Despite being one of the world's fastest-growing clean energy markets, India's share of global demand for most critical energy transition minerals is projected to remain below 10% under the Net Zero by 2050 scenario, ranging from approximately 4.5% for nickel to around 12.5% for silicon. While domestic demand for these minerals is expected to increase significantly as renewable energy, electric mobility and energy storage deployment accelerates, India will remain one among several major participants in global critical mineral markets.

The growing importance of critical minerals highlights the need for reliable and diversified supply chains to support clean energy technologies, batteries, electric vehicles and modern power infrastructure. At the same time, global refining and processing capacity for several critical minerals remains concentrated in a limited number of countries, underscoring the importance of supply-chain diversification, international partnerships and domestic capability development.

As the energy transition progresses, strengthening resilience across the critical mineral value chain will become increasingly important. Continued efforts in domestic exploration, processing and refining, international collaboration, recycling and circular economy initiatives can support long-term supply security while enhancing the competitiveness and resilience of India's clean energy ecosystem.

India's share of global critical-mineral demand, Net Zero by 2050 (%)



5%-12% India's share of 2050 global demand (NZS)

Source: NITI Aayog Critical Mineral Assessment.

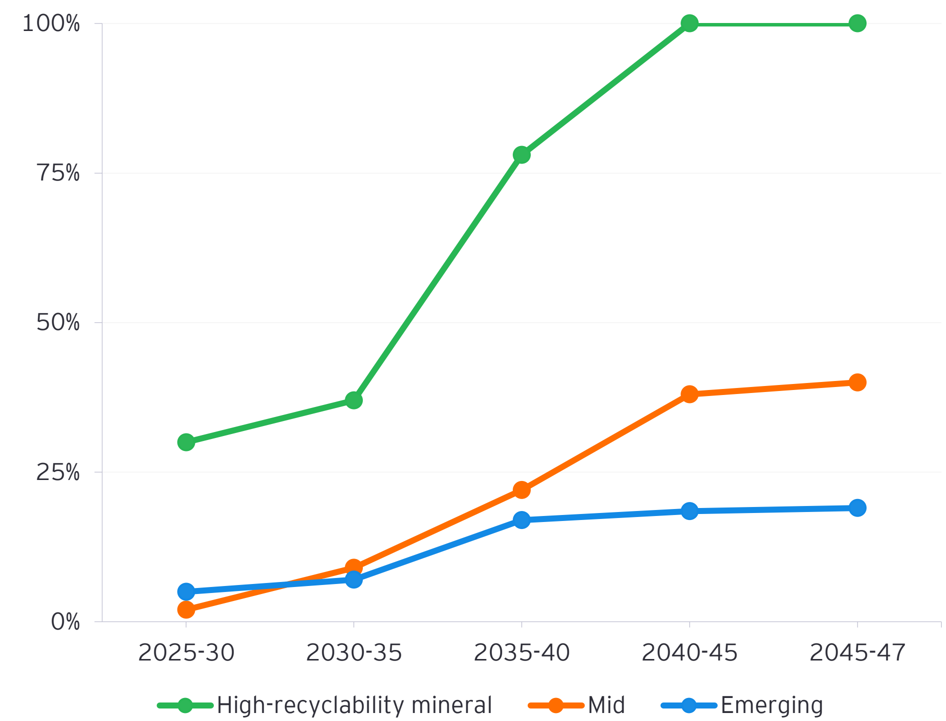
Circularity and domestic value chains are the independence levers

While India's demand for critical minerals is expected to increase significantly over the coming decades, recycling is projected to become an increasingly important domestic source of supply. Unlike fossil fuels, which are consumed only once, critical minerals can be recovered from end-of-life batteries, electric vehicles, renewable energy equipment and industrial products, enabling repeated use within the economy. The analysis indicates that the contribution of recycling to meet India's critical mineral demand is expected to increase substantially by 2047. Highly recyclable minerals could see recycled material meeting nearly 100% of annual demand by the mid-2040s, while moderately recyclable minerals are projected to meet around 40% of demand, and emerging mineral recycling streams could contribute close to 20%. The differing trajectories reflect variations in product lifecycles, technology maturity, collection systems and material recovery efficiency.

As larger volumes of batteries, electric vehicles, solar photovoltaic modules, wind turbines and other clean energy technologies reach end-of-life, the availability of secondary raw materials is expected to increase steadily. This marks a gradual transition from a linear mineral supply chain, dependent primarily on mining and imports, to a more circular material economy, where recycled materials increasingly supplement primary production.

Although it is unlikely to eliminate import dependence in the near term, the increasing contribution of secondary materials has the potential to reduce exposure to international supply disruptions, improve resource efficiency and strengthen long-term critical mineral security. The emergence of a domestic circular mineral ecosystem therefore represents a key structural shift in India's journey towards greater supply-chain sovereignty.

Share of mineral demand met by recycling, to 2047 (CPS) in India



1 **Domestic exploration**

2 **Processing and refining**

3 **Indigenous manufacturing**

4 **Recycling and circularity**

Source: IEA, Global Critical Minerals Outlook 2025 (recycling share, CPS). Approximate; legend labels indicative.

8 The resilience outlook: Redefining energy security by 2047

The grid's new shape: Firm share falls below half by 2029-30

The analysis presented throughout this report indicates that India's energy system is entering a fundamentally different phase of development. The transition towards a cleaner electricity system is accelerating, with intermittent renewable energy projected to account for nearly 60% of installed capacity by 2035-36. This represents a major structural shift in the composition of the power system, increasing the importance of flexibility, balancing resources, storage technologies and modern grid infrastructure in supporting reliable and efficient system operations.

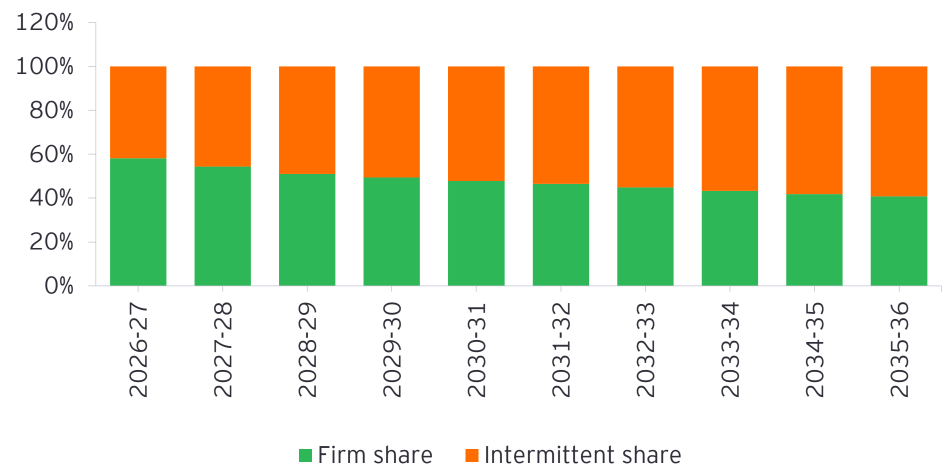
At the same time, India's energy import requirements are expected to evolve as the energy mix changes. While dependence on thermal coal is projected to decline gradually, international supply chains will continue to play an important role in meeting the country's energy and technology requirements. The composition of imports is expected to shift progressively from conventional fuels towards critical minerals, clean energy technologies and advanced manufacturing value chains. As a result, the focus of energy security is expanding beyond fuel availability to encompass supply-chain resilience, domestic capabilities and technological competitiveness.

Taken together, these trends suggest that the future of India's energy security will be determined not by a single fuel or technology, but by the ability of the overall energy system to remain reliable, efficient and resilient amid changing patterns of demand, generation and global supply chains. Energy independence is increasingly becoming a multidimensional concept encompassing domestic generation, firm low-carbon capacity, modern grid infrastructure, digital intelligence, manufacturing capability and resilient supply chains.

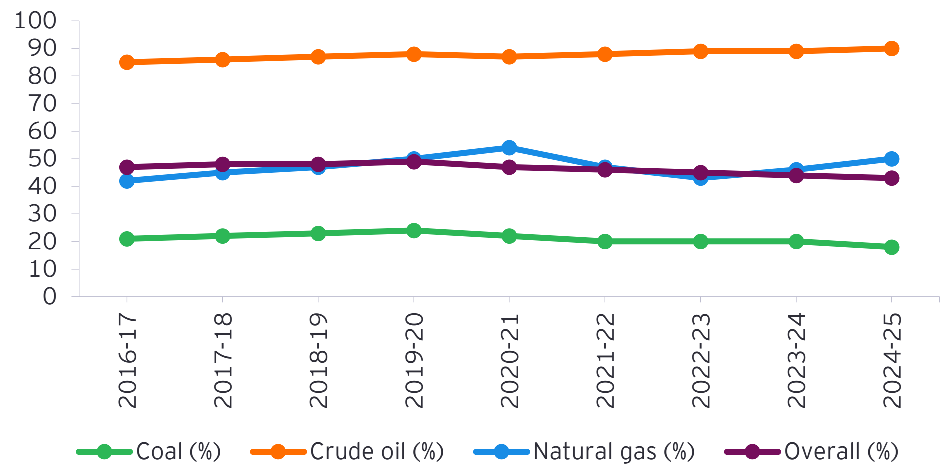
The analysis presented across this report indicates that India's progress towards Viksit Bharat 2047 will depend on successfully balancing these interconnected dimensions. The transition ahead is not simply one of replacing fossil fuels with renewables, but of building an energy system that is simultaneously cleaner, more self-reliant, technologically competitive and resilient, while supporting sustained economic growth and long-term energy security.

Source: https://cea.nic.in/wp-content/uploads/notification/2026/04/Long_term_National_Resource_Adeqaucy_Plan2026_27_to_2035_36.pdf ; https://beeindia.gov.in/WriteReadData/L45218/4600785880366907.pdf, publications_reports1776237477541_45c77e58-ea65-49e7-bb5e-7bb36d931d15_Chapter-8.xlsx
Ministry of Statistics and Program Implementation | Government Of India

Firm vs intermittent capacity share, 2026-27 to 2035-36



India's import dependency on primary fuel supply



India's energy security is a multidimensional challenge

The analysis presented throughout this report demonstrates that India's energy security challenge is both unprecedented in scale and increasingly multidimensional. As the world's third-largest energy consumer, third-largest crude oil importer, fourth-largest refining hub and fourth-largest LNG importer, India has emerged as one of the most significant players in global energy markets. At the same time, the country's rapidly growing economy and rising energy demand mean that dependence on global energy and technology markets will remain an integral part of its energy landscape.

The findings across the report indicate that the nature of energy security is undergoing a fundamental transformation. While conventional concerns around crude oil, natural gas and LNG imports remain highly relevant, the clean energy transition is simultaneously creating new strategic dependencies on critical minerals, advanced manufacturing, batteries, solar modules, power electronics and digital technologies. Consequently, the challenge is no longer limited to securing fuel supplies but extends across the entire energy value chain—from resource availability and manufacturing to electricity infrastructure, digital systems and global supply chains.

The report also highlights that India's electricity system is evolving rapidly, with renewable energy expected to account for nearly 60% of installed capacity by 2035-36, while overall energy import dependence is projected to remain above 40%. These trends illustrate that the transition to cleaner energy does not automatically eliminate external vulnerabilities; rather, it changes their nature. Future energy security will increasingly depend on the ability to integrate large-scale renewable energy, maintain adequate firm and flexible capacity, strengthen domestic manufacturing, improve energy efficiency, and enhance the resilience of critical supply chains.

Taken together, the evidence presented across all chapters suggests that energy independence is not synonymous with complete self-sufficiency or the elimination of imports. For an economy of India's size and growth trajectory, such an objective is neither practical nor necessary. Instead, long-term energy security will be determined by the country's ability to reduce strategic vulnerabilities, diversify sources of supply, strengthen domestic capabilities and build a resilient, efficient and technologically competitive energy ecosystem capable of supporting sustained economic growth and the vision of Viksit Bharat 2047.

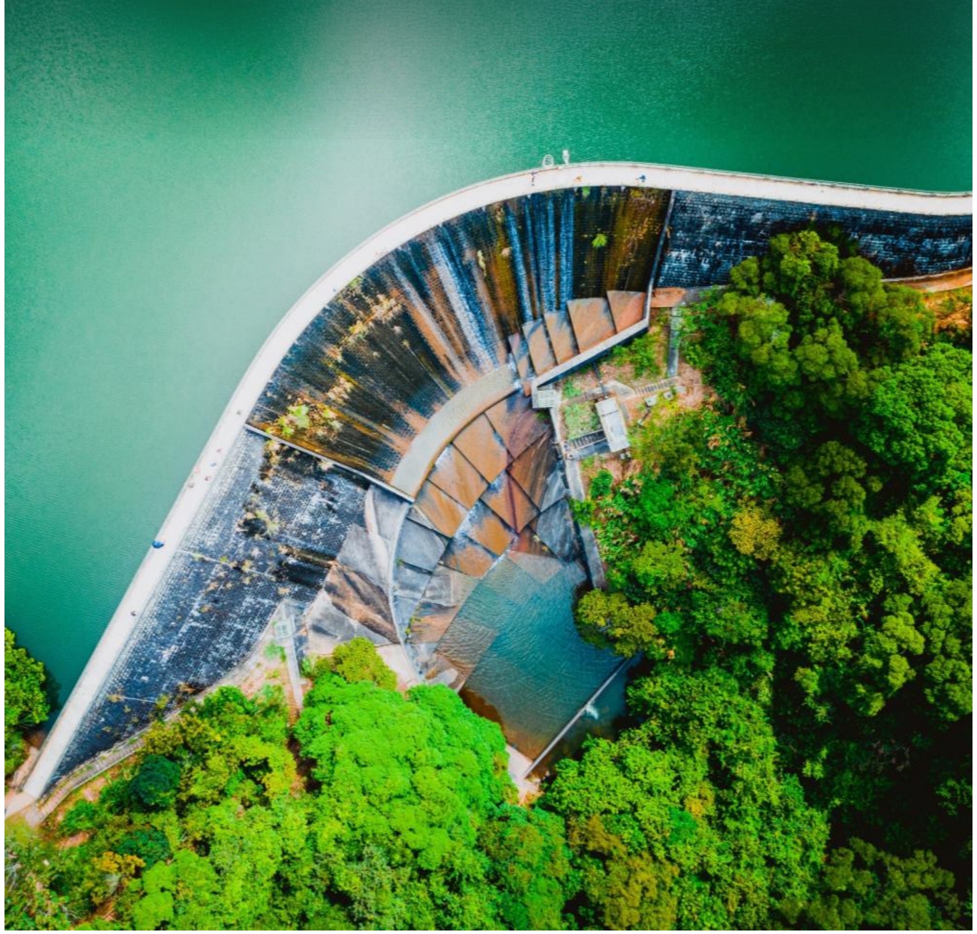
Source: https://mopng.gov.in/files/TableManagements/2026-02-25-141451-b06fw-IPNG_Statistics-Report_2024-25.pdf

Global versus India comparison table

Indicator	World	India	India's ranking
Total primary energy consumption (Exajoules)	592	39	3
Refining capacity (thousand barrels daily)	1,04,523	5,172	4
Crude oil consumption (thousand barrels daily)	1,01,418	5,621	3
Natural gas consumption (BCM)	4,128	70	11
Crude oil import (thousand barrels daily)	45,706	4,795	3
Petroleum products imports (Thousand barrels daily)	28,983	1,214	5
Petroleum products exports (Thousand barrels daily)	31,785	1,342	6
LNG import (BCM)	544.1	37.9	4

Source: https://mopng.gov.in/files/TableManagements/2026-02-25-141451-b06fw-IPNG_Statistics-Report_2024-25.pdf

India is already one of the world's largest energy economies. In the clean energy era, energy security is no longer defined solely by access to fuels, but by the resilience of the entire energy ecosystem—spanning domestic energy resources, manufacturing, critical mineral supply chains, modern infrastructure, technological capability and system-wide efficiency.



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Acronyms

ADS	Accelerator Driven System
AEC	Atomic Energy Commission
AHWR	Advanced Heavy Water Reactor
AI	Artificial Intelligence
ALWR	Advanced Light Water Reactor
APS	Atomic Power Station
AT&C	Aggregate Technical and Commercial (losses)
BARC	Bhabha Atomic Research Centre
BCM	Billion Cubic Meters
BEE	Bureau of Energy Efficiency
BESS	Battery Energy Storage System
BHAVINI	Bharatiya Nabhikiya Vidyut Nigam Limited
BSMR	Bharat Small Modular Reactor
BSR	Bharat Small Reactor
BU	Billion Units
BWR	Boiling Water Reactor
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CETM	Critical Energy Transition Mineral
CII	Confederation of Indian Industry
ckm	Circuit Kilometer
CPS	Current Policies Scenario
DAE	Department of Atomic Energy
DER	Distributed Energy Resources
DGFT	Directorate General of Foreign Trade
DSM	Deviation Settlement Mechanism
EMDE	Emerging Market and Developing Economies
ESS	Energy Storage System

EV	Electric Vehicle
FBR	Fast Breeder Reactor
FY	Financial Year
GDP	Gross Domestic Product
GJ	Gigajoule
GVA	Giga Volt-Ampere
GW	Gigawatt
GWh	Gigawatt-hour
HTGCR / HTGR	High Temperature Gas Cooled Reactor
HVDC	High Voltage Direct Current
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IESA	India Energy Storage Alliance
kt	Kiloton
kWh	Kilowatt-hour
LCOE	Levelised Cost of Electricity
LEU	Low Enriched Uranium
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LWR	Light Water Reactor
MAPE	Mean Absolute Percentage Error
mb/d	Million Barrels per Day
MMSCM	Million Standard Cubic Meters
MMT / MT	Million Metric Tonnes
MOX	Mixed Oxide (fuel)
MSF	Million Square Feet
$MtCO_2$	Million Tons of Carbon Dioxide
MTOE	Million Tons of Oil Equivalent

MU	Million Units
MVA	Mega Volt-Ampere
MW/MWe/MWth	Megawatt / Megawatt electric / Megawatt thermal
MWh	Megawatt-hour
NZS	Net Zero Scenario
PAT	Perform, Achieve and Trade
PFBR	Prototype Fast Breeder Reactor
PGE	Platinum Group Elements
PHWR	Pressurised Heavy Water Reactor
PLF	Plant Load Factor
PPAC	Petroleum Planning and Analysis Cell
PPP	Purchasing Power Parity
PSP	Pumped Storage Project
PV	Photovoltaic
PWR	Pressurised Water Reactor
SCADA	Supervisory Control and Data Acquisition
SLDC	State Load Despatch Centre
SLNP	Street Lighting National Programme
SMR	Small Modular Reactor
SPR	Strategic Petroleum Reserve
T&D	Transmission and Distribution
TFC	Total Final Consumption
ToD	Time of Day
TWh	Terawatt-hour
UJALA	Unnat Jyoti by Affordable LEDs for All
USD / US$	United States Dollar
USGS	United States Geological Survey
VPP	Virtual Power Plant
WNA	World Nuclear Association

We acknowledge the authors from the EY team

Somesh Kumar

Partner and Leader -
Power & Utilities

EY India

Gaurav Moda

Partner and Energy
Sector Leader

EY-Parthenon India

Shuboday Ganta

Director -
Power & Utilities

Strategy and Transactions
EY India

Sai teja Jupudi

Associate Vice President -
Power & Utilities

Strategy and Transactions
EY India

We acknowledge contributions on edit and design from

Tobit Pinto

Senior Associate -
Brand, Marketing and
Communications

EY India

Harshika Arora

Associate -
Brand, Marketing and
Communications

EY India

Notes

Our Offices

Ahmedabad
22nd Floor, B Wing, Privilon
Ambli BRT Road, Behind Iskcon Temple
Off SG Highway, Ahmedabad - 380 059
Tel: + 91 79 6608 3800

Gandhinagar
8th Floor, Building No. 14A
Block 14, Zone 1
Brigade International Financial Centre
GIFT City SEZ
Gandhinagar - 382 355
Tel: + 91 79 6608 3800

Bengaluru
12th & 13th Floor
"UB City", Canberra Block
No.24 Vittal Mallya Road
Bengaluru - 560 001
Tel: + 91 80 6727 5000

Ground & 1st Floor
11, 'A' wing
Divyasree Chambers
Langford Town
Bengaluru - 560 025
Tel: + 91 80 6727 5000

3rd & 4th Floor
MARKSQUARE
#61, St. Mark's Road
Shantala Nagar
Bengaluru - 560 001
Tel: + 91 80 6727 5000

1st & 8th Floor, Tower A
Prestige Shantiniketan
Mahadevapura Post
Whitefield, Bengaluru - 560 048
Tel: + 91 80 6727 5000

Ecospace
1st Floor, Campus 1C
Ecospace Business Park
Outer Ring Road,
Bellandur - Sarjapura Area, Varthur Hobli,
Bengaluru Urban - 560103

Bhubaneswar
8th Floor, O-Hub, Tower A
Chandaka SEZ, Bhubaneswar - 751024
Tel: + 91 674 274 4490

Chandigarh
Elante offices, Unit No. B-613 & 614
6th Floor, Plot No- 178-178A
Industrial & Business Park, Phase-I
Chandigarh - 160 002
Tel: + 91 172 6717800

Chennai
6th & 7th Floor, A Block,
Tidel Park, No.4, Rajiv Gandhi Salai
Taramani, Chennai - 600 113
Tel: + 91 44 6654 8100

Delhi NCR
Aikyam
Ground Floor
67, Institutional Area
Sector 44, Gurugram - 122 003
Tel: + 91 124 443 4000

3rd & 6th Floor, Worldmark-1
IGI Airport Hospitality District
Aerocity, New Delhi - 110 037
Tel: + 91 11 4731 8000

4th & 5th Floor, Plot No 2B
Tower 2, Sector 126
Gautam Budh Nagar
Noida - 201 304
Tel: + 91 120 671 7000

Hyderabad
THE SKYVIEW 10
18th Floor, "SOUTH LOBBY"
Survey No 83/1, Raidurgam
Hyderabad - 500 032
Tel: + 91 40 6736 2000

THE SKYVIEW 20
2nd Floor, 201 & 202
Right Wing, Survey No 83/1
Raidurgam, Hyderabad - 500 032
Tel: + 91 40 6736 2000

Jaipur
9th floor, Jewel of India
Horizon Tower, JLN Marg
Opp Jaipur Stock Exchange
Jaipur - 302018
Tel: + 91 141 4618415

Kochi
7th Floor, ABAD Nucleus
NH-49, Maradu PO
Kochi - 682 304
Tel: + 91 484 433 4000

Kolkata
22 Camac Street
3rd Floor, Block 'C'
Kolkata - 700 016
Tel: + 91 33 6615 3400

6th floor, Sector V,
Building Omega, Bengal Intelligent
Park, Salt Lake Electronics Complex
Bidhan Nagar, Kolkata - 700 091
Tel: + 91 33 6615 3400

Mumbai
14th Floor, The Ruby
29 Senapati Bapat Marg
Dadar (W), Mumbai - 400 028
Tel: + 91 22 6192 0000

5th Floor, Block B-2
Nirlon Knowledge Park
Off. Western Express Highway
Goregaon (E)
Mumbai - 400 063
Tel: + 91 22 6192 0000

3rd Floor, Unit No.301
Building No.1, Mindspace-Gigaplex
IT Park, MIDC, Plot No. IT-5
Airoli Knowledge Park
Airoli West, Navi Mumbai - 400 708
Tel: + 91 22 6192 0003

18th Floor, Altimus
Pandurang Budhkar Marg
Worli, Mumbai - 400 018
Tel: + 91 22 6192 0503

Pune
C-401, 4th Floor
Panchshil Tech Park, Yerwada
(Near Don Bosco School)
Pune - 411 006
Tel: + 91 20 4912 6000

10th Floor, Smartworks
M-Agile, Pan Card Club Road
Baner, Pune - 411 045
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Confederation of Indian Industry

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For 2026-27, CII has identified "Accelerating Competitiveness: Growth, Resilience, Inclusion, Sustainability, Trust" as its theme, prioritising five key pillars. During the year, CII will align its policy advocacy, institutional initiatives, partnerships, and outreach to support Indian industry in strengthening these five interconnected pillars of competitiveness.

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Confederation of Indian Industry
The Mantosh Sondhi Centre, 23, Institutional Area, Lodi Road, New Delhi – 110 003 (India)
T: 91 11 45771000, E: info@cii.in W: www.cii.in