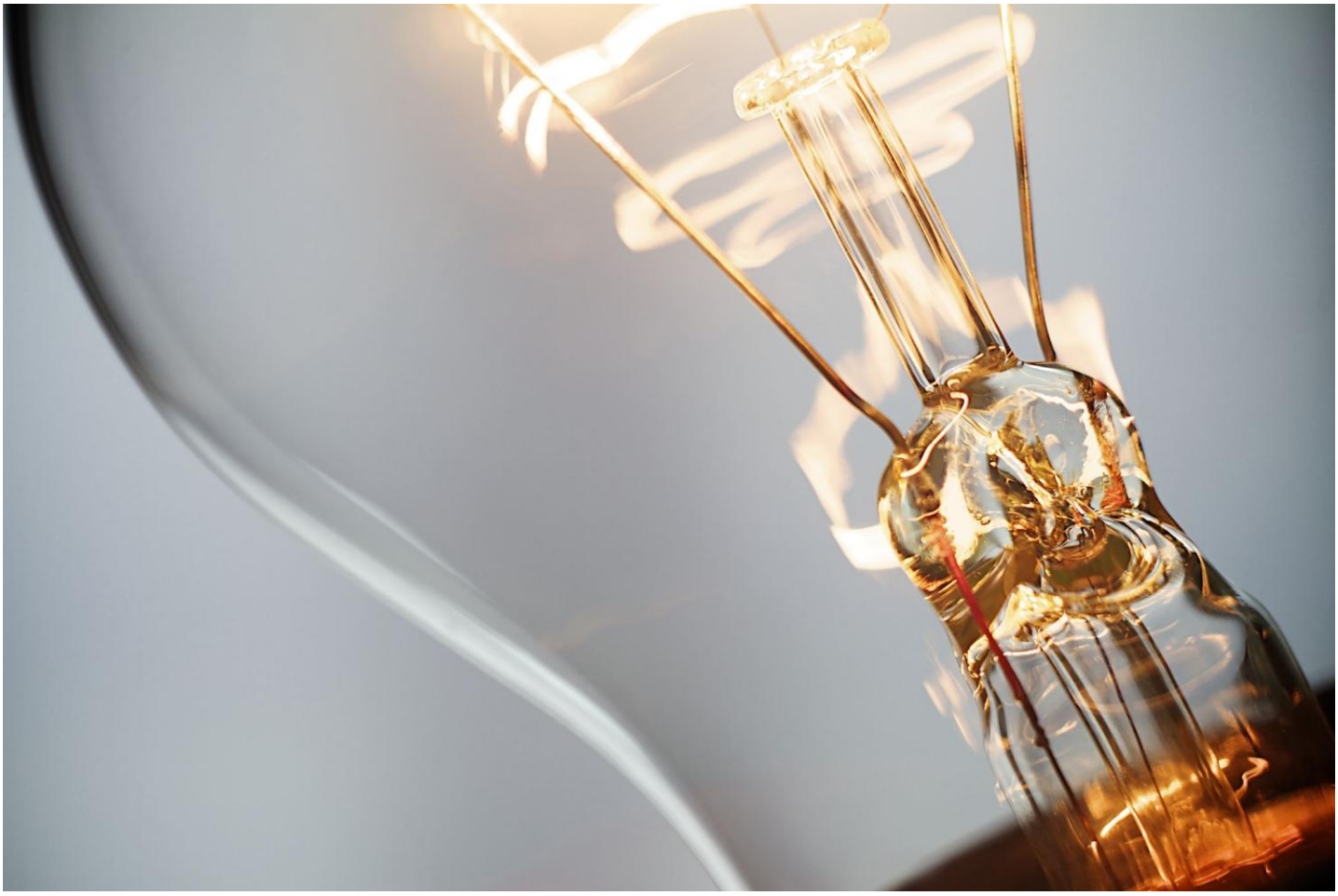
Indian Renewable Energy Report

POWERICA

Industry report	August 2025



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Module 1: Indian macroeconomic view

GDP review and outlook

India’s growth to be driven by a relatively balanced set of domestic drivers

Despite ongoing global geopolitical instability, India has maintained its position as one of the fastest-growing major economies globally. The country's real GDP is estimated to have grown at 6.5% year-on-year in fiscal 2025, according to National Statistical Office’s (NSO) second advance estimate of national income. In fiscal 2024 the GDP of India was Rs 176.5 trillion which grew at 9.2% over fiscal 2023. India is the fifth largest economy in the world in fiscal 2024 according to the International Monetary Fund’s (“IMF”) World Economic Outlook (April 2025). As per IMF GDP Forecasts, India’s GDP growth is estimated at 6.2% in fiscal 2025, the highest amongst the top 10 economies. World Bank has also forecasted India’s GDP to grow at 6.3% in fiscal 2025.

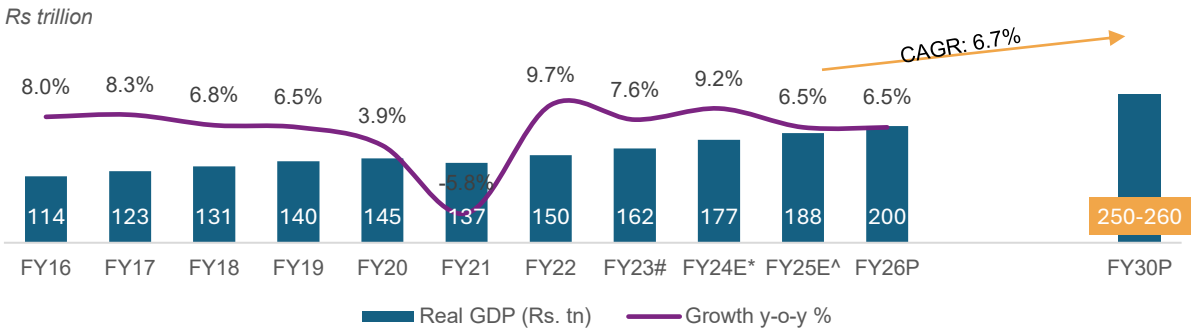
Looking ahead, Crisil Intelligence expects India to maintain its GDP growth at 6.5% in fiscal 2026 with downside risk owing to external headwinds. US tariff hikes pose a key downside risk to the industrial outlook this fiscal. As of now, the pause on the US’s reciprocal tariff increase provides temporary relief, but the 10% universal tariff hike by the Trump administration is in force since April. Slower global growth, along with anticipated reciprocal tariff hikes after July, are likely to hit goods exports this fiscal. Uncertainty regarding tariffs may hinder investments. The eventual impact of these factors will depend on the trade deal India strikes with the US. A 90-day pause in the reciprocal tariffs proposed by the Trump administration in the United States on all countries, excluding China, was further extended to end of July 2025. These developments have made the global environment extremely uncertain and raised downside risks to global as well as India’s growth. The escalation of the tariff war, with intermittent de-escalation, continues. However, on domestic front the combination of easing inflation, the RBI rate cuts, and the personal income tax cuts announced in the fiscal 2026 budget are expected to benefit households and boost consumption.

Over fiscals 2022-2025, Indian economy has outperformed its global counterparts by witnessing a faster growth. Going forward as well, the Indian economy will remain strong and would continue to be one of the fastest growing economies.

The Indian economy is expected to maintain its growth momentum, driven by a combination of domestic factors. The government's efforts to boost private consumption, invest in infrastructure, and promote economic growth will be crucial in sustaining the economy's growth trajectory. While government capital expenditure is expected to remain a key enabler, the continued emphasis on fiscal consolidation implies that investment prospects will hinge on a sustained revival in private capital expenditure. However, a new set of shocks emanating from current and potential US tariff actions could pose a downside risk in overall growth. The GDP

grew 6.5% on-year in the first quarter of fiscal 2025, in line with Crisil forecast of 6.8%. This was a deceleration as compared to the fourth quarter of fiscal 2024, in which the economy expanded by 8.4% on-year. In the first quarter of fiscal 2024, the economy had grown 9.7% on-year.

Figure 1: India's economy expected to grow at 6.5% in fiscal 2026, with possibility of downside risk



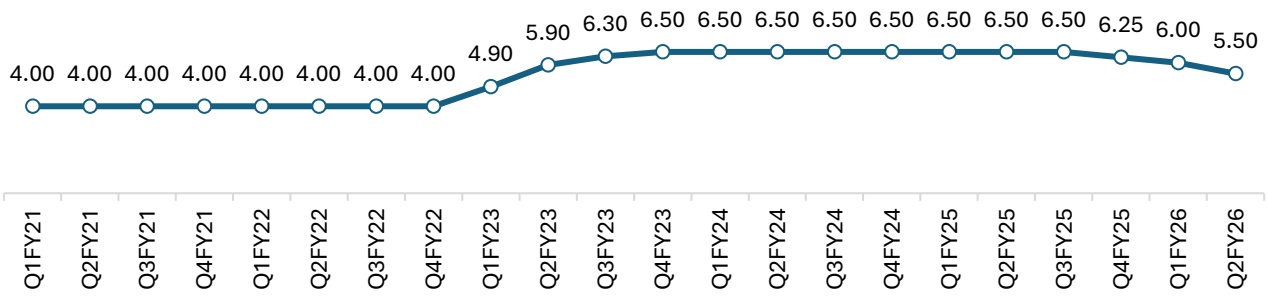
Note: E = Estimated, P = Projected; GDP growth till fiscal 2022 is actual, fiscal 2023 is Final Estimate *fiscal 2024E is First Revised Estimate, ^fiscal 2025E is Second Advanced Estimate, fiscal 2026 is projected based on Crisil Intelligence estimates and that for fiscals 2026-2030 is based on IMF estimates
Source: NSO, Crisil Intelligence

One more rate cut expected in fiscal 2026

Inflation rose in India and across the world in fiscal 2023 led by the fallout of Russia-Ukraine and a shortfall in crop harvests resulting in soaring food and fuel prices. This prompted major central banks to hike interest rates to combat inflation. The RBI raised the repo rate by a cumulative 250 bps to 6.5%. The Fed had increased interest rates by a cumulative 525 bps between February 2022 and July 2023.

Currently, major global central banks are at various stages in their rate-cutting cycles. The Fed cut the federal funds rate by a total of 100 bps, with the first rate cut of 50 bps in September 2024 followed by 25 bps each in November and December 2024 in response to easing inflationary pressures. The Monetary Policy Committee (MPC) of the Reserve Bank of India (RBI) cut the repo rate by 50 basis points (bps) in June, following a 25-bps cut in April, with the repo rate currently at 5.5%. Crisil Intelligence expects one rate cut in the remainder of this fiscal.

Figure 2: Repo rate in India (%)



Source: RBI, Crisil Intelligence

Table 1: Outlook for fiscal 2026

Macro parameters	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26F	Rationale for outlook
Real GDP growth (on-year %)	6.5	3.9	-5.8	9.7	7.6	9.2	6.5	6.5^	Lower inflation and the RBI's rate cuts are expected to maintain growth in fiscal 2026, assuming a normal monsoon and lower crude oil prices. The budget will be mildly supportive of growth, though overall fiscal impulse will moderate with fiscal consolidation. Any substantial pick-up in investment growth will hinge on accelerating private capex. Exports face headwinds from tariff hikes initiated by the US

Note: ^ with downside risk; F-forecast
Source: Crisil Intelligence

Except for CY21 when the COVID-19 pandemic led to a global economic downturn, India's GDP growth rate has consistently outpaced that of other major economies, solidifying its position as the world's fastest-growing major economy.

Table 2: Economy-wise GDP growth outlook

Country	2020	2021	2022	2023	2024	2025P	2026P
Brazil	-3.3%	4.8%	3.0%	3.2%	3.4%	2.0%	2.0%
China	2.3%	8.6%	3.1%	5.4%	5.0%	4.0%	4.0%
Germany	-4.1%	3.7%	1.4%	-0.3%	-0.2%	0.0%	0.9%
India*	3.9%	-5.8%	9.7%	7.6%	9.2%	6.5%	6.5%
Euro area	-6.0%	6.3%	3.5%	0.4%	0.9%	0.8%	1.2%
UK	-10.3%	8.6%	4.8%	0.4%	1.1%	1.1%	1.4%
US	-2.2%	6.1%	2.5%	2.9%	2.8%	1.8%	1.7%
Japan	-4.2%	2.7%	0.9%	1.5%	0.1%	0.6%	0.6%

Note: *India numbers are on a fiscal-year (FY) basis (Apr-Mar), where CY26 would correspond to fiscal 2026; on calendar year basis for other countries; ^ Estimates for India as per MOSPI, Crisil Intelligence; E – estimated; P – projected; Euro area includes Germany, France, Italy and Spain

Source: IMF World Economic Outlook, April 2025, Crisil Intelligence

India is poised to emerge relatively stronger amidst the prevailing global uncertainties, with GDP growth projected at 6.5% in fiscal 2026. The Indian economy's resilience and adaptability in the face of global challenges will be crucial in sustaining its growth momentum, and the country is likely to remain one of the fastest growing major economies in the world. Recently, according to the April 2025 edition of IMF's World Economic Outlook report, India's nominal GDP for FY26 is expected to reach around $4,187.017 billion, which is slightly higher than that of Japan which is estimated at $4,186.431 billion. This will take India from its current fifth position to fourth place by the end of 2025. Over the medium term, India is set to continue to be a dominant player in the global economy, with projections, as per IMF, indicating it might overtake Germany also to become the third largest economy.

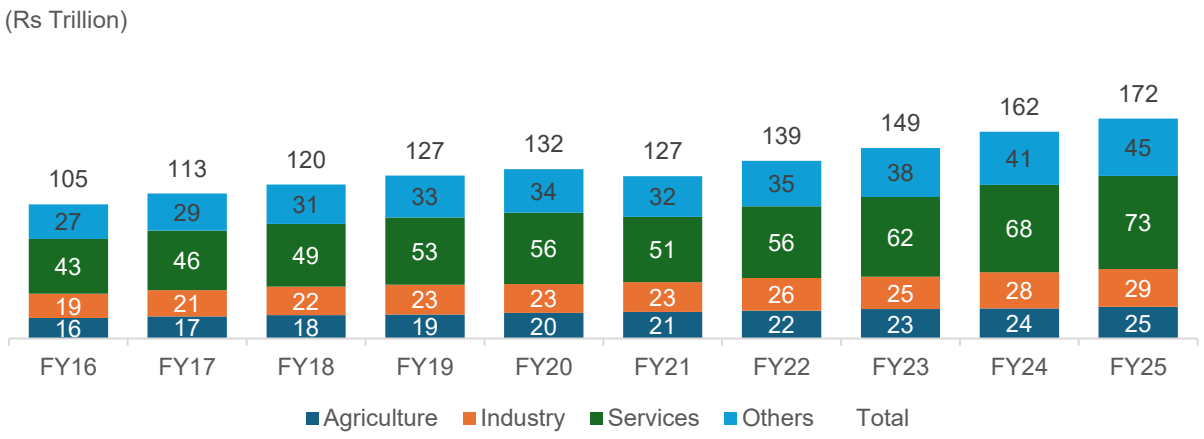
Contribution of key sectors to gross value added

An analysis of India's gross value added (GVA) shows it has grown consistently over the years except in fiscal 2021, when it was impacted by the pandemic-induced lockdown. The services sector has remained a significant contributor to GVA over the years. Growth in services exports, accounting for half of the country's overall exports, has continued to outpace the economic growth.

The growth in the manufacturing GVA (5.0% CAGR between fiscals 2016 and 2025) is attributable to various government initiatives such as Aatmanirbhar Bharat, Make in India and the PLI scheme. Although the share of industry in the GVA has remained constant at 17%, a large percentage of PLI capex is yet to be commissioned. This is expected to aid growth in the share of both manufacturing and exports.

The agriculture GVA logged a 4.9% CAGR between 2016 and 2025, driven by the government's subsidy support to farmers and various other initiatives such as the PM Krishi Sinchayee Yojana ("PMKSY"). Normal monsoon, implementation of various government schemes and favourable agricultural commodity prices over the past two fiscals have aided the growth.

Figure 3: Contribution of key sectors (industry, agriculture and services) to GVA



Source: MoSPI, Crisil Intelligence

Private consumption is expected to hold up in fiscal 2026

With more than 58% share in the GDP, private consumption remains the key driver of the economy. However, in fiscal 2025, middle class consumption was subdued owing to high interest rates and food inflation. To address this, measures announced in the union budget fiscal 2026 aimed at providing shot in the arm for the consumer sectors.

- **Tax relief measures to prop up consumption**: The government has reduced income tax rates under the new tax regime, which will increase the disposable incomes of the middle class. The tax rebate limit has been raised to Rs 1.2 million from Rs 0.7 million, leading to tax savings of ~Rs 80,000 annually for an individual earning Rs 1.2 million. Tax slabs have also been revised, which will reduce the tax burden across income levels. These measures will durably support spending by the middle class beyond fiscal

2026 as well, though some of the increase in disposable income can also go towards savings and debt repayment.

- **Lower food inflation:** Food inflation is likely to cool down in fiscal 2026 on expectation of a normal monsoon. Food inflation has soared in recent years and has been constraining households. The share of food in total consumption is the highest among lower income households. So, softer food inflation should create space in household budgets for discretionary spending.

- **Policy rate cuts:** The Monetary Policy Committee (MPC) of the Reserve Bank of India (RBI) cut the repo rate by 50 basis points (bps) in June, following a 25-bps cut in April. Lower interest rates are expected to mildly support consumption as they are gradually transmitted to other interest rates in the economy, thereby lowering borrowing costs.

- **Support from the rural economy**: In addition to the budgetary support, favourable monsoon has supported farm prospects in fiscal 2025. In terms of rural incomes, stable agricultural output is expected to provide some relief. Rural India remains largely agrarian, with 86% of land holdings belonging to small and marginal farmers, who dominate the Indian agricultural landscape. These farmers rely heavily on the monsoon for irrigation, making its timely arrival and adequacy crucial for a good crop. Any negative impact on crop supply due to low rainfall has a cascading effect on the rural economy, leading to reduced earnings and lower spending. Over the last five years, the performance of the agriculture sector has been encouraging. Given the significant role of the rural economy in driving demand for the automotive industry, particularly for two-wheelers, three-wheelers, and tractors, which source large share of their demand from rural areas, demand for these segments is expected to remain robust.

Regulatory and policy developments that could drive the private capex cycle

- **Government push for infrastructure development:** The NIP was launched with the projected infrastructure investment of Rs 111 trillion ($1.5 trillion) during the period 2020-2025. Sectors like energy, roads, urban infrastructure, and railways have a major share in the NIP. The focused infrastructure initiative will boost the economy, generate better employment opportunities, and drive the competitiveness of the Indian economy. Roads, Urban and Housing, Railways, Power (Conventional and Unconventional) and Irrigation have received the most from NIP amounting to almost 80% of the funds.

- **Private sector participation:** With the government normalizing capex, the private sector is expected to drive the lead in furthering the investment momentum. The ability of private corporates to invest is supported by their deleveraged balance sheets, the healthy balance sheets of lenders, and turning of the interest rate cycle. Private corporate investments have been sluggish so far. For a full-fledged and sustainable revival in overall capex, the private corporate sector will need to regain its position as a key driver of investments. The share of private corporate investment in total fixed

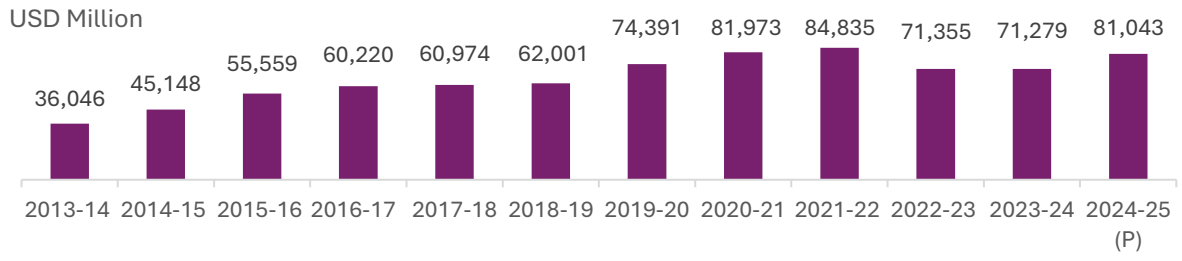
investment saw a sustained decline to 34.4% in fiscal 2024 from its peak of 41% in fiscal 2016, following a steady climb from ~33% in fiscal 2012. A revival in private corporate investment will need to be accompanied by faster growth in machinery and equipment (or capacity addition) and intellectual property creation (or innovation).

- **Production Linked Incentive (PLI) Schemes:** The PLI scheme, which aims to drive industrial capex of Rs 2.6-2.8 trillion during the scheme period, is projected to contribute ~5% to capex in key sectors. The incentives, totaling Rs 1.8-1.9 trillion, are expected to generate incremental revenue of Rs 30 trillion. Launched in March 2020, the scheme, as of November 2024, has attracted investments of Rs 1.61 trillion, highlighting healthy momentum in key targeted sectors. The PLI scheme is poised to drive significant growth in India's manufacturing sector over the next two years, particularly in capital-intensive segments. The scheme has already made considerable strides in reducing India's reliance on imports and boosting export revenue in fourteen key sectors, including electronics, textiles, and automobiles. Historically, these sectors have struggled with a substantial 20% cost disadvantage compared with Chinese imports. However, the scheme has yielded promising results in sectors such as mobile, telecom and pharmaceuticals.

Foreign direct investment

India has achieved a remarkable milestone in its economic journey, with gross foreign direct investment (FDI) inflows reaching an impressive $1 trillion since April 2000. FDI inflows have seen a steady rise—from USD 36.05 billion in FY 2013–14 to USD 81.04 billion (provisional) in FY 2024–25, marking a 14% increase from USD 71.28 billion in FY 2023–24. Such growth reflects India's growing appeal as a global investment destination, driven by a proactive policy framework, a dynamic business environment, and increasing focus on competitiveness. Initiatives like "Make in India," outcome oriented sectoral policies, and the Goods and Services Tax (GST) have enhanced investor confidence.

Figure 4: Growth in India's FDI Inflows



Note: P- provisional

Source: DPIIT

Capex cycle

Increased private sector participation is necessary for balanced and sustainable investment momentum

The government's post-pandemic strategy of providing extraordinary support to investments via budgetary spending has paid off, with fixed investments the key driver of GDP growth until fiscal 2024. Now, there is a greater shift in policy strategy towards incentivising private corporate investments. After having risen from 1.7% of GDP in fiscal 2020 (pre-pandemic period), central government capex is budgeted to stabilise at 3.1% of GDP in fiscal 2026, same as fiscal 2025. While central government capex remains supportive, the focus should also be on reducing cost and time overruns. As of December 2024, 63.7% of central sector projects totalling Rs 1.5 billion and above had time overruns, higher than the 29.8% of projects on time. And 41.1% of projects faced cost overruns. Here, creating a pipeline of shovel-ready projects and better coordination with states will help get the best bang for the buck. Reducing time and cost overruns will be critical for meeting the capex target.

With the government normalising capex, it is time for the private sector to take the lead in furthering the investment momentum. The ability of private corporates to invest is supported by their deleveraged balance sheets, the healthy balance sheets of lenders, and turning of the interest rate cycle. The government is also taking steps to encourage investments by the private sector. Total allocation for the Production Linked Incentive (PLI) schemes is budgeted to rise 87% on-year in fiscal 2026, particularly in sectors such as electronics, textiles, automobiles and components. Efforts at deregulation will help, too. That said, heightened global uncertainty and uneven private consumption demand conditions have been the key hindrances to a revival in corporate investment so far.

Aatmanirbhar Bharat Abhiyan

Production Linked Incentives (PLIs) in the 14 sectors for the Aatmanirbhar Bharat vision received an outstanding response, with a potential to create 6 million new jobs (as per government estimates)

Table 3: Aatmanirbhar Bharat Vision for select sectors

Sector	Government spends	Key schemes
Renewable energy	~Rs 1.3 trillion	Rs 45 billion Production Linked Incentive Scheme 'National Programme on High Efficiency Solar PV Modules'. This was further increased by Rs 195 billion in the budget for fiscal 2023, taking it to Rs 240 billion; in Tranche I 8.7 GW and in Tranche II 39.6 GW capacity were allocated for domestic solar module manufacturing capacity under PLI. PM Surya Ghar Muft Bijli Yojna: This scheme has a proposed outlay of Rs 750 billion and aims to light up 10 million households (rooftop solar) by providing up to 300 units of free electricity every month. Implementation of Pradhan Mantri Kisan Urja Suraksha Utthan Mahabhiyan (PM KUSUM) scheme; MNRE, in November 2020,

		scaled up and expanded the PM KUSUM scheme to add 30.8 GW by 2022 with central financial support of Rs 344.22 billion. The scheme has been extended till March 31, 2026 Approved Models & Manufacturers of Solar Photovoltaic Modules (Requirement for Compulsory Registration) Order, 2019 List of manufacturers and models of solar PV modules and cells recommended under ALMM Order Scheme of grid connected wind-solar hybrid power projects Basic customs duty (BCD) of 20% on solar cells, 20% on solar invertors, and 20% on modules, respectively, effective February 1, 2025
Power distribution companies (discoms)	~Rs 970 billion	Rs 1.35 trillion liquidity infusion for discoms via Power Finance Corporation/ Rural Electrification Corporation (PFC/ REC) against receivables Rebate for payment to be received by generation companies (gencos) to be passed on to industrial customers Revamped distribution sector scheme (RDSS) to help discoms improve their operational efficiencies and financial sustainability by providing result-linked financial assistance; outlay of Rs 3.03 trillion over 5 years i.e., fiscals 2022 to 2026. The outlay includes an estimated Government Budgetary Support (GBS) of Rs 976.31 billion.
New Energy	~Rs 388 billion	Rs 181 billion under PLI scheme for Advanced Chemistry Cell (ACC) Battery Storage in India launched in October to achieve 50 GWh manufacturing capacity Green Hydrogen Policy launched in February 2022 to facilitate production of green hydrogen/green ammonia PLI scheme on green hydrogen manufacturing with an initial outlay of Rs 197.44 billion with an aim to boost domestic production of green hydrogen.

Source: Official portal of the Government of India; various ministries, PIB press releases, Crisil Intelligence

Government policies and schemes driving manufacturing in India

The Indian manufacturing and allied sectors have seen a host of reforms to aid in improving the competitiveness. Reforms can be categorised in three major categories – manufacturing focused, infrastructure focused and overarching reforms. Overarching reforms such as Startup India, Goods and Service Tax have aided in formalisation of the economy and in also attracting capital. Infrastructure focused reforms have helped in building out infrastructure to aid in bringing down power cost, improving connectivity via roads, ports, airports aiding reduction in logistics cost. Manufacturing reforms have helped in seeding new age sectors and providing a boost to existing manufacturing sectors along with helping in the employment generation and

catering to the export market. Programs such as Make in India launched in 2014 followed by UDAY scheme in 2015, National Industrial Corridor Development Programme in 2017, National Infrastructure Pipeline in 2019, PLI in 2020, Semiconductor Mission in 2021, National Logistics Policy and PM Gati Shakti in 2022 are some of the initiatives undertaken.

China plus one strategy being adopted globally

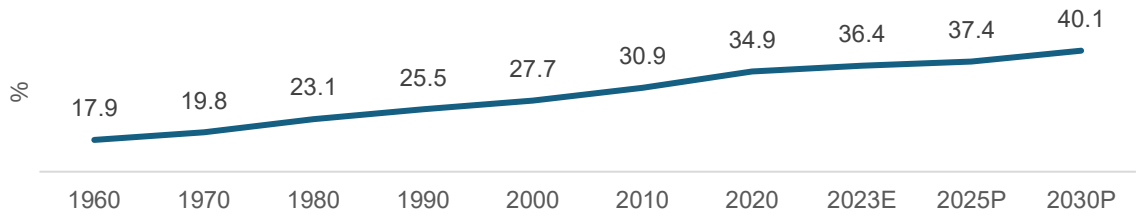
The China plus one strategy encourages companies to diversify their operations by expanding outside of China while still maintaining a presence in the country. This strategy is becoming increasingly popular in the solar industry, as companies look to reduce their dependence on China and diversify their supply chains. There are several factors encouraging the China plus one strategy for solar. Some of these factors include the rising cost of labour in China, increasing complexity of the Chinese regulatory environment, growing political risk in China, increasing demand for diversification from investors and several other countries that are emerging as potential destinations. Additionally, the US sanctions on imports from Xinjiang region imposed in June 2022 had opened doorways for other exporting economies such as Vietnam, Malaysia, Thailand and India. These countries offer several advantages, including lower labour costs, favourable government policies and access to new markets. India is one of the potential destinations for solar manufacturing due to its low labour cost as well as favourable political and regulatory environment for manufacturing. Rising manufacturing base has enabled domestic manufacturers to tap the export potential with nearly 97% of exports focused on the US alone.

Global tariff actions are also placing India in a favourable light in terms of manufacturing alternatives to China. While the situation is dynamic, any incremental barriers to trade placed on China will be favourable for India as a manufacturing destination.

Growth in urbanisation in India

Urbanisation is one of India's most important economic growth drivers. It is expected to drive substantial investments in infrastructure development, which in turn is expected to create jobs, develop modern consumer services, and increase the ability to mobilise savings. India's urban population has been rising consistently over the decades. As per the 2018 revision of World Urbanisation Prospects, the urban population was estimated at 36% of India's total population in 2023. According to the World Urbanisation Prospects, the percentage of the population residing in urban areas in India is expected to increase to 40% by 2030.

Figure 5: Urban population as a percentage of total population



Note: E- Estimated, P – Projected, Figures in percentage

Source: Census 2011, World Urbanization Prospects: The 2018 Revision (UN)

Global focus increases on energy transition and power decarbonisation

The urgent need to address climate change has led to a global shift towards renewable energy, with initiatives like the Paris Agreement and RE 100 promoting its adoption. Solar power has experienced remarkable growth, with installed capacity reaching 1,865 gigawatts by 2024, accounting for 42% of the world's total renewable energy capacity. Governments have supported the solar industry through policies like feed-in tariffs, tax incentives, and subsidies, driving global growth in solar photovoltaics.

The 2021 United Nations COP26 conference aimed to update the time frame for revised targets, with India updating its Nationally Determined Contributions (NDCs) to reduce emissions intensity of its GDP by 45% by 2030, achieve 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, and achieve Net Zero by 2070. The Indian government has initiated efforts to combat climate change through multiple programmes and schemes, including the National Action Plan on Climate Change (NAPCC) and the National Solar Mission.

To promote renewable power in India, the government has undertaken several measures, including allowing foreign direct investment up to 100% under the automatic route, extending waivers of inter-state transmission system charges, and setting up Ultra Mega Renewable Energy Parks. Additionally, the government has introduced schemes such as PM-KUSUM, Solar Rooftop Phase II, and the Green Energy Corridor Scheme to facilitate the growth of renewable energy. The government has also notified standards for deployment of solar PV systems, set up a project development cell, and established standard bidding guidelines for tariff-based competitive bidding processes. Furthermore, the government has mandated timely payment by distribution licensees to renewable energy generators through the Electricity (Late Payment Surcharge and related matters) Rules, 2002 and promoted renewable energy through the Green Energy Open Access Rules, 2022. These efforts aim to support India's transition to renewable energy and achieve its climate change targets.

Global Electricity Outlook

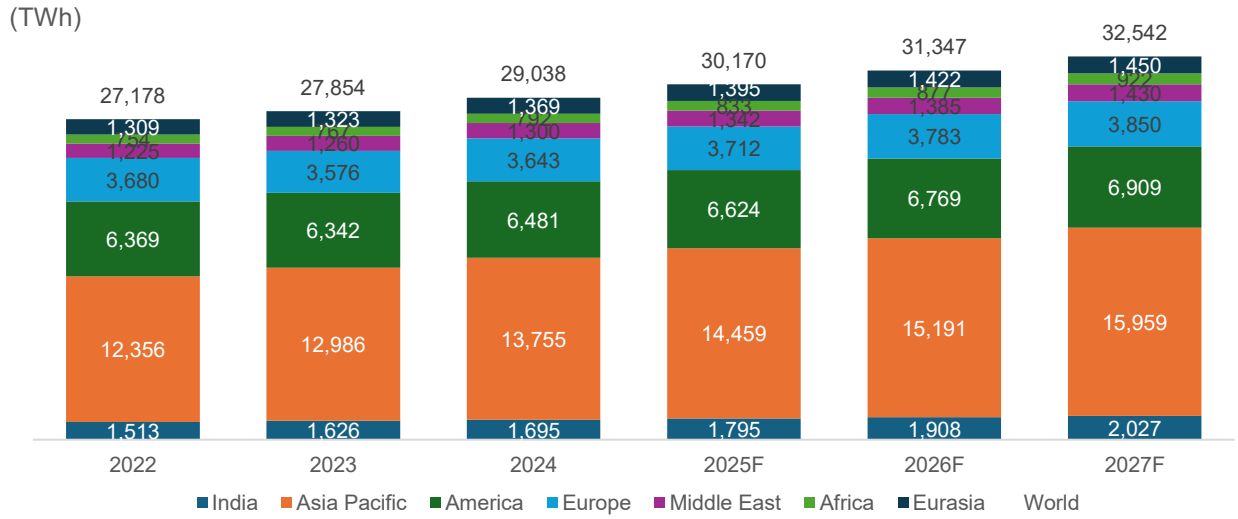
Global power demand picks up in 2024, expected to rise further by 2027

As per the IEA Electricity 2025, global power demand grew 4.3% in 2024, faster than the 2.5% in 2023. More than 75% of global electricity demand growth in 2024 came from the Asia Pacific region, where countries like China, India, and Southeast Asia experienced robust growth in power demand. On the other hand, advanced economies saw stable power demand in 2024, with the US and Europe experiencing marginal growth of 2% and 1.4%, respectively, led by increased use of heat pumps and electric vehicles and higher demand from data centres.

Going ahead, global power demand is projected to experience a compounded growth rate of 3.9% over calendar years 2024-2027, driven by rising industrial production, higher use of air conditioning, accelerating electrification, and the expansion of data centres worldwide. Power demand in Asia pacific is expected to rise by CAGR of 5-6% from 2024 to 2027, with China electricity demand easing gradually till 2027 since its economy is expected to slow as it shifts

away from traditional heavy industry. From 2024-2027, power demand in Americas is expected to increase on average by 2-3% per year, driven by a recovery in industrial activity and growing demand for electricity in the transportation sector. Europe is expected to witness power demand of 1-2% over 2024-2027 supported by an increased industrial activity that continues to recover while electrification gathers pace.

Figure 6: Global electricity demand to log 3.9% CAGR between 2024 & 2027



1. Note: F: Forecasted. The above chart is on a calendar year basis, while for India data is on a fiscal year basis (e.g., 2024 is fiscal 2025)
2. The projected numbers for India for fiscal 2026, 2027 and 2028 are based on Crisil Intelligence estimates
3. In the graph, Asia Pacific region includes India as well. The total demand should be looked at without including data for the Indian power demand series.

Source: IEA Electricity 2025 report (February 2025), Crisil Intelligence

Renewable energy to lead global electricity installed capacity and generation

As per the IEA Electricity 2025, global power generation grew 4% in 2024 to nearly 31,029 TWh. In 2024, fossil fuels (coal and natural gas) accounted for 56% of the global power supply- their lowest share in last 50 years. Coal accounted for the largest share of the total, 34%, whereas natural gas accounted for 22%. Beyond fossil fuels, nuclear power generation remained 9%. Renewables, led by solar and wind, count for 32% of the total power generation.

Table 4: Global power generation to grow by 3-4% CAGR between 2024-2027

Electricity generation (TWh)	2022	2023	2024	2027F
Coal	10,437	10,611	10,704	10,674
Natural gas	6,525	6,608	6,777	6,889
Nuclear	2,686	2,742	2,840	3,036
Other non-renewable	927	891	860	717
Renewables	8,543	8,969	9,848	13,250
Total generation	**29,119**	**29,822**	**31,029**	**34,566**

Note: F: Forecasted

Sources: IEA Electricity 2025 report (February 2025), Crisil Intelligence

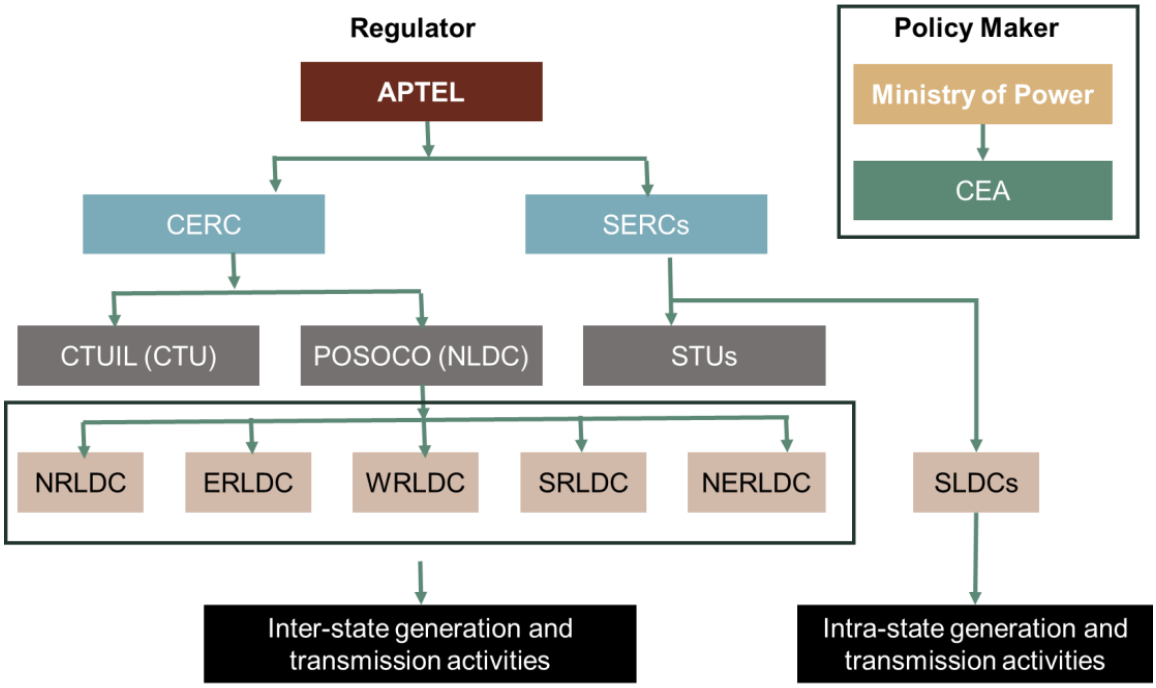
As per IEA, the incremental electricity generation between 2024 and 2027 will be driven by renewable energy (96%).

Module 2: Overview of Indian Power sector

The Indian power sector and its structure

Electricity is a concurrent subject in India with the Ministry of Power, Government of India ("GoI"), mainly being responsible for creating the overall policy framework for the power sector in the country. All state-level policies and issues come under the purview of the respective state governments.

Figure 7: Institutional and structural framework



Source: Crisil Intelligence

All states and union territories have set up electricity regulatory commissions ("SERCs") to regulate and determine tariffs for generation, transmission as well as distribution companies ("discoms"). The Central Electricity Regulatory Commission ("CERC") fulfils this responsibility for inter-state generation and transmission and for central power utilities. The Appellate Tribunal for Electricity ("APTEL") was established to hear appeals against the orders of adjudicating authorities (SERCs, JERC and CERC).

Grid Controller of India Ltd (formerly Power System Operation Corporation Ltd) manages the national and regional grid through the National Load Despatch Center ("NLDC") and its five-regional load-despatch centers ("RLDCs"). These entities operate in unison to ensure the integrated operation of the grid in a reliable, efficient and secure manner. While the NLDC controls the load flow within the country, the RLDCs and state load despatch centers ("SLDCs")

are responsible for ensuring the integrated operation of the power system in the concerned regions and states.

Central Transmission Utility of India Limited ("CTUIL"), 100% subsidiary of Power Grid Corporation of India Limited ("PGCIL"), is notified as the Central Transmission Utility ("CTU") and is responsible to undertake transmission of electricity through the inter-state transmission system ("ISTS") and other functions as per the provisions of Electricity Act 2003. The National Committee on Transmission ("NCT") is responsible for planning and examining the proposals of ISTS scheme for approval. The state transmission utilities ("STUs") are tasked with the development of the intra-state transmission system. The transmission lines are operated in accordance with regulations/ standards of Central Electricity Authority ("CEA") / CERC / SERCs.

Power exchanges set up for trading of power and deepening markets are a distinct licensed activity (from generation, transmission and distribution) as recognised by the Electricity Act 2003. Power trading was introduced to meet the short-term requirement of electricity and to ensure optimum utilisation of power resources across regions, given demand-supply mismatches. Several traders, both Central government and the private sector, have established their presence; a few states have companies (e.g., Gujarat, Uttar Pradesh, Karnataka and Madhya Pradesh) to procure power on behalf of their state discoms.

The power distribution system is the last leg of the electricity value chain. The main function of the power distribution system is to provide power to the premises of individual consumers. Responsibility for distribution and supply of power to end-consumers rests with the states. The power distribution segment in India is largely dominated by the state government-owned distribution companies, although a few private entities are also present in the sector to serve end-consumers. Further, open access allows large consumers to procure power through traders, exchanges or via captive/group captive generation.

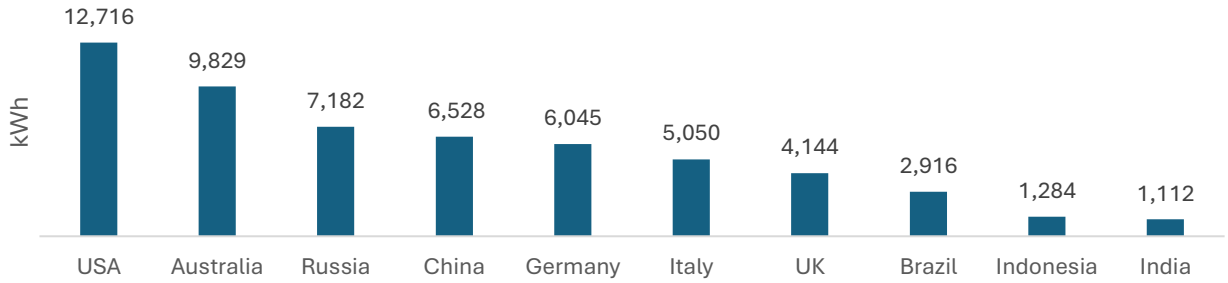
Structure of the power sector in India

The power sector is one of the most critical drivers for any country. According to IEA, electricity consumption rose by an estimated 4.3% y-o-y in 2024, up from 2.5% in 2023, with growth expected to continue at a robust 3.9% between 2025-2027.

As per IEA, India is the third largest consumer as of CY 2023, in the world after the United States (US) and China.

Despite this, India's per capita power consumption is the lowest in the global power consuming countries such as China, US and Germany. In CY 2023, US recorded the highest per capita power consumption of 12,716 kWh followed by 9,829 kWh in Australia. China recorded a per capita power consumption of 6,528 kWh and India stood at 1,112 kWh.

Figure 8: Per capital electricity consumption across countries in CY2023



Note: The above numbers are calculated using electricity consumption and population.

Source: World Bank, IEA, Crisil Intelligence

This low per capita consumption along with a burgeoning population indicates that India's full potential is yet to be achieved. While, the advanced economies have already witnessed their spurt in power demand due to past economic growth cycles, developing nations of China, Indonesia and India are now emerging as the new power demand leaders, despite global headwinds

The value chain of power mainly comprises of three components:

- Generation: It is the process of generating power using different fuels as a source of energy. It is carried out in generation plants.
- Transmission: Generated bulk power from generating units is transmitted over long distances through high voltage transmission networks and grid distribution substations
- Distribution: The transmitted power received by distribution agencies is then distributed to the last mile customer. Distribution is the retail stage and operates at lower voltages.

Sale of power from generators to consumers happens through different routes such as:

- Direct tie-ups
    - Competitive bidding: It is a contract between generators and procurer (intermediary/DISCOM) in which the procurer issues a tender for which interested generators bid. Bidding criteria can be per unit price or based on the cost of the set-up.
    - Bilateral: It is a contract between generators and procurer (direct DISCOM or private consumers) in which the generator may enter an agreement directly with the procurer
        - Memorandum of Understanding (MoU): Distribution companies can sign MoU/agreement with generators for direct procurement of power without competitive bidding. For example, hydropower projects are largely based on bilateral model, where developers can sign agreements directly with the distribution companies through MoUs
        - Third-party sale: It is a contract between generators and customers (industrial and commercial) in which direct contracts are signed between the generators and consumers (typically those with high load requirements). This type of contract involves little intervention from the government and hence is more private in nature

- Captive power: In this method, the consumer has self-setups or participate as equity contributors in projects set up by a generator. Consumers are direct investors in the project, which may or may not be setup through them. Group captive is a special case in which a group of entities jointly own a captive with at least 26% of total ownership in generating plant and consume at least 51% of electricity generated

- Merchant sale: In this method, the generators directly sell power on the day ahead/real-time market of power exchanges

For proper functioning, as well as policy regulation for the above-mentioned components, various government agencies such as Central Electricity Regulatory Commission (CERC), State Electricity Regulatory Commission (SERC), Ministry of Power (MoP), and Ministry of New and Renewable Energy (MNRE) are in place.

SECI (Solar Energy Corporation of India Limited) which is a "Navratna" Central Public Sector Undertaking (CPSU) under the Ministry of New and Renewable Energy (MNRE) plays a crucial role in India's renewable energy sector by facilitating the development and implementation of solar, wind, and hybrid energy projects. SECI acts as an intermediary between renewable energy generators and the power distribution companies (DISCOMs). SECI would come under Direct tie-ups agreement where it operates through Power Purchase Agreements (PPAs) and Power Sale Agreements (PSAs) between the power generators and the DISCOMs.

Indian power supply capacity base and fuel mix till 2030

Installed capacity to breach 750 GW mark by fiscal 2030, renewable installed capacity (ex-hydro) to account for 45-50%

The renewable energy capacity is expected to increase to 365-375 GW mark by fiscal 2030 on back of strong renewable capacity additions between fiscal 2026-2030 (excluding hydro and storage elements). The renewable energy capacity would account for 45-50% of the total capacity, which is expected to reach 745-755 GW. On the other hand, moderate coal-based capacity additions of 25-30 GW are expected to lower coal's share to 30-35% in fiscal 2030. Other fossil fuels (including lignite, gas, and diesel) are expected to remain stagnant due to negligible capacity additions. Inclusion of hydro, nuclear power and storage capacity in clean energy, compared with coal plants, is expected to provide a fillip to non-fossil capacity, taking it to 470-480 GW by fiscal 2030, constituting a staggering 60-65% share in installed capacity.

Growing need for energy storage systems is expected to drive the capacity additions of PSP and battery energy storage systems (BESS) over the next five years. Energy storage is estimated to penetrate 5-6% of total power capacity by fiscal 2030.

Indian power generation trends

RE to account for ~50% of India's installed capacity by fiscal 2030

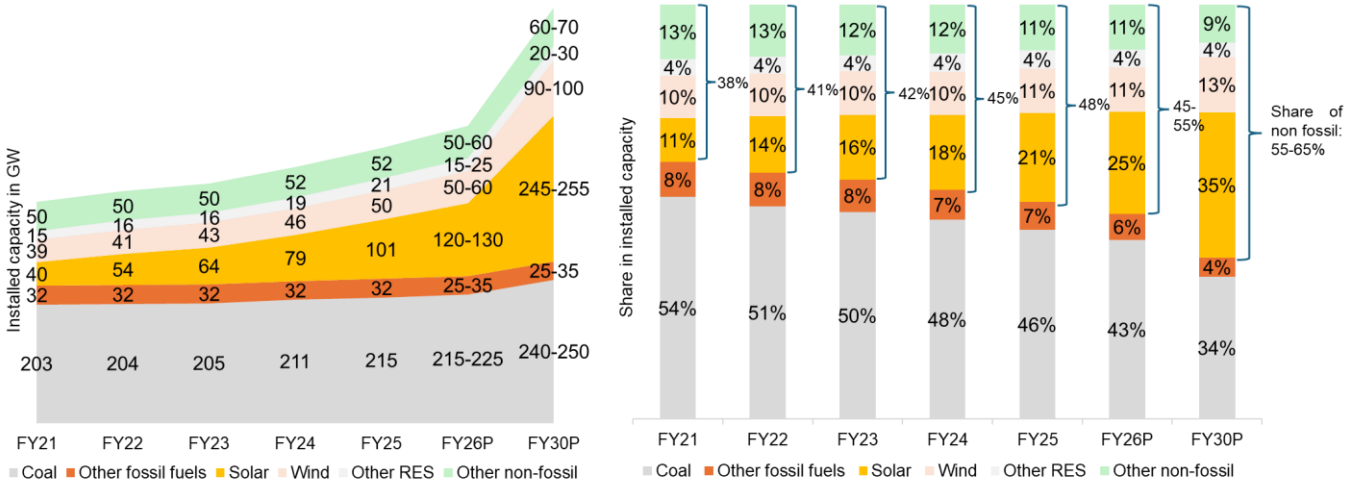
India's installed generation capacity is estimated to be 515-525 GW as of fiscal 2026 from 356 GW at the end of fiscal 2019. As of fiscal 2026, the country's power generation mix is estimated to be dominated by thermal power, which is expected to account for 45-50% of the total capacity, renewable energy sources (35-40%), followed by hydroelectric power (8-10%) and

nuclear power (1-5%). The majority of India's thermal power generation is based on coal, with a small share from natural gas and diesel.

The sources of electricity generation in India can be broadly classified into conventional and non-conventional. The conventional sources of power generation are thermal (coal, lignite, natural gas, and oil), hydro and nuclear power, while non-conventional sources of power generation (renewable energy sources) include solar, wind, hybrid, and other renewables.

The total conventional capacity (coal, lignite, diesel, hydro, nuclear, and natural gas) in India is estimated to have reach 305-315 GW at the end of fiscal 2026 from 278 GW in fiscal 2019.

Figure 9: Snapshot of Indian installed power generation capacity



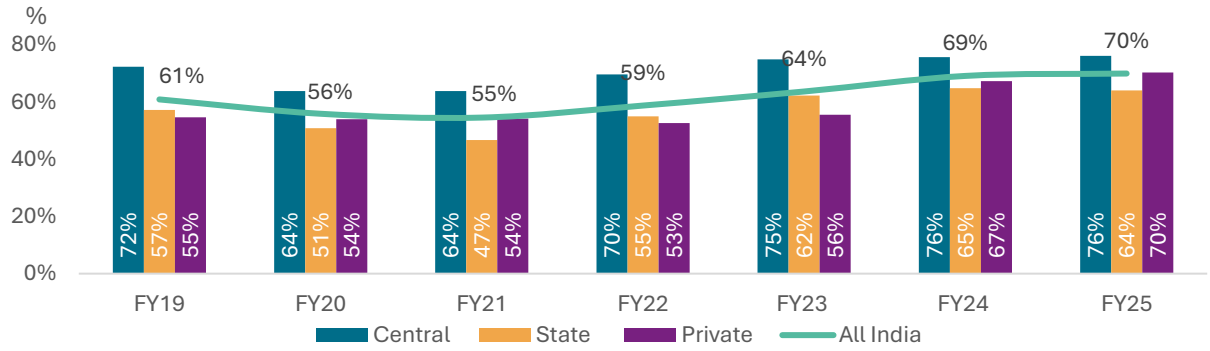
Note: Other fossil fuels include diesel, lignite and natural gas; Other RES includes bio power and small hydro. Other non-fossil fuels include Nuclear and hydro. Excludes storage capacity.

Source: CEA, Crisil Intelligence

A total of 108 GW of generation installed capacity was added over fiscals 2021-2025. Out of this, renewable capacity additions (excluding hydro) were 98 GW owing to government's push to the industry and commitment to COP26 targets. The remaining 24 GW were added in the conventional capacity segment, largely driven by coal-based capacity. The increase in coal capacity in India was primarily driven by a combination of factors, including the need to meet growing base and peak power demand.

For instance, privately owned coal capacity has seen a sharp increase in plant load factor to 70% in fiscal 2025 from 55% in fiscal 2019, registering an improvement of 15%.

Figure 10: Private PLFs see sharpest improvement while central continues to remain highest in fiscal 2025



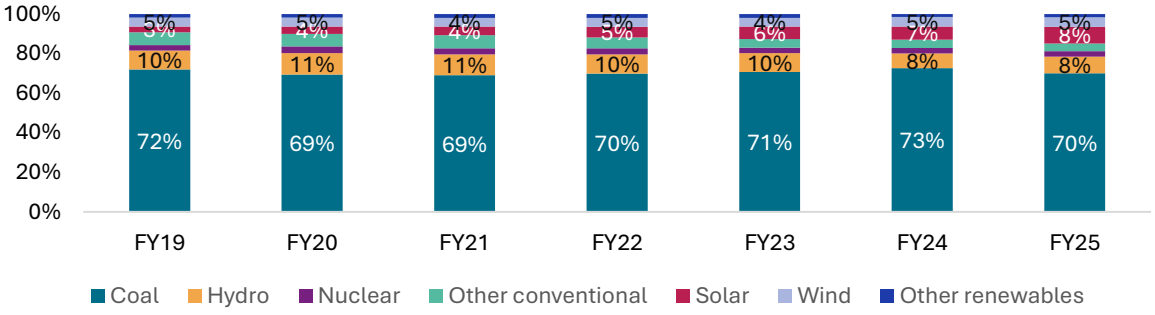
Source: CEA, Crisil Intelligence

Renewables share low in generation but rising

Despite renewables accounting for 35-40% of the installed generation capacity as of fiscal 2026, the share in generation was estimated to be limited at 15-20%. This is primarily due to intermittent nature of renewables. Generation from solar plants is limited to daytime and is further subjected to number of sunny days during the year. While wind generation is dependent on adequate wind speeds and generally sees spike in generation during the monsoon season. Traditionally, India has relied upon thermal, primarily coal generation to meet its power demand owing to intermittency challenges of renewable fuels and easy rampable nature of coal. The share of coal in power generation has averaged 71% between fiscals 2019-2025.

With additions in renewable capacity, its share in total power generation has increased from 9% in fiscal 2019 to 15% in fiscal 2025. Solar energy accounted for 8% driven by rapid additions of 82 GW between fiscal 2019-2025. While wind energy generation has increased, its share has remained stable at 5%. In wind energy, a seasonality is generally observed. For example, wind energy generation in India shows higher output during the high wind season (April to September) and lower output during the low wind season (October to March). Similarly, wind energy PLFs are generally higher during the high-wind season (April to September) and lower during the low-wind season (October to March).

Figure 11: Share of renewable energy has increased to 15% but coal continues to remain dominant fuel



Source: CEA, Crisil Intelligence

Indian power demand trends

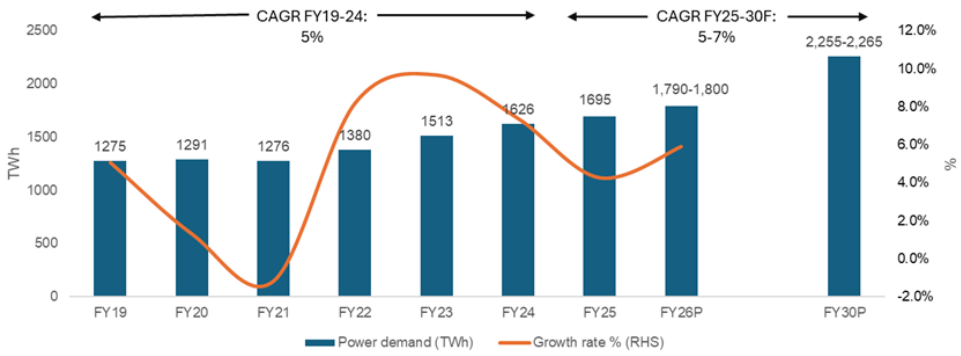
Power demand has maintained a robust growth momentum

India's electricity requirement has grown at a steady pace, with a 5.2% CAGR to 1,695 TWh between fiscal 2019-2025, driven by economic growth, population growth, urbanisation, and improved transmission and distribution infrastructure.

The growth in fiscal 2025 moderated to 4.3% on year. Coming on a high base, the power demand growth was volatile in fiscal 2025. While severe weather conditions drove demand up 10.9% on year in the first quarter, favourable monsoon and slower industrial activity moderated the pace at 0.2% on year in the second quarter. Demand rebounded 2.9% on year in the third quarter driven by cold waves in the north. The fourth quarter witnessed 3.6% growth on year owing to above normal temperatures and pick in industrial and manufacturing activities. The first quarter of fiscal 2026 witnessed a fall of ~1% owing to due to lower temperatures and heavy monsoon.

Ample economic activity has driven growth between fiscal 2019-2025. Overall, the power demand has marginally outpaced the real GDP growth of 5.0% CAGR between fiscal 2019-2025.

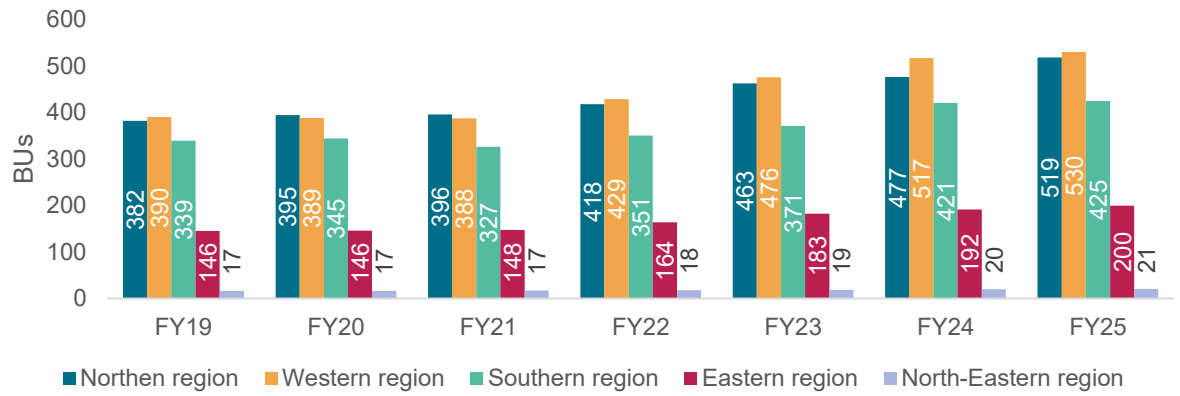
Figure 12: Snapshot of Indian power demand



Source: CEA, Crisil Intelligence

The growth in power demand shows low regional variation between fiscal 2019-2025. The Eastern region grew at a 5.4% CAGR between fiscal 2019-2025 contributed by rapid rural electrification in Bihar and West Bengal and increased industrial expansion in metals and mining industries across other states. The western region grew at a 5.2% CAGR during the same period owing to growth in industrial base such as refineries, chemical and cement along with rising urban commercial demand. The demand in the northern region grew at a 5.2% CAGR during the same period from increased household electrification and agricultural load. The southern region has grown at 3.8% CAGR owing to growth in IT parks, data centers and electronic manufacturing, airport and metro expansions, and high agricultural consumption.

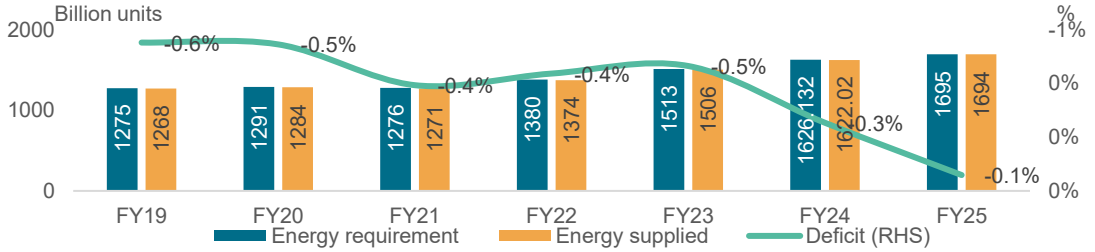
Figure 13: Eastern, western, and northern region grow register a 6.3% CAGR between fiscal 2019-2025



Source: CEA, Crisil Intelligence

In fiscal 2025, base power deficit declined to 0.1% as a ~6% rise in generation supported by higher hydro generation due to above normal rainfall along with declining coal prices. May 2024 saw a historic peak power demand of 250 GW; the entirety being serviced thus leading to a 0% deficit for the month. This was aided by 16.3% increase in generation. In fiscal 2024, deficit declined to 0.3% as higher power demand was met with a 7.4% increase in power generation. Peak demand in August 2023 reached 239 GW which then touched 243 GW in September 2023 which led to these months registering deficits of 0.6% and 0.4% respectively. In fiscal 2023, due to sudden surge in base and peak demand, generation struggled to keep up with the sudden surge which led to deficit increasing to 0.5% from 0.4% seen in the previous fiscal.

Figure 14: Aggregate base power demand supply and deficit over fiscals 2019-2025



Source: CEA, Crisil Intelligence

Peak demand: An instantaneous surge

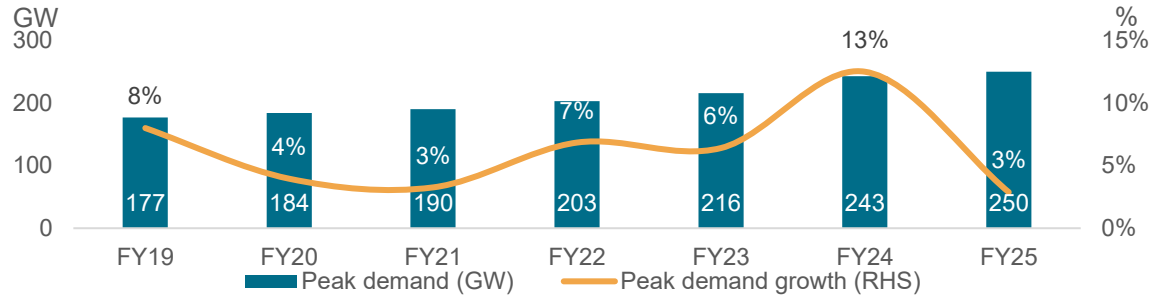
While base demand follows a consistent pattern, peak demand is an instantaneous surge in power requirement, often occurring when many consumers (including utility segment commercial and industrial consumers) use electricity simultaneously, such as in the evenings. In India, peak demand has grown to 250 GW in fiscal 2025 from 177 GW in fiscal 2019. This increase is attributed to rising cooling demand due to warmer temperatures and surge in economic activity.

Peak demand has outpaced base demand on several instances. While base demand has grown at 5.2% CAGR between fiscal 2019-2025, peak demand has grown at 5.9% CAGR during the same period. Even during COVID-19 affected fiscal 2021, base demand entered

negative territory and fell 1.2% while peak demand grew 3.5% to 190 GW, equivalent to about half of country's installed capacity.

Before pandemic struck, electricity demand in India usually peaked during August and September, comprising a majority of monsoon season. This spike in peak demand was primarily owing to an increase in domestic and commercial load, mainly air conditioning load. However, following the pandemic, annual peak demand occurred in the summer (April-July) because of high heatwave conditions. The constant rise in peak demand can be attributed to the economic growth, seasonal vagaries, and an increasing daily average temperature that India has experienced over the past decade, leading peak demand to touch 250 GW in May 2024.

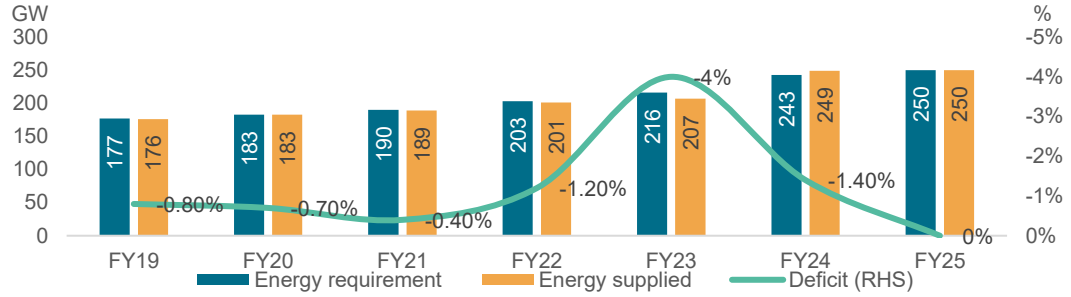
Figure 15: Peak demand growth has outpaced base demand growth



Source: CEA, Crisil Intelligence

The peak demand deficit has seen an improvement in fiscal 2025. The country's peak demand of 250 GW in May 2024 was catered to, resulting in no deficit for the month.

Figure 16: Aggregate peak demand supply and deficit over fiscals 2019-2025



Source: CEA, Crisil Intelligence

Power demand to maintain healthy growth between fiscal 2026-2030

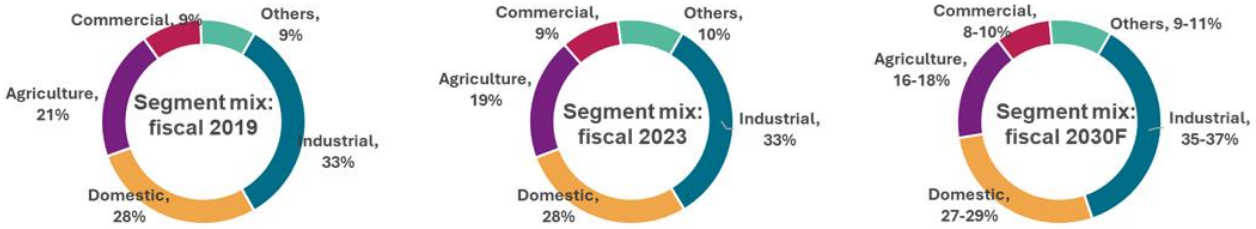
Between fiscal 2026-2030, power demand is expected to clock 5-7% CAGR on back of healthy economic growth and expansion of electricity footprint via strengthening of the distribution infrastructure. The government's continued infrastructure and industrial manufacturing push is expected to drive power demand, with climate-change induced temperature fluctuation also a key reason for peak demand surges. Major reforms initiated by the central government towards improving the health of the power sector, particularly that of state distribution utilities, are expected to improve the quality of power supply, thereby boosting power penetration levels as well.

Power demand growth between fiscal 2026-2030 is expected to marginally outpace the growth witnessed in fiscal 2020-2025.

Industrial and domestic category to dominate and grow till fiscal 2030

Commercial and industrial consumers dominate power consumption in India accounting for nearly 50% of the total electricity consumed.

Figure 17: Segment wise power consumption



Note: Others category includes consumption from traction, electric vehicles, and other sources, Industrial category includes captive consumption. Commercial category of includes power used by businesses and other non-industrial establishments. Domestic segment includes power used by households for various purposes. Agriculture segment includes power consumption in all stages of agricultural production and processing

Fiscal 2030 data is estimated.

Source: CEA, Crisil Intelligence

In the medium term, climate change related temperature variations along with rising urbanisation are going to be key drivers for rapid growth of the domestic power category. Industrial consumption will continue to dominate power consumption as industrial manufacturing push and government led infrastructure related investments bolster production activity. Initiatives like reduced power cuts, agricultural feeder segregation, and solarization of distribution feeders are expected to drive agricultural power demand. However, these efforts will also lower AT&C losses, which currently affect the agriculture segment. Commercial power demand recovered in fiscal 2023, as office spaces and educational institutions reopened to full capacity.

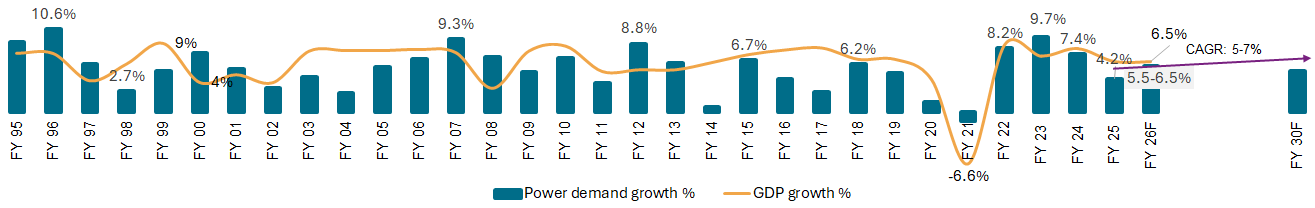
Power demand growth drivers and constraints

Power demand closely linked to the growth in GDP

Power demand is closely linked to GDP growth where historically power consumption largely follows economic cycles. Except for a few years such as fiscal 2023, 2021 and 2013 etc., power demand has lagged GDP growth by 0.5-1 percentage points and is estimated to continue to do the same till fiscal 2030.

In fiscal 2023, electricity demand surged by 9.7%, outpacing the country's GDP growth of 8.2%. This uptick was driven by a resurgence in economic activity following the full lifting of COVID-19 lockdowns. Furthermore, the warmer temperatures brought on by El-Nino, combined with below-average rainfall in the second quarter of fiscal 2023, led to increased demand for cooling and irrigation, respectively. Reduction in industrial and commercial activity due to COVID-19 lockdowns led to GDP growth trailing behind power demand growth in fiscal 2021.

Figure 18:Snapshot of relation between power demand growth and GDP growth



Source: CEA, Crisil Intelligence

Crisil Intelligence expects power demand to increase 5.5-6.5% on year in fiscal 2026 to 1,790-1,800 BU. Buoyant economic performance and weather changes are expected to be the key drivers for power demand growth in the fiscal.

Crisil Intelligence expects the economy to maintain its 6.5% growth in fiscal 2026. With more than 55% of the GDP being driven by private consumption, it is likely to improve further in fiscal 2026, driven by budgetary support and easing inflation, expectations of healthy monsoon and RBI's interest rate cuts. That being said, investment prospects hinge on the pickup in the private capex while geo-political headwinds to exports remain a monitorable. The recently announced reciprocal trade tariff by the US is expected to provide a significant downside risk to global trade and as a result to Indian exports and imports. In the interim, the private capex cycle may remain muted till clarity emerge on global trade dynamics.

Overall, the power demand is expected to sustain high growth trends between fiscal 2026-2030, logging a 5-7% CAGR on the back of healthy economic growth and expansion of power footprint via strengthening of distribution infrastructure.

Broad-based manufacturing, infrastructural push, and temperature highs to aid power demand

With nearly half of India's power demand coming from industrial and commercial consumers, expansion of relevant activities is crucial for power demand to continue growing. Key factors driving power demand include expansion of railways and metro routes, capacity addition by companies in steel, cement, oil and gas and pharmaceutical sectors, continued thrust on manufacturing sectors for global opportunities, push towards backward integration and focus on high tech sectors. However, increasing energy efficiency and reduced technical losses will cap growth. Power demand would reduce by 8-9 BUs on an average every year owing to the improvement in T&D losses between fiscal 2026-2030.

India's power demand is also heavily influenced by temperature, with peak demand increasing by 20% during summer months and 5% in winter months due to heating requirements. This trend is expected to continue driven by rising urbanisation, economic growth, and infrastructure development.

Government policies and schemes to aid power demand

The Indian manufacturing and allied sectors have seen a host of reforms to aid in improving the competitiveness. Reforms can be categorised in three major categories – manufacturing focused, infrastructure focused and overarching reforms. Overarching reforms such as Startup India, Goods and Service Tax have aided in formalisation of the economy and in also attracting

capital. Infrastructure focused reforms have helped in building out infrastructure to aid in bringing down power cost, improving connectivity via roads, ports, airports aiding reduction in logistics cost. Manufacturing reforms have helped in seeding new age sectors and providing a boost to existing manufacturing sectors along with helping in the employment generation and catering to the export market.

Per capita trends to rise with urbanisation

India's per capita electricity consumption has increased steadily, driven by economic growth, urbanisation, and electricity access. According to the Central Electricity Authority (CEA), it rose from 819 kWh in fiscal 2011 to 1,395 kWh in fiscal 2024, at a 4% CAGR

Urbanisation is a key driver, with India's urban population expected to grow from 377 million in 2011 to 583 million by 2030. The household consumption expenditure survey (2023-24) shows a significant difference in average monthly per capita expenditure on fuel and light between rural (Rs 252) and urban (Rs 391) areas. As India urbanises, per capita electricity consumption is likely to rise, driven by increasing demand for energy intensive appliances and services.

Past electrification drives and untapped residential potential to support power demand

India has made significant progress in electrifying its villages and households through schemes like Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), Deen Dayal Upadhyay Gram Jyoti Yojana (DDUGJY), and Saubhagya Scheme. The RGGVY electrified over 1.2 million villages by 2018, while Saubhagya Scheme electrified over 25 million households by 2020. Despite this progress, there are still over 10 million rural households that lack access to electricity, presenting a significant opportunity for power demand growth. Electrifying those households could increase power demand by upto 10 GW, while providing reliable and affordable electricity to urban slums could add another 5 GW. Overall, India's past electrification drives have made significant progress, but there is still untapped residential potential to drive power demand, with growing demand for electricity-intensive appliances and increasing access to electricity for low-income households.

Allocation to Railway electrification rises 6% to Rs 61.5 billion in union budget 2026

Indian Railways, one of the world's largest rail networks, aims to become a net zero emitter by 2030. As of March 2024, 97% of the Broad-Gauge network is electrified, with a goal to reach 100% electrification by fiscal 2026. This is expected to lead to an incremental power demand of approximately 27 billion units per year between 2026-2030. The Ministry of Railways has been allocated Rs 2.5 trillion in the Union Budget 2025-26, with Rs 61.5 billion earmarked for electrification projects, driving growth in the sector and supporting the creation of new lines, doubling existing lines, and electrification of existing lines.

Growth in the operational and upcoming metro projects to increase electricity requirements

The electricity consumption of the urban metro system mainly comes from electricity consumption for train traction and the electricity consumption for station operation. Metro rail has seen substantial growth in India in recent years, and the rate of growth is going to become twice or thrice in the coming years with multiple cities requiring the need for metro rail to meet daily mobility requirements. As of March 31, 2025, around 943 kms of metro routes are operational across 18 cities of India. Around 732 kms of metro line is under construction and 1,888 kms of metro lines are proposed further. Electricity consumption from the aforesaid

categories is expected to add an average incremental power demand of 6-7 BUs every year between fiscal 2026 and 2030. As of fiscal 2025, Crisil Intelligence estimates metro projects constituted ~6% of the total incremental demand, but the share is expected to increase to 15-20% by fiscal 2030 due to a large quantum of planned metro projects.

EVs, Green hydrogen, data centres are growing segment with impact on power

India aims to increase the share of EVs in the overall car population to 30% by 2030. Under the National Electric Mobility Mission, the government envisages to promote EV adoption through demand-side incentives, i.e. subsidies, promoting charging infrastructure, and encouraging research and development in battery technology, power electronics, battery management and system integration, etc. EV sales in India have been supported by Demand incentives across various government schemes such as the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) II followed by the EMPS and PM E-Drive scheme. EV sales have picked up sequentially over the years aided by improved model availability and favourable cost dynamics compared to their ICE variants in the Two and Three-Wheeler Segments.

Green hydrogen is another area that will increase power demand. The government introduced the National Green Hydrogen Mission in January 2023, aiming for 5 million metric tons per annum of green hydrogen capacity by 2030. According to IEA, green hydrogen production could increase power consumption by upto 1000 TWh by 2050, equivalent to India's current electricity demand. India aims to add 125 GW due to green hydrogen production.

The growth of data centers in India is also driving up power consumption. This growth will primarily be driven by increasing demand for Artificial Intelligence (AI) which require massive amounts of computational power, data storage, and energy to operate, cloud computing, e-commerce, and digital services.

In conclusion, the growth of EVs, green hydrogen, and data centers is expected to drive up power consumption in the coming years.

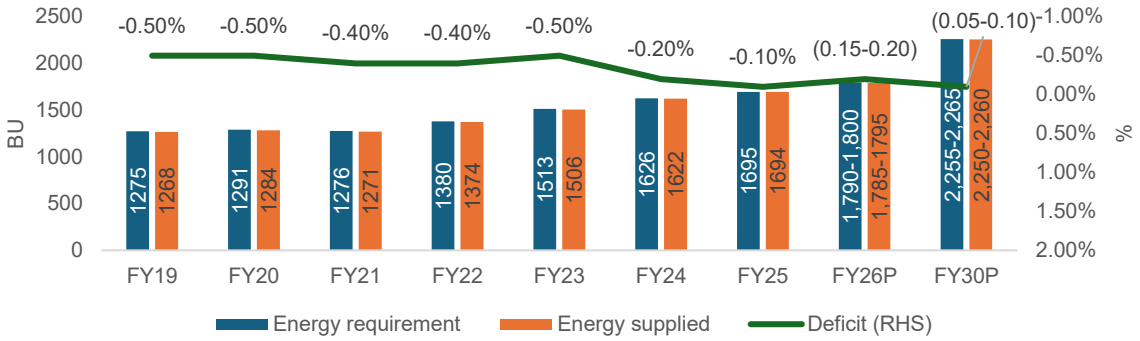
Efficiency gains caused by reduction in technical losses limit power demand to an extent

Technical losses during electricity transmission and distribution can be reduced through government initiatives, leading to significant efficiency gains. The Indian government has launched the Revamped Distribution Sector Scheme (RDSS) with Rs 3.04 trillion to reduce losses, and approved projects worth Rs 1.21 trillion for loss reduction and Rs 1.30 trillion for smart metering. Additionally, the Unnati Jyoti by Affordable LEDs for ALL (UJALA) scheme aims to replace 770 million inefficient bulbs with LED bulbs, with 368 million replacements achieved so far, is expected to reduce power demand by 1-2 GW between fiscals 2026-2030. Implementing smart grid technologies, grid modernization, and energy efficiency measures can help reduce technical losses, improve power sector efficiency, and meet India's growing electricity demand.

Demand supply gap

India's power demand deficit reduced to 0.1% in fiscal 2025 from 0.6% seen in fiscal 2019 as high-power demand was met with a generation increase at 4.9% CAGR during the same period.

Figure 19: Aggregate power demand supply and deficit over fiscals 2019-2030P



Source: CEA, Crisil Intelligence

With power demand expected to clock 5-7% CAGR between fiscal 2026-2030, significantly higher than 5.0% CAGR over the past 5 years, Crisil Intelligence estimates all-India deficit to be in the range of 0.05-0.15% in fiscal 2030.

Despite improvements, under serviced regions (mainly northern, north-eastern, and eastern) are also a key reason for expected continuation in pan-India deficit in the medium term despite an oversupply situation in terms of generation. The government is expected to improve connectivity within these regions, with inter-regional transmission capacity of the National Grid at 118,740 MW as of March 2025, aiding in reduction of the deficit.

Apart from this, although base deficit has reached below 1% in almost all major states except for Andaman and Nicobar Islands as of fiscal 2025. Crisil Intelligence believes that terming this scenario as a power surplus situation is not appropriate. There is still off-grid untapped latent demand in the country, and 100% intensive rural electrification and 24x7 power supply have not yet been achieved.

As per data available on the SAUBHAGYA dashboard, all households in the country are connected to the electricity grid. However, many of these are deprived of 24x7 power supply. States such as Haryana, Jharkhand, Uttar Pradesh, Karnataka, Arunachal Pradesh, Jammu and Kashmir, and Mizoram are yet to provide round-the-clock power supply to rural areas. As of fiscal 2024, the national average for daily power supply to urban and rural areas stood at 23.4 hours and 21.9 hours respectively, highlighting unmet demand in the country.

On the other hand, healthy capacity in coal, gas, diesel, lignite, nuclear, hydro and PSP capacities addition in the past (gross capacity additions of 27 GW between fiscal 2019 and 2025) and 57-59 GW of upcoming over the next 5 years would add to supply over the forecast period. This, coupled with expected healthy investments in T&D infrastructure, is expected to support rising demand. However, Crisil Intelligence expects base deficit to persist, though remaining negligible over the next 5 years, as deficit is expected to gradually come onto the grid in the long term.

Module 3: Overview of Indian Renewable Energy sector

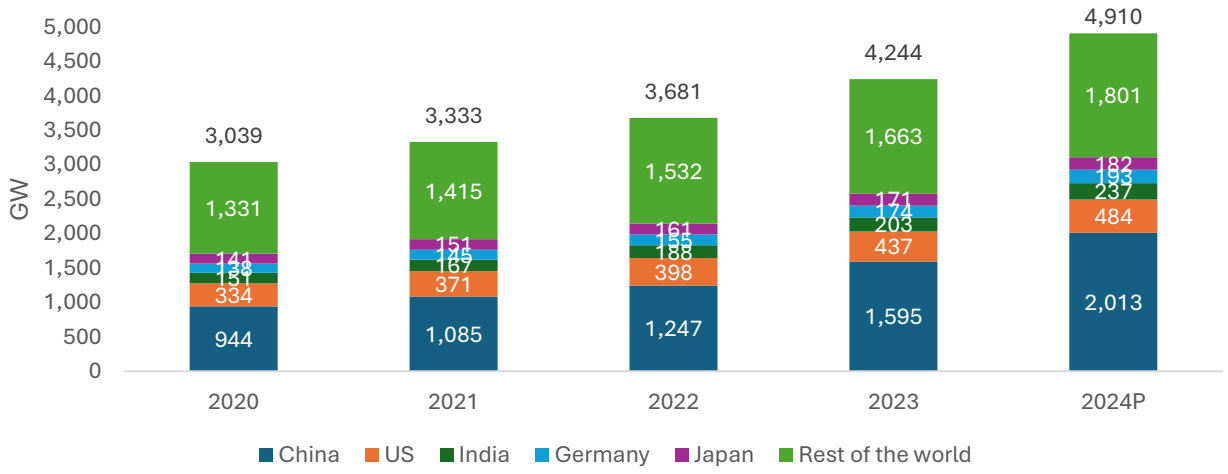
Drive to push renewable takes a center stage

The global push for clean energy is fueling a surge in renewable energy installations worldwide, driven by decreasing costs, supportive policies, and growing concerns about energy security, access, and socio-economic benefits. Over the past decade, the solar PV and wind sectors has undergone a remarkable transformation, marked by large-scale deployments, significant tariff reductions, and technological advancements.

The urgent need to address climate change is driving the shift towards renewable energy, and its increased adoption is crucial for decarbonisation. International initiatives such as the Kyoto Protocol, Paris Agreement, and RE 100 have bolstered the renewable energy sector. To limit global warming to below 2°C and ideally 1.5°C above pre-industrial levels, a transition to renewable energy is critical.

Countries party to Paris Agreement are required to submit and monitor their nationally determined contributions (NDCs), outlining their plans to reduce emissions. Governments have implemented various policies to support renewable industry, including feed-in tariffs, "must-run" status, renewable purchase obligations, tax incentives and subsidies. These majors have accelerated global growth of renewable energy.

Figure 20: India has the third largest renewable base in the world



Note: P stands for projected

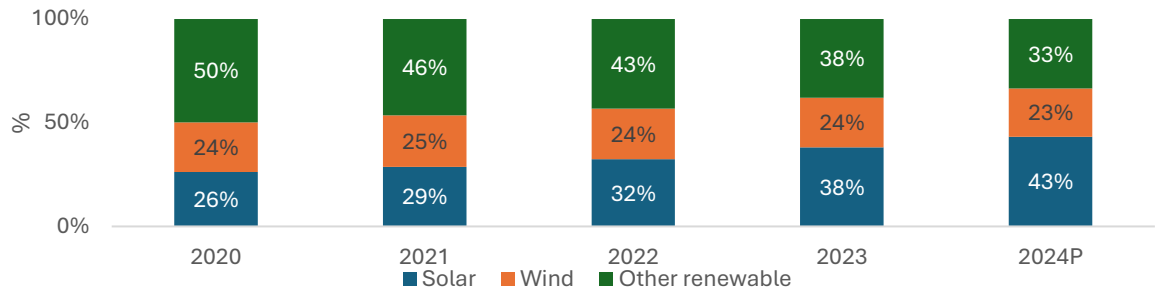
Source: IEA

As per the IEA, global renewable installed capacity increased at an 13% CAGR between 2020 and 2024P driven by the policy push across countries. China accounted for nearly 57% of the addition during the period with an installed base of 1.6 TW. US and India ranked second and third, respectively, with total installed base of 484 GW and 237 GW, respectively.

While India's renewable energy capacity has grown consistently over the years, its share in the global installed base remained stable at nearly 5% between 2020 and 2024P.

Nearly 66% of the global renewable installed base by 2024P was solar and wind while the balance was driven by other renewable fuels.

Figure 21: Wind accounted for ~26% of renewable additions globally from 2020-2024



Source: IEA

Falling prices of solar and improvement in technology resulted in solar gaining its market share over wind.

Over 1,800 GW of solar and wind energy potential in India

The evolution of renewable energy in India

Industry Overview – Renewable Energy Sector

Renewable energy (RE) represents a clean and sustainable alternative to conventional energy sources. Unlike fossil fuels, renewable sources do not undergo combustion and hence do not emit air pollutants or greenhouse gases during electricity generation. Increasing reliance on renewable energy is expected to significantly reduce carbon emissions, thereby playing a critical role in limiting global warming and mitigating the adverse effects of climate change. Moreover, renewables are abundantly available in nature, reducing the risk of depletion commonly associated with fossil fuel-based energy.

India's renewable energy sector includes multiple sources such as solar, wind, small hydro, biomass, and bagasse. Among these, solar and wind energy have emerged as dominant contributors to capacity addition, driven by policy incentives and technological advancements.

The country has witnessed substantial growth in renewable energy capacity over the past decade. As of March 2025, the total installed renewable energy capacity (including large hydro) stood at approximately 220 GW, a significant increase from approximately 76 GW in March 2014 and 134 GW in March 2020. This expansion has been supported by a favourable regulatory environment, investment incentives, and strong commitments under India's climate action goals.

Notably, solar energy has been a major driver of this growth, with installed capacity rising from a modest 2.8 GW in March 2014 to approximately 106 GW by March 2025. The country's installed renewable energy capacity (including large hydro) accounted for approximately 46% of the total installed power generation capacity as of March 2025, underscoring the sector's increasing importance in the national energy mix.

Despite this significant capacity addition, the actual energy generation from renewables remains relatively lower due to lower capacity utilisation factors compared to conventional sources. For fiscal 2025, the renewable energy sector (including large hydro) contributed approximately 404 Billion Units (BU) to total electricity generation in the country.

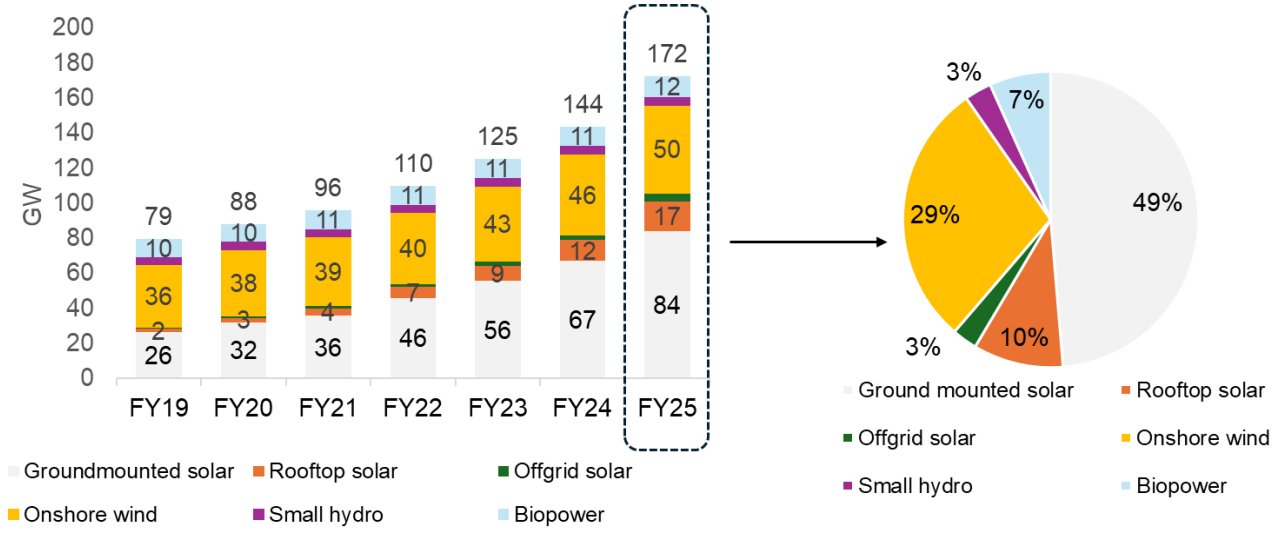
The continuing growing trends towards renewable energy on account of greater environmental awareness and the general trend to move away from non-renewable sources of energy provide with a significant opportunity for renewable energy power developers. For example, the Government is expected to achieve 50% of its energy from non-fossil sources by 2030 and has set the renewable energy target at 500 GW by 2030. In addition, the regulatory requirements will incentivise certain private entities to source their power requirements from renewable sources. Interstate transmission charges have also been waived for 25 years for projects commissioned until June 30, 2025, which will expand offtake options in the short-term power market. The Power Grid Corporation of India Limited is constructing green energy corridors to integrate renewable energy with the main grid, connecting renewable energy-rich states to states that lack renewable energy generation potential, which is expected to boost inter-state sale of renewable energy.

India stands 3rd globally in Renewable Energy Installed Capacity, 4th in Wind Power capacity and 3rd in Solar Power capacity. Despite strong capacity additions, there is huge untapped potential for RE installations in India.

India's renewable energy market has been driven by the solar and wind energy fuels while the balance comprises of small hydro and biopower. The renewable energy capacity (excluding hydro) in India stood at 172 GW, registering a growth of 13.8% CAGR between fiscals 2019-2025.

While solar led the renewable energy additions at 82% between fiscals 2019-2025, India's installed base was dominated by wind energy till fiscal 2020 driven by additions under the feed-in tariff regime till fiscal 2017. Fiscal 2021 witnessed convergence between the solar and wind energy. Infact, 66% of India's 106 GW of solar base was installed between fiscal 2021-2025.

Figure 22: Renewable energy base grows at a 13.8% CAGR between fiscals 2019-2025



Source: MNRE, Crisil Intelligence

Solar power grew at CAGR of 24% between fiscal 2019-2025, increasing from 29 GW in fiscal 2019 to ~106 GW in fiscal 2025. While in the same duration, wind grew 6% CAGR going from ~36 GW in fiscal 2019 to 50 GW in fiscal 2025.

This capacity addition demonstrates the strategic shift in India's renewable energy focus towards solar, driven by the country's long-term decarbonisation goals.

Despite disruptions caused by the COVID-19 pandemic, particularly during the second wave, the solar sector remained resilient. In fiscal 2022, approximately 13 GW of solar capacity was added. To support developers impacted by pandemic-related delays, the Ministry of New and Renewable Energy (MNRE) granted a cumulative extension of seven and a half months for affected projects. This led to the deferment of several projects, causing a spillover of commissioning timelines into fiscals 2023 and 2024.

In fiscal 2023, approximately 13 GW of new solar capacity was added. The momentum continued in fiscal 2024, with solar additions reaching approximately 15 GW.

The continued expansion of solar energy capacity reinforces India's commitment to its renewable energy targets and underscores the strategic importance of solar within the country's overall energy transition framework. The Government of India (GoI) introduced solar Renewable Purchase Obligations (RPOs) across Indian states in 2011, which, combined with a significant decline in capital costs, catalysed widespread policy support for solar energy. This regulatory push spurred a surge in investments in the solar sector.

Until fiscal 2012, only Gujarat and Rajasthan had formal state-level solar policies. However, the success of Gujarat's solar policy prompted several other states—such as Andhra Pradesh, Tamil Nadu, Karnataka, Madhya Pradesh, and Telangana—to roll out their own solar energy frameworks.

The renewable energy penetration in Indian states varies from state to state. In the top 10 renewable energy rich states, the penetration is higher than national average. The following table summarises the share of renewable energy in total power consumption. The share of renewable energy in most states is increasing.

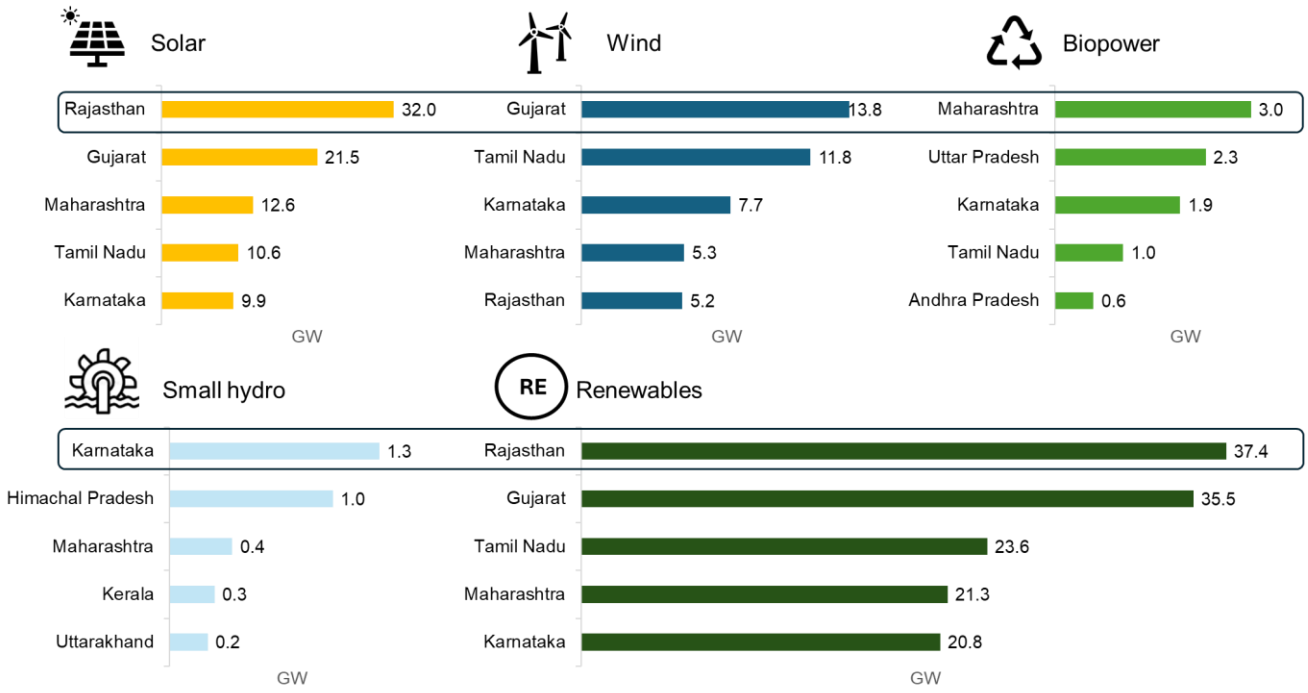
Table 5: Trends of Renewable energy consumption in total electricity consumption in key states

State	Share in RE installed base as of FY25	Share of RE consumption for state in FY24	Share of RE consumption for state in FY23	Share of RE consumption for state in FY22	Share of RE consumption for state in FY21	Share of RE consumption for state in FY20	Share of RE consumption for state in FY19
Andhra Pradesh	6%	19%	21%	24%	27%	32%	28%
Chhattisgarh	1%	13%	5%	4%	3%	2%	2%
Gujarat	18%	16%	16%	15%	15%	14%	12%
Haryana	1%	8%	7%	4%	2%	1%	1%
Karnataka	12%	26%	26%	25%	25%	21%	14%
Madhya Pradesh	5%	17%	14%	9%	8%	8%	9%
Maharashtra	11%	12%	11%	9%	8%	7%	6%
Rajasthan	20%	18%	16%	17%	16%	17%	17%
Tamil Nadu	13%	10%	10%	11%	11%	9%	8%
Telangana	3%	15%	14%	12%	12%	12%	12%

Note: As per ICED database, a large capacity of solar park in Andhra Pradesh is discontinued from fiscal 2021 onwards

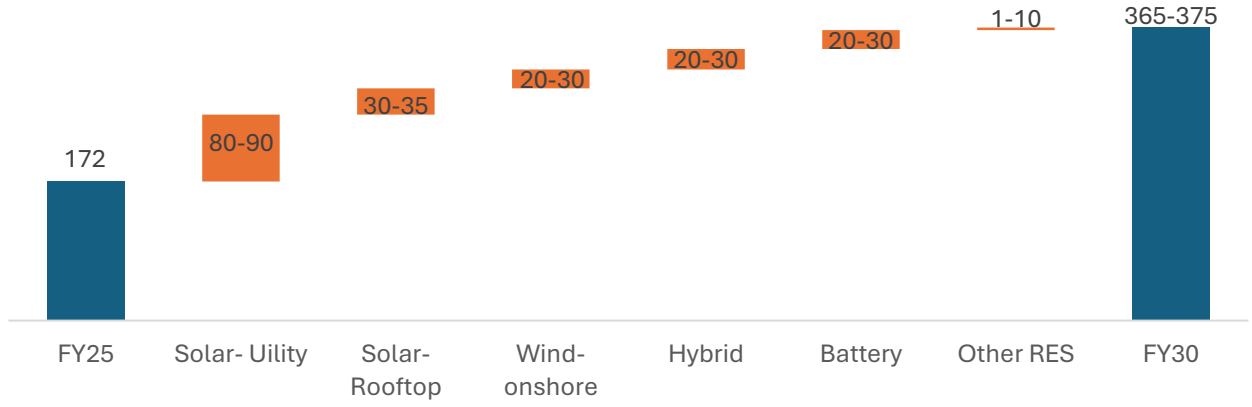
Source: ICED, MNRE, Crisil intelligence

Figure 23: Top performing states in Renewable energy by installed base as of June 2025



Source: Crisil Intelligence

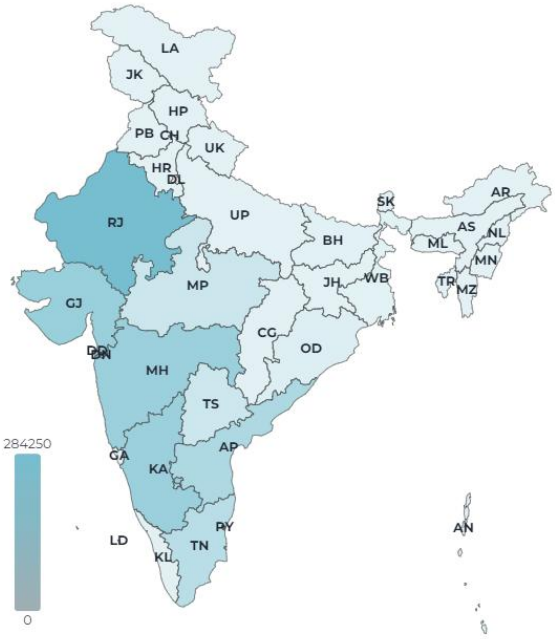
Figure 24: Renewable energy base to reach 360-370 GW by fiscal 2030



Source: Crisil Intelligence

India wind potential higher than solar

Figure 25: Wind potential concentrated in few states



Note: Wind energy potential is assessed at 150m above ground level. Map is not to scale.

Source: ICED Niti Aayog, Crisil Intelligence

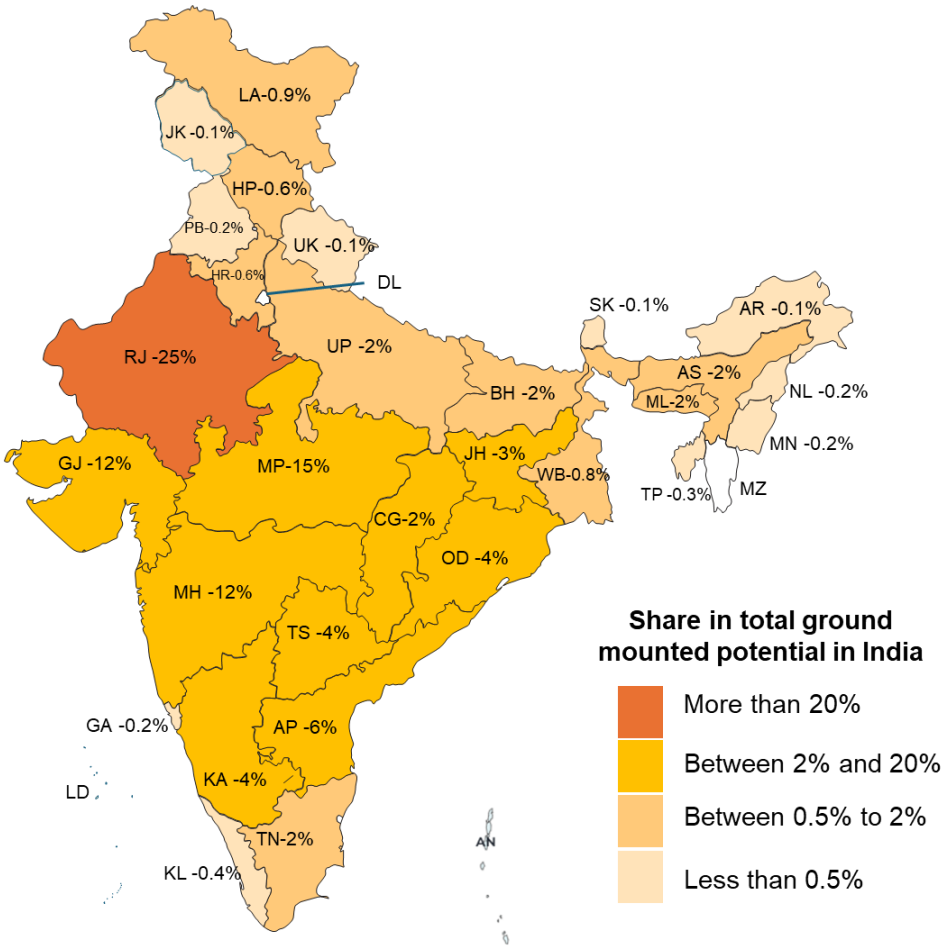
India has vast wind energy potential of 1164 GW at 150 m above ground level (as per National Institute of Wind Energy), although it is concentrated in five states of Rajasthan (24%), Gujarat (16%), Maharashtra (15%), Karnataka (15%), and Andhra Pradesh (11%).

The high wind speeds at 150 m significantly increase the feasibility of large-scale wind projects compared to lower hub heights. As turbine technology continues to evolve, more areas across the country could become viable for harnessing wind energy. Additionally, India's long coastline and open terrains present opportunities to further explore both onshore and offshore wind potential.

On the other hand, TERI's reassessment of India's solar energy potential suggests it to be around 10.8 TW The country's location makes it an ideal spot for harnessing solar energy, with 300 days of sunshine annually.

The global horizontal irradiance (GHI) in India ranges from 3.77-5.64 kWh/m^2. The GHI varies across the north-eastern hilly regions and the western cold desert areas. The Indian summer monsoon, which typically lasts from June to September, can affect solar generation in western and central India, while the northeast monsoon can impact southern regions during the winter months. Additionally, unseasonal rainfall can also negatively impact solar energy production.

Figure 26: Ground mounted solar potential distributed across India



Note:

1. Map is not to scale.
2. RJ – Rajasthan, GJ – Gujarat, MH – Maharashtra, KA – Karnataka, TS – Telangana, KL – Kerala, TN – Tamil Nadu, GA – Goa, LD – Lakshadweep, AP – Andhra Pradesh, OD – Odisha, CG – Chhattisgarh, JH – Jharkhand, MP – Madhya Pradesh, WB – West Bengal, BH – Bihar, UP – Uttar Pradesh, DL – Delhi, HR – Haryana, PB – Punjab, HP – Himachal Pradesh, UK – Uttarakhand, JK – Jammu and Kashmir, LA – Ladakh, AN – Andaman and Nicobar, TP – Tripura, MZ – Mizoram, MN – Manipur, NL – Nagaland, AR – Arunachal Pradesh, AS – Assam, ML – Meghalaya, SK – Sikkim.
3. Potential is calculated on barren and unculturable land
4. The percentage within the state boundary represents the total potential for ground-mounted installations in the state, divided by the total ground-mounted potential in India.

Source: TERI, Crisil Intelligence

Apart from the ground mounted solar potential of 4,909 GW, TERI's findings also suggest that India has 100 GW of floating solar, 960 GW of rooftop solar and 4,177 GW of Agri-PV for horticulture corps, coffee and tea plantation solar potential.

Table 6: Solar and wind potential in key states and progress

State	Solar		Wind	
	Potential (GW)	Achievement	Potential (GW)	Achievement
Rajasthan	1,234	3%	128	4%
Maharashtra	607	2%	98	5%
Madhya Pradesh	731	1%	15	21%

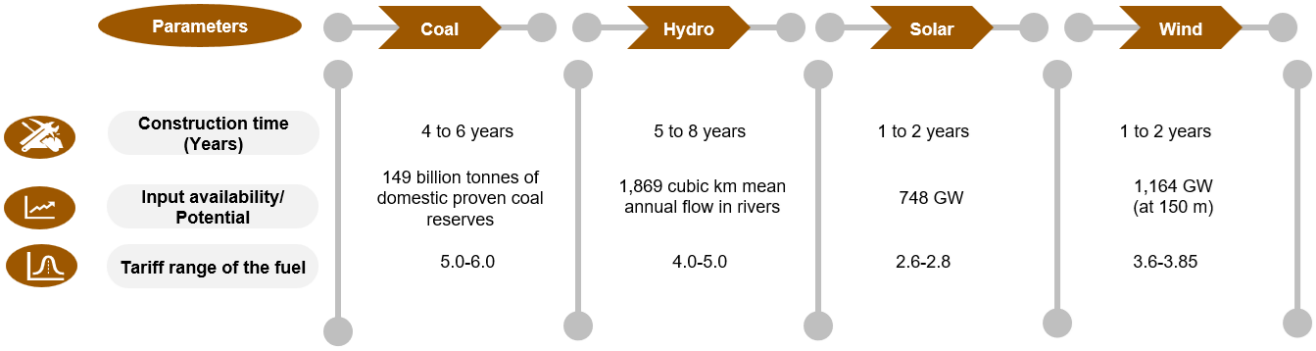
Andhra Pradesh	274	2%	75	6%
Gujarat	593	4%	143	10%
Karnataka	172	6%	124	6%
Tamil Nadu	98	11%	69	17%
Telangana	183	3%	25	1%
Haryana	27	8%	0.0	-
Punjab	8	19%	0.0	-

Note: Potential is calculated as of June 2025 installed base

Source: ICED Niti Aayog for Wind potential and TERI for solar potential, MNRE

Pricing difference pushes renewables growth

Figure 27: Renewables are now cheaper and faster to construct than conventional power plants



Source: ICED, MNRE, Crisil intelligence

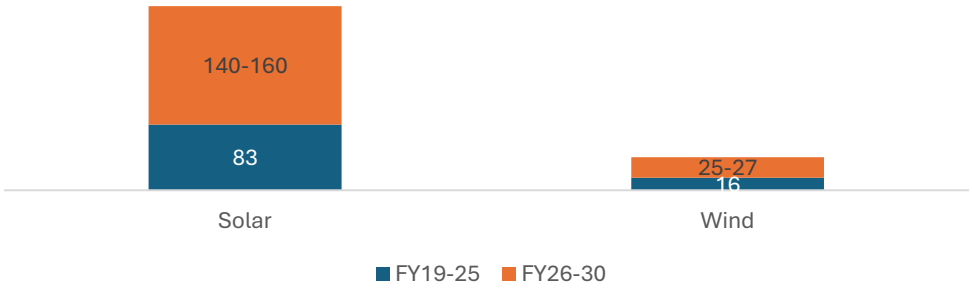
The pricing for renewables is now more competitive than coal, the predominant fuel for India. With volatility in coal pricing as well leading to rapid increases in coal power pricing in the past, stable long-term pricing agreements for renewables is also another positive driver for clean power purchase agreements. Beyond the declining costs of renewables and India's vast potential, two critical aspects cement renewables power's position as the preferred category: scalability and modularity, and site flexibility. Given a potential, renewables can be scaled up or down depending on the energy requirements across the country, making it adaptable to both small residential needs and large industrial demands. Additionally, construction time for renewable power plants is lower compared to conventional counterparts, leading to faster turnaround time in the overall cycle.

Indian renewable energy outlook and growth drivers

Solar and wind to witness 180-200 GW of additions between fiscal 2026-2030

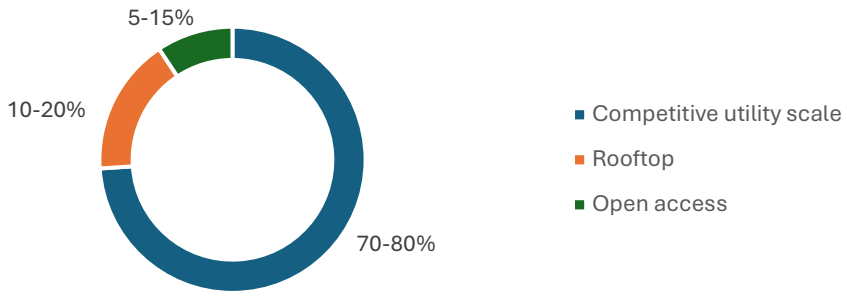
Between fiscals 2026-2030, India is projected to witness the addition of 140-160 GW of solar and 25-27 GW of wind additions, marking a significant acceleration in renewable energy deployment. This capacity build out is nearly 2 times the aggregate additions recorded during the fiscals 2019-2025, underscoring a strong policy push and growing investor interest in the sector.

Figure 28: Solar and wind capacity additions between FY19-30



Source: Crisil Intelligence

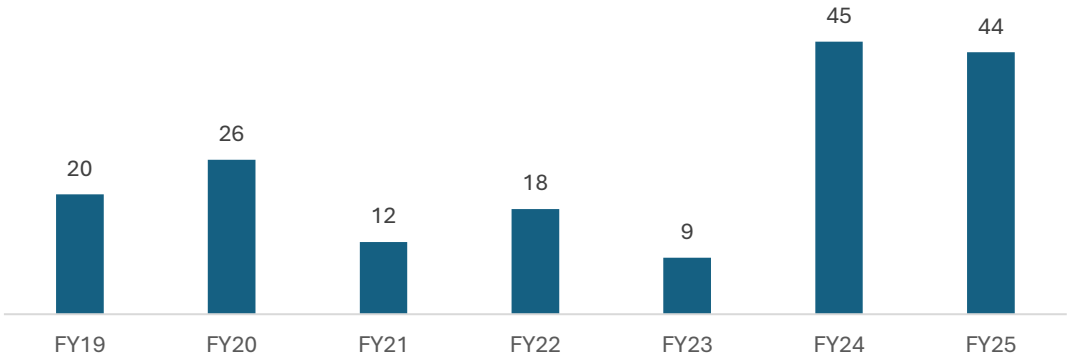
Figure 29: Competitive utility segments to drive additions between fiscal 2026-2030



Source: Crisil Intelligence

Majority of the incremental capacity is expected to be driven by the competitive utility scale segment, accounting for approximately 70-80% of the total additions. This reflects the continued emphasis on large scale tenders issued by central and state agencies supported by falling levelised tariffs and improved grid integration infrastructure. Over the course of fiscal 2019-2025 RE projects to the tune of ~174 GW were allocated via competitive route leading to the current installed base of 51 GW wind and ~108 GW solar power.

*Figure 30: RE Projects allocated between FY19-FY25**



Note: *: Projects allocated include solar, wind and hybrid across multiple business models

Source: Crisil Intelligence

Rooftop solar is anticipated to contribute around 10-20%, propelled by increasing commercial and residential demand and push from PM SuryaGhar Yojana. The Open Access market is

expected to contribute the remaining 5-15%, aided by rising participation from corporate buyers pursuing sustainability goals and cost optimisation strategies. A notable trend within this expansion cycle is the rising share of hybrid renewable energy systems particularly wind solar hybrids with battery storage. The demand for schedulable renewable energy is expected to grow, driven by industrial off takers, distribution companies, and grid operators seeking round-the-clock power supply solutions. As a result, hybrid projects are increasingly being favoured in the center and state procurement programs, offering both generation diversity and improved capacity utilisation. This shift aligns with India's broader energy transition goals, with emphasized grid reliability, decarbonisation, and domestic manufacturing between fiscals 2026-2030. It is thus expected to not only deliver high volumes of renewable capacity but also a more balanced and resilient portfolio mix positioning India as a key market in the global clean energy landscape.

Growth drivers for renewable energy additions in India

The robust capacity expansion in renewable energy in India is expected to be driven by demand and supply led growth drivers.

a. **Renewable energy parks:** Renewable energy parks help overcome higher project cost per MW and higher transmission losses. The scheme for “Development of Solar Parks and Ultra-Mega Renewable Energy Power Projects” was rolled out in December 2014 to facilitate the project developers to set up projects expeditiously. As of January 2025, 41 GW of capacity parks were envisaged across 13 states. Gujarat and Rajasthan account for 30% and 28%, respectively. Further as of January 2025, with nearly 28 GW awarded, of which 15 GW was under construction and 13 GW commissioned. Adani Green Energy Limited is developing an RE park in Khavda of 30 GW. The park had 4.1 GW operational capacity as of March 2025.
b. **PM SuryaGhar Yojana:** Launched in February 2024, the scheme aims for the installation of solar rooftop on 10 million households. The yojana achieved 10% of its target by 10th March 2025. With 4.7 million applications received, the initiative has already disbursed Rs 47.7 billion in subsidies to 0.6 million beneficiaries, making solar energy more accessible than ever. The scheme’s easy financing options, including collateral-free loans up to Rs 0.2 million at a 6.75% subsidised interest rate through 12 Public Sector Banks, have further accelerated adoption. Crisil Intelligence expects the PM SuryaGhar Yojana to add 15-17 GW between fiscal 2026-2030.
c. **The 50 GW tendering pipeline:** The government has decided to invite bids for 50 GW of renewable energy capacity annually for five years i.e. fiscals 2024-2028. These annual bids of ISTS connected renewable energy will also include setting up of wind power capacity of at least 10 GW per annum. Tenders of 48 GW and 33 GW in fiscal 2024 and 2025 have been issued by four RE implementing agencies (REIAs) – (SECI, NTPC, SJVN and NHPC).
d. **RPO:** To renewable purchase obligation is a regulatory requirement set by the State Electricity Regulatory Commission (SERC), which mandates that Obligated Entities procure a minimum percentage of their total energy consumption from renewable sources. As of April 1, 2024, a revised renewable purchase obligation (RPO) trajectory took effect, replacing the previous one set in September 2022 to promote wind, hydro

and distributed renewable energy sources. However, any excess energy consumption from "Other" renewable energy sources in a given year could be used to make up for shortfalls in wind or hydro renewable energy consumption.

Table 7: New RPO trajectory guideline till fiscal 2030

Category	FY25	FY26	FY27	FY28	FY29	FY30
Wind	0.67%	1.45%	1.97%	2.45%	2.95%	3.48%
Hydro	0.38%	1.22%	1.34%	1.42%	1.42%	1.33%
Distributed RE	1.50%	2.10%	2.70%	3.30%	3.90%	4.50%
Other RE	27.35%	28.24%	29.94%	31.64%	33.10%	34.02%
Total	**29.91%**	**33.01%**	**35.95%**	**38.81%**	**41.36%**	**43.33%**

Source: Ministry of Power, Crisil Intelligence

Table 8: RPO compliance of select states

State	RPO Target	RPO Compliance
Andhra Pradesh	20%	21.15%
Gujarat	20.70%	22.10%
Haryana	27.08%	25.63%
Karnataka	29.91%	21.60%
Madhya Pradesh	29.17%	29.18%
Maharashtra	29.91%	11.17%

Note: The above states constitute 42% of the domestic power demand

Source: Ministry of Power, Crisil Intelligence

e. **Green Energy Open Access (GEOA):** The MoP took a significant step towards promoting the use of green energy by introducing the Green Energy Open Access Rules, 2022. As of December 2024, 22 states have released draft or final regulations to adopt these rules.

f. **State renewable energy policies:** India's leading states are advancing ambitious renewable energy policies to meet national sustainability goals. Rajasthan's integrated clean energy policy 2024 targets 125 GW of renewable capacity by 2030, including 90 GW solar and 25 GW wind and hybrid energy, with provisions for top solar installations up to 1 MW under gross metering. Gujarat's Renewable Energy Policy 2023 aims for 50% of its power from renewables by 2030, planning to harness 36 GW solar and 143 GW wind capacity, and attract investments of approximately Rs 5 trillion. Andhra Pradesh's Integrated Clean Energy Policy 4.0 aspires to achieve net zero carbon emissions by 2047 targeting 78.5 GW solar, 35 GW wind, and 22 GW pump storage capacity, while offering incentives like land acquisition and power subsidies. Tamil Nadu and Maharashtra are also enhancing their renewable energy frameworks, focusing on solar and wind energy expansions, and integrating battery storage systems to ensure grid stability.

g. **Viability gap funding (VGF):** In September 2023, the government approved the VGF scheme for development of 4,000 MWh of BESS capacity by fiscal 2031. An initial outlay of Rs 94 billion including budgetary support of Rs 37.6 billion has been provided under the scheme. The VGF would be provided from fiscals 2024-2026 and will be capped at 40% of the capital cost. The Union Cabinet also approved the VGF scheme for offshore

wind energy projects at a total outlay of Rs 74.53 billion, including an outlay of Rs 68.53 billion for installation and commissioning of 1 GW of offshore wind energy projects (500 MW each off the coast of Gujarat and Tamil Nadu), and grant of Rs 6 billion for upgradation of two ports to meet logistics requirements for offshore wind energy projects. While offshore wind energy installations are expected to commence from fiscal 2031, BESS is expected to benefit between fiscals 2026-2030.

h. **PM KUSUM:** In March 2019, the Government of India launched the Pradhan Mantri Kisan Urja Suraksha evan Utthaan Mahabhivan Scheme (PM-Kusum Scheme), with an outlay of Rs 344 billion as central financial support. The objective is to install 10 GW of solar capacity under component A, 1.4 million standalone solar-powered pump systems under component B and 3.5 million grid connected solar-powered pump systems including feeder level solarisation under component C in off-grid areas to provide energy and water security for farmers, reduce the consumption of diesel, promote the use of renewable energy in the agricultural sector and reduce environmental pollution. While the progress has been sluggish in component A with 563.48 MW installations, component B and C have seen a better pace with 0.77 million pump installations, and 0.34 pumps solarised respectively as of March 2025.

i. **Energy storage with solar:** To achieve India's 500 GW non-fossil fuel target by 2030, the capacity of variable renewable energy (VRE) sources such as solar and wind needs to be enhanced significantly. This can pose significant challenges to grid stability, as the VRE sources are intermittent and variable in nature and may not be available for generation during the periods of low renewable energy or high demand. In this context, energy storage systems (ESS) would be essential to ensure grid stability, reliability, and optimal energy utilisation. Thus, the CEA has proposed to all renewable energy implementing agencies and state utilities to incorporate a minimum of 2 hours of collocated ESS, equivalent to 10% of the installed solar project capacity in the future solar tenders. This is expected to result in 14 GW/28 GWh of storage installed base by 2030.

j. Late payment surcharge (LPS) rules: The MoP introduced LPS Rules on June 3, 2022, to tackle the problem of non-payment of generator dues by power distribution companies (discoms). The rules enable Power System Operation Corporation Limited (POSOCO) to penalise discoms for non-payment of both current dues and overdues by blocking of their access to the short-term energy market. Overdues of discoms after introduction of LPS rules have reduced significantly from over Rs 1.1 trillion as of June 2022 to Rs 0.6 trillion as of June 2025, for all generating fuels, including renewable energy.

k. Transmission infrastructure augmentation: As of fiscal 2025, total installed renewable energy capacity was ~220 GW (comprising solar, wind, bio energy and small and large hydro) out of total ~475 GW power generation capacity in India. However, based on the units supplied, renewable energy's share amounts to only ~14% of total power supplied. Its share is expected to rise to 25-30% in generation by fiscal 2030. This may result in grid instability due to variable nature of generation of power from renewable energy sources. Hence, renewable generation may have to be backed down to maintain grid stability. To address this, the government is taking measures such as planning electricity generation reserves, augmenting transmission infrastructure, and

introducing technical standards and regulations. Various schemes are being implemented for transmission infrastructure augmentation to cater to growing renewable energy installed base. Renewable plants are often located in remote areas, requiring robust transmission planning to connect them to cities and industrial areas. To address this, the government has launched schemes like the Green Energy Corridor (GEC) and Renewable Energy Zones (REZ) aimed to integrate renewable energy into the grid. GEC Phase-I aimed to develop evacuation corridors for renewable energy in key states. The inter-state component was completed in March 2020, and the intra-state component is near completion, with 9,135 ckm of transmission lines constructed as of June 2024. GEC Phase-II, approved in March 2022, aims to integrate approximately 19 GW of renewable energy.

I. **Green hydrogen push:** India aims to achieve 5 Million Metric Tonne Per Annum (MMTPA) of green hydrogen manufacturing capacity by 2030. The mission aims to reduce dependence on production of hydrogen using fossil fuels and engage renewable energy for the same. The target of 5 MMTPA green hydrogen provides an additional upside of 125 GW of renewable energy capacity additions.

Availability of finance for funding mechanism

To facilitate growth of renewable energy, the government of India has provided several measures to facilitate availability to developers. Some of these steps taken are as follows:

- **Funding from lending institutions such as PFC, IREDA, REC and PFC:** Government financial institutions such as Power Finance Corporation (PFC), Rural Electrification Corporation (REC) and IREDA finance renewable energy projects. As of December 2024, the renewable energy portfolio of PFC crossed Rs 694 billion, 28% increase on year. Similarly, REC has sanctioned Rs 791 billion loans to renewable energy including large hydro in 9M fiscal 2025. IREDA's outstanding loans amounted to Rs 690 billion, marking an increase of 36% on year.
- **Green bond/masala bonds market:** A green bond is like any other bond; however, it invests the proceeds to support green investments including renewable energy projects. The tenure of the bond typically ranges from 18 to 30 months. India is the second country after China to have national level guidelines for green bonds. Green bonds may be issued by a national government, multilateral organisations, financial institutions, and corporations.
- **Pension funds/endowment funds:** Pension/endowment funds are expected to play a key role in financing renewable energy projects. Long-term 25-year PPAs with limited operational risk are very suitable to this investor category.
- **Funding from multilateral banks and International Solar Alliance:** The central government channelises the funds available from multilateral banks and financing institutes such as the World Bank and KfW. The central government or its representatives receive the funds and further allocate it to various states/state government schemes. Funds are also provided to various CPSUs/Central non-banking financial companies (NBFCs) with Indian government backing under the Climate Investment Fund of the World Bank.

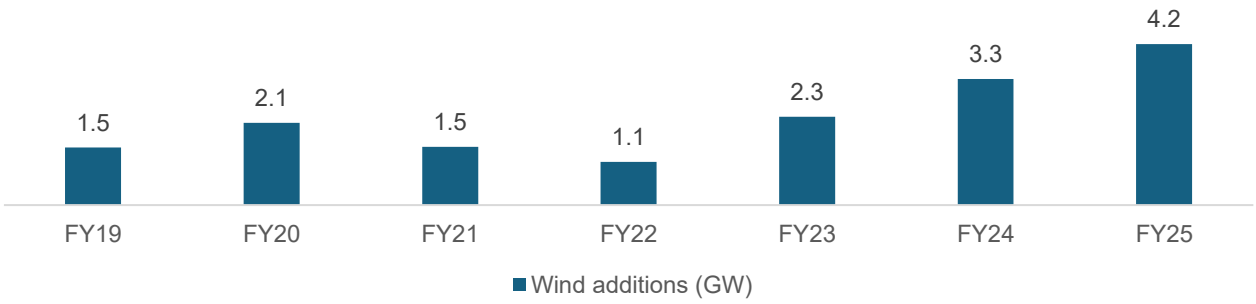
Module 4: Overview of Indian Wind Energy sector

Capacity additions momentum continues in fiscal 2025

SECI projects drive installations

India has seen 15.8 GW of wind energy additions between fiscals 2019-2025. Within the block years, fiscal 2025 witnessed record breaking additions of 4.2 GW after the cessation of feed-in tariff regime. This came on the back of commissioning of projects under schemes such as SECI Tranches-V, VIII, IX, X and XI and Hybrid Tranche-VII. The average monthly capacity addition in fiscal 2025 stood at ~346 MW, up 28% on year and ~4 times that of fiscal 2022. This pickup in the execution rate in recent years was attributed to pent up pipeline. Overall SECI schemes were responsible for ~46% of the capacity additions between fiscals 2019-2025.

Figure 31: Wind capacity additions cross 4 GW mark in fiscal 2025



Source: MNRE, Crisil Intelligence

The sector, however, continues to face delays due to execution challenges such as grid connectivity issues, congestion of good wind resource regions, limited choice in OEM suppliers, land acquisition with 5dx7d, right of way for logistics of WTG and transmission line, turning radius and movement of material challenges for the project. SECI and other state entities cumulatively allocated ~21.2 GW of standalone wind capacity between fiscals 2017-2025, of which ~7.1 GW (34%) has been commissioned and ~5.5 GW (26%) cancelled. With commissioning timelines of 18-24 months, projects are now lined up for commissioning over the next five fiscals.

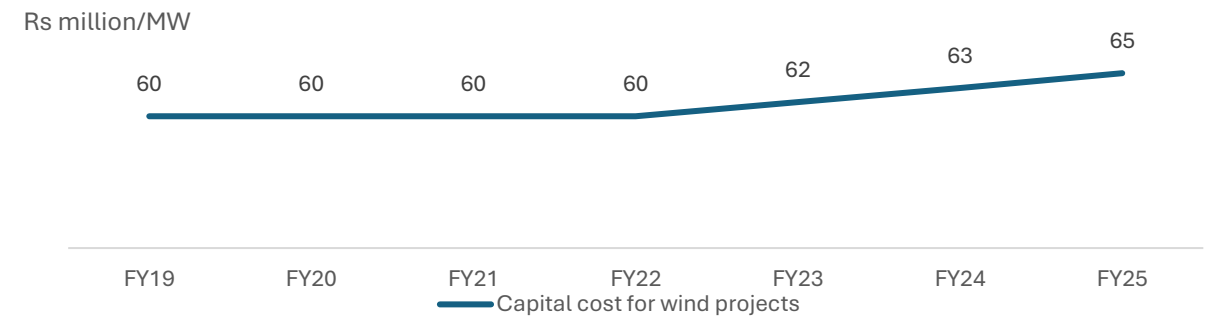
Awarded schemes are facing execution headwinds, due to delays in receiving regulatory approvals, issues relating to land acquisition, long-term access to transmission, locating land in windy regions and monsoon-related disruptions.

In addition, previously, volatility in prices of key commodities, such as cement and steel (4% and 26% on-year, respectively) in fiscal 2022 and a further increase (of ~3% and 4%) in fiscal 2023 because of supply-chain disruptions amid geopolitical challenges, contributed to cost escalations and higher capital cost for wind projects.

Through the years, the capital cost of wind power (Rs million per MW) has become competitive compared to other conventional sources of power due to economies of scale and the large manufacturing capacity for wind turbine generators in India. With demand for wind-solar hybrid

("WSH") projects on the rise, driven by corporate buyers and discoms seeking reliable green power, the MNRE introduced the National Wind-Solar Hybrid Policy in 2018 to promote better grid stability and reduce renewable energy variability. Several states, including Gujarat, Andhra Pradesh, and Rajasthan, have also implemented their own WSH policies.

Figure 32: Capital cost of wind projects



Source: CEA

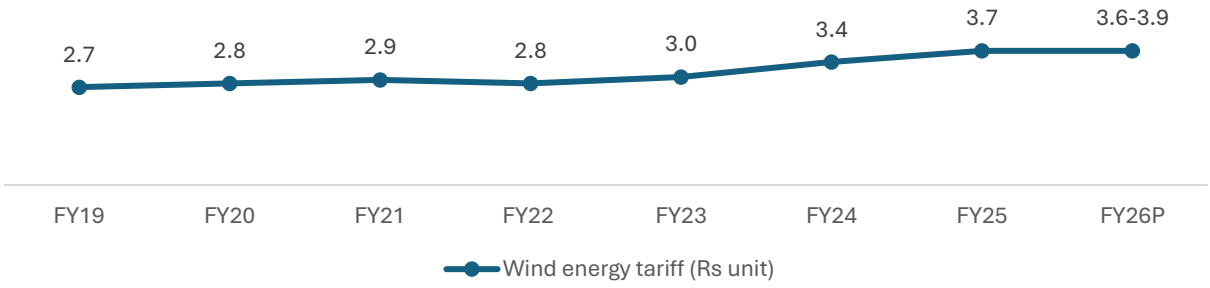
The higher input prices seeping into turbine costs, compared with the past have reduced project returns, impacting execution of delayed projects bid at lower tariffs. This has also caused bid tariffs to increase 10% CAGR between fiscals 2022 and 2024 as developers treaded cautiously for new allocations. Tariffs in fiscal 2025 continued to rise, growing by 12% on year, despite relief in commodity prices. The rise can be attributed to issues with regards to acquisition of land, concentration in type I wind sites, availability of adequate transmission infrastructure, falling cost of solar energy leading to developers favouring it over wind.

Going ahead, concrete prices are expected to correct after two years of consecutive fall while steel prices are expected to remain flat in fiscal 2026. Despite this, Crisil Intelligence expects the bid tariffs to be range bound at Rs 3.6-3.9 per unit in fiscal 2026. With this, wind is expected to remain on parity with fossils which combined with improvement in technology and government support, will help the wind base to continue to increase.

Tariff trends

The wind power industry in India has transitioned from a feed-in-tariff regime to a competitively bid regime. To help non-windy states fulfil their renewable purchase obligation, MNRE apportions wind power capacity by way of reverse auction where bidders compete by lowering the offered tariff creating a dynamic price discovery process.

Figure 33: Weighted average wind tariff on the rise



Source: Crisil Intelligence

To provide relief to wind developers, the Ministry of New and Renewable Energy (MNRE) had previously permitted the extension of scheduled commercial operation dates for wind projects facing difficulties, subject to certain conditions and adequate proof. The same extension may be granted owing to:

1. Any change in land policy in a state post bidding or any delay in handing over of land by the state as per policy
2. Modifications in land and building rules of Tamil Nadu (for projects with PPAs signed post July 2018)
3. Extension of 60 days post operationalisation of concomitant ISTS infrastructure
4. Delays in approval of request from the Ministry of Defense (MoD) beyond 60 days, subject to the condition that the request to the MoD must have been applied within 30 days of effective date of the PPA
5. Extension of financial closure timelines in keeping with the extensions given to the final commercial operational date
6. Any other extension request sent by SECI to the MNRE

Apart from this, the MNRE had also granted a 2.5-month extension for renewable energy projects that had a scheduled commissioning date on or after April 1, 2021, to 15th June 2021. In fiscal 2021, the ministry also provided a 5-month extension in addition to its initial blanket extension of lockdown plus 30 days amid the Covid-19 lockdown. It had clarified that any delays because of constraints related to the pandemic will be treated as force majeure.

Further, to provide relief to wind project developers on account of supply-chain disruptions, owing to the pandemic and monsoon-related disruptions, the ministry had decided that for wind power projects, for which the PPA was signed and orders for wind turbine generators were placed before June 2021, the implementing agencies can grant up to 3 months extension from the scheduled commissioning date. However, the extension was to be considered by the MNRE after due diligence and scrutiny of the specific circumstances of the case.

As the extension deadlines have now ended, Crisil Intelligence expects capacity addition to pick up pace over the next five fiscals, along with the support of favourable policies by the MNRE. Cancellation rate has already reduced as developers are more cautious with bidding of wind projects.

Capacity additions pick up in fiscal 2025

Capacity additions plummeted from the peak of fiscal 2017, mainly because of the abrupt phasing out of the feed-in tariff (FiT) regime and implementation of the competitive bidding mechanism at the end of fiscal 2017. Moreover, halving the accelerated depreciation benefit (from 80% in fiscal 2017 to 40% in fiscal 2018) and elimination of generation-based incentives of Rs 0.5 per unit had also reduced investments in the sector from non-independent power producers.

In February 2017, the government conducted the first reverse e-auction for wind power, which saw tariffs falling to Rs 3.46 per unit, 17% lower than the lowest wind FiT of Rs 4.16 per unit in Tamil Nadu. With such a sharp drop in tariffs, several discoms in Gujarat, Andhra Pradesh, Rajasthan and Karnataka expressed their unwillingness to buy power under the FiT regime even for approved and under-construction projects as PPAs were not signed.

Wind power tariffs then fell to Rs 2.5 per unit level, with tariffs as low as Rs 2.43 per unit in December 2017 in the Gujarat wind auctions of 500 MW. However, tariffs have since reached a weighted average of Rs 3.4 and Rs 3.7 per unit in fiscal 2024 and 2025, respectively, a rise compared with those recorded in the previous years. The weighted average tariffs were Rs 2.89, Rs 2.80 and Rs. 2.97 per unit in the fiscals 2021, 2022 and 2023, respectively.

Three central allocations concluded on fiscal 2025, two by SJVN and one by SECI. SJVN Wind Tranche-I and Tranche-II recorded weighted average tariff of Rs 3.99 and 3.77 per unit respectively. The SECI auction under Wind Tranche-XVII with a weighted average tariff of Rs 3.81 per unit in fiscal 2025. A sole state led allocation concluded by GUVNL under Tranche-VIII witnessed weighted average tariff of Rs 3.59. Fiscal 2025 concluded with a weighted average tariff of Rs 3.7 per unit, still lower than the Rs 4-5 per unit witnessed by the sector under FiT.

The sector continues to adjust to the significantly lower tariffs under competitive bidding as well as land availability and grid connectivity challenges, where developers are facing issues from delayed/ congested infrastructure.

Wind capacity additions have been primarily concentrated in Gujarat, Tamil Nadu and Karnataka contributing 46%, 19% and 18% between fiscal 2019-2025 respectively.

Table 9: State-wise yearly capacity additions fiscal 2019-2025

State	Installed base	Capacity additions							Installed base
	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY25
Andhra Pradesh	3,967	124	2	4	-	-	-	281	4,377
Gujarat	5,613	460	1,468	1,020	647	770	1,744	955	12,677
Karnataka	4,608	87	96	148	192	164	725	1,331	7,351
Kerala	53	-	10	-	-	-	1	8	6471
Madhya Pradesh	2,520	-	-	-	-	324	-	351	3,195
Maharashtra	4,784	10	206	-	13	-	195	77	5,285
Rajasthan	4,298	2	-	27	-	867	2	13	5,209
Tamil Nadu	8,197	772	335	304	258	151	586	1,136	11,740

Telangana	101	27	-	-	-	-	-	-	128
Pan India	**34,145**	**1,481**	**2,118**	**1,503**	**1,111**	**2,276**	**3,253**	**4,151**	**50,038**

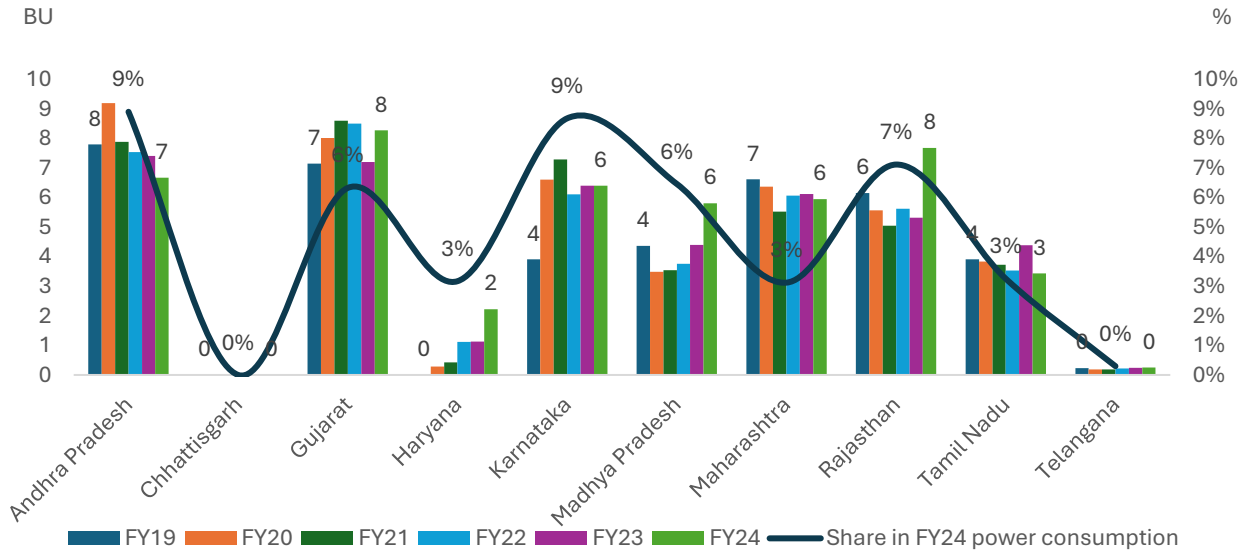
Source: MNRE, Crisil Intelligence

State-wise wind energy consumption

Wind energy formed ~5% of average power consumption among top states

The wind energy consumption among top 10 states has increased 2% CAGR between fiscals 2019-2024. In fiscal 2024, wind power accounted for approximately 5% of the total electricity consumption among major states in the country, which collectively represented around 63% of the nation's overall power consumption. Notably, Andhra Pradesh and Karnataka led the rankings, with wind energy meeting around 9% of their respective power demands. Rajasthan followed closely, with wind power accounting for 7% of its total power requirement. Meanwhile, Gujarat and Maharashtra each derived 6% of their power from wind sources during the same fiscal year.

Figure 34: Share of wind power among top states

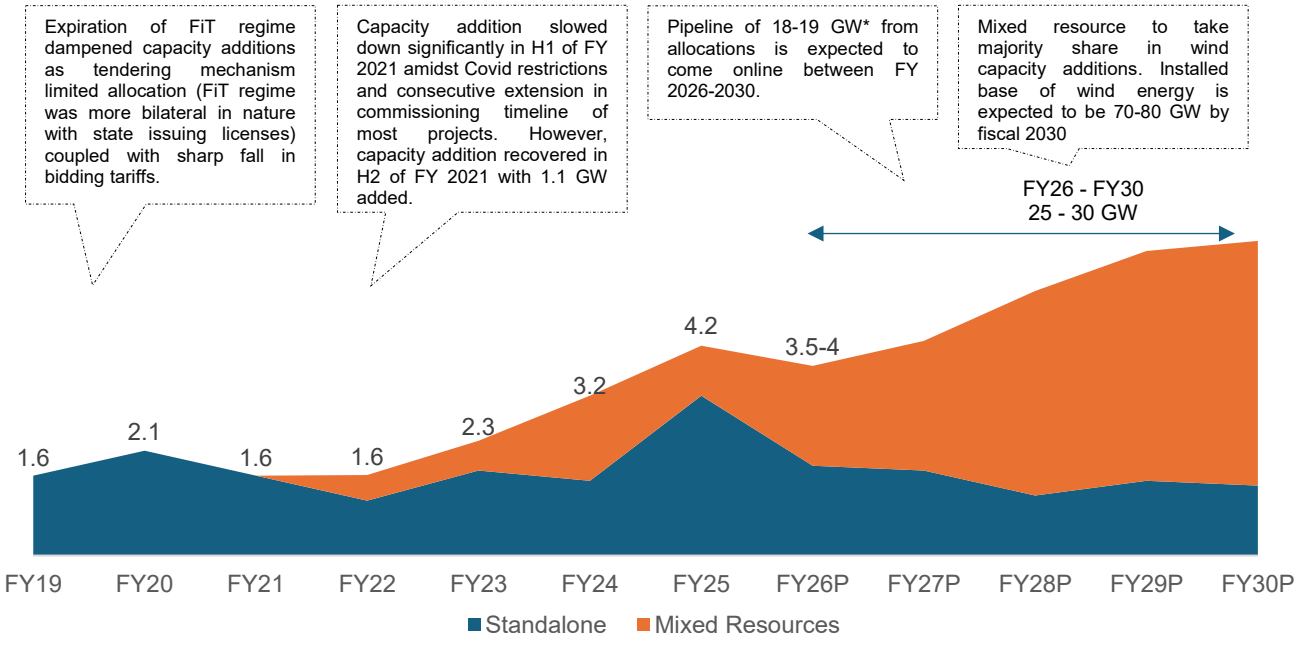


Note: As per ICED database, a large capacity of solar park in Andhra Pradesh is discontinued from fiscal 2021 onwards

Source: ICED- Niti Aayog

Capacity additions expected to accelerate over fiscal 2026-2030

Figure 35: Wind expected to add 25-30 GW between fiscal 2026-2030



Note: *: This excludes additions from green hydrogen

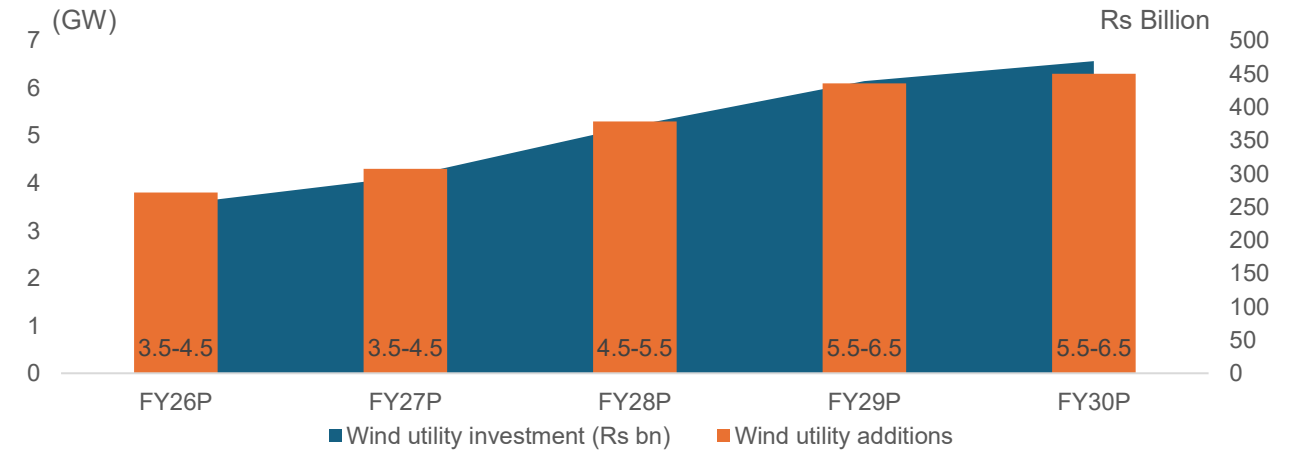
Source: MNRE, Crisil Intelligence

Crisil Intelligence estimates the wind energy base to reach 70-80 GW by the end fiscal 2030, registering a robust growth of 1.5 times on the 50 GW installed base at the end of fiscal 2025. This marks robust additions between 2.0-2.5 times over fiscals 2026 to 2030 compared to fiscals 2021 to 2025.

Investments to the tune of Rs 1.8-2.0 trillion expected

Crisil Intelligence expects wind capacity additions of 25-30 GW over fiscals 2026 to 2030, entailing investments of Rs 1.8-2.0 lakh crore excluding renewable energy capacity driven by green hydrogen

Figure 36: Wind to see investment of Rs 1.8-2.0 trillion



Source: Crisil Intelligence

Rising allocation of new business models such as RTC, peak power and plain hybrid will be the key drivers. That said, capacity additions over the long term will be driven by increased hybrid tenders, storage and new business model-based tenders, and central government allocations. The central government off-take route, via relatively strong off-takers such as SECI, will also reduce risks, compared with direct exposure to state discoms. State allocation has already slowed as several states have instead signed power sale agreements with PTC and SECI for procurement of wind power to fulfil their non-renewable purchase obligation targets.

Improved financial health of DISCOMs

The power distribution sector has seen various reforms measures/ rules for improving financial viability of distribution utilities (DISCOMs). Some of the key initiatives of Ministry of Power, for power distribution sector include Ujjwal DISCOM Assurance Yojana (UDAY, 2015) which provided for gradual takeover of DISCOM's debt by State Governments, Revamped Distribution Sector Scheme (RDSS, 2021) which targets nationwide deployment of prepaid smart meters along with other performance improvement measures, Electricity (Right of Consumers) Rules 2020, Electricity Late Payment Surcharge and Related Matters (LPS Rules) 2022 etc.

The financial health of DISCOMs in India has shown improvement in the fiscal 2024, with 15 DISCOMs and 6 Power Departments experiencing an upgrade in their grades compared to the previous year. This improvement is also reflected in the scores, with 25 DISCOMs and 9 Power Departments demonstrating an "Improving" trend, characterised by a more than 5% increase in scores from the previous year. Furthermore, the number of DISCOMs with a grade of C or lower has decreased from 21 in the 12th Ratings to 18 in the 13th Ratings, indicating a positive trend in the financial performance of these utilities.

GUVNL (Gujarat Urja Vikas Nigam Limited) is the major power distribution company in Gujarat and has shown significant improvement in its operating parameters. It has 4 subsidiaries viz Dakshin Gujarat Vij Company Limited (DGVCL), Madhya Gujarat Vij Company Limited (MGVCL), Paschim Gujarat Vij Company Limited (PGVCL), and Uttar Gujarat Vij Company Limited (UGVCL). As per 13th Annual Integrated Report dated February 2025 by Ministry of pawer, GUVNL had an average integrated score of 94 in fiscal 2024. All four subsidiaries had A+ ratings. The AT&C loss of GUVNL decreased from 10.67% in fiscal 2023 to 9.12% in fiscal 2024, collection efficiency improved from 98.96% in fiscal 2023 to 99.06% in fiscal 2024 and billing efficiency improved from 90.27% in fiscal 2023 to 91.75% in fiscal 2024.

Further, SECI also plays a vital role in achieving the government's renewable energy goals. Additionally, SECI holds a Category I Trading License from CERC, enabling it to engage in power trading across India. SECI benefits from a robust financial position, with surplus funds available, including free cash balances and a payment security fund cushion. The allocation of encumbered cash balances for grants, subsidies, and viability gap funding ensures adequate liquidity. Moreover, SECI's healthy cash flow and debt-free status contribute to a strong financial profile, which is further reinforced by the letter of credit mechanism and tripartite agreement.

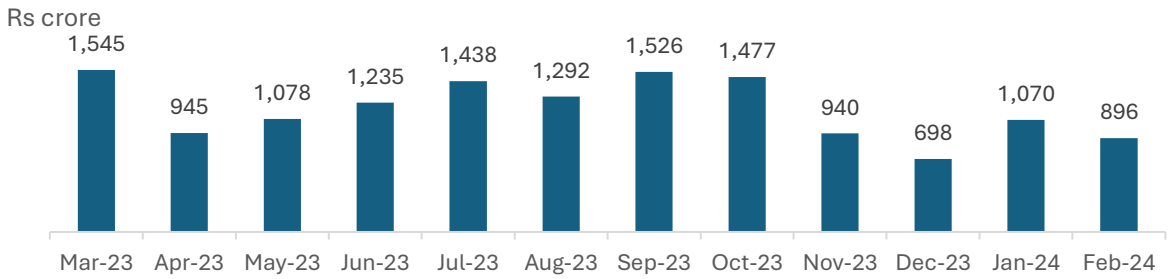
Figure 37: SECI credit rating history

Mar-18	Jun-19	Jan-20	Jan-21	Aug-21	Jul-22	Sep-23	Dec-23	May-24	May-25
AA+	AA+	AA+	AA+	AAA	AAA	AAA	AAA	AAA	AAA
ICRA	ICRA	ICRA	ICRA	ICRA	ICRA	ICRA	ICRA	ICRA	ICRA

Source: Crisil Intelligence

SECI is one of the beneficiaries of the TPA (tripartite agreement) signed among the Central Government, the state governments and power developers.

Figure 38: Trend of SECI payments to power producers



Source: SECI

Policy initiatives taken by the government to boost wind capacity additions over the long-term

New tender opportunities, technology and exposure to central intermediaries are key drivers

1. Large scale allocations
   After the competitive bidding of 1 GW by SECI in February 2017, SECI further allocated ~15.1 GW (excluding cancelled contracts) over March 2017-March 2025 through wind-only tenders. MNRE has outlined plans to tender 10 GW of capacity each year, of which the majority portion should be expected from SECI/NTPC. This bodes well as central sector PPAs have lower counterparty risk, compared with PPAs directly with state discoms. The latter are known to delay payments to developers and have poor financial ratings, while SECI and NTPC are better rated and provide various payment security mechanisms (LCs, payment security fund and SECI being party to the tripartite agreement). SECI acts as the procurement intermediary between project developer and DISCOMs, offering payment security to developers SECI helps to aggregate bids through a transparent e-bidding process followed by an e-reverse auction, ensuring competitiveness in tariffs and encouraging innovation.

Table 10: SECI wind allocations since fiscal 2019

Fiscals	Standalone capacity allocation (MW)	Weighted average tariff (Rs per unit)	Hybrid capacity allocation (MW)	Weighted average tariff (Rs per unit)
FY19	4,400	2.67	840	2.68
FY20	920	2.82	1,800	3.64
FY21	1,200	2.78	2,370	2.69

FY22	1,200	2.69	3,700	2.92
FY23	2,600	2.82	1,170	2.53
FY24	1,865	3.48	2,580	4.34
FY25	100	3.81	2,630	4.15

Note: Hybrid capacities include plain hybrid, RTC, Peak Power Supply and FDRE. Excludes solar with storage hybrid.

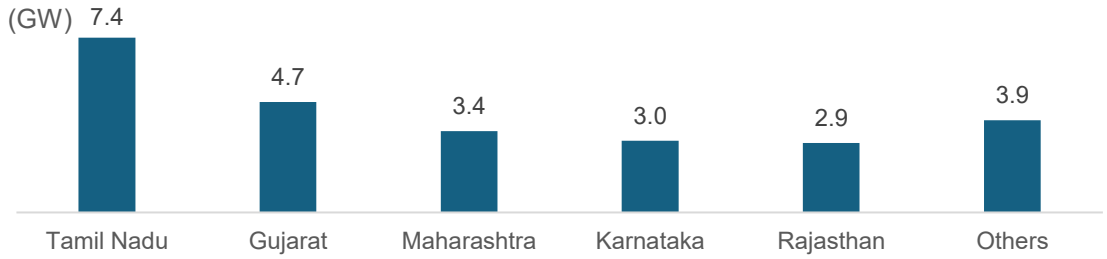
Source: SECI, Crisil Intelligence

Similarly, NTPC and SJVN have also allocated ~12 GW and ~10 GW of standalone wind and hybrid capacities till June 2025. The tariffs for standalone wind allocations across the two entities range Rs 2.8/unit to Rs 3.85/unit. Similarly, the tariffs for hybrid allocations range Rs 3.67/unit to Rs 4.06/unit.

2. Revision in RPO targets
    a) The Ministry of Power (MoP) has provided a new renewable purchase obligation (RPO) long-term trajectory for wind energy till fiscal 2030, which proposes increasing the target for wind from 0.81% in fiscal 2023 to 6.94% in fiscal 2030. The target, however, needs to be met from wind plants commissioned after March 31, 2022, thus requiring installation of new capacity.
    b) To meet the increased targets, states would have to procure more RE either via the REC route (which still leads to capacity additions) or competitively bid-out capacities. The waiver of ISTS charges by Central Electricity Regulation Commission (CERC) for all projects set up until June 2025 also enabled the states with low renewable potential to procure renewable power from more able states. However, RPO compliance is dependent on strict enforcement by regulatory authorities.
3. Improved technology
   Manufacturers are seen to innovate technology to solve the issue of land availability by manufacturing turbines with higher hub height to get better PLF. This can also be seen from the evolution of wind turbines at the global level. The world has evolved towards the solution of increasing hub heights and size of turbines, to maximise generation potential at a location. It started with 0.05 MW turbines at a hub height of 26 m in 1980 and gradually moved to 10 MW capacity turbines at a hub height of 245 m currently. India has followed similar suit by manufacturing turbine size of 0.05 MW capacity at 25-30 m hub height when it first started in 1986 and gradually followed the global trend where it recently developed turbine of 5.2 MW capacity at hub height above 150 m. Hence, India is developing its technology, and the turbine size and capacity is doubling almost every decade.
4. Repowering of wind assets: While the addition in the next five years is expected to be driven by an existing pipeline of over 20 GW on account of new tendering. Concentration in wind sites already impacts the sector, wherein lies an opportunity to improve the PLF by repowering old projects with latest technology which the Government is also focusing on. With legacy projects of almost 32 GW installed under the feed-in tariff regime which may have PPAs near expiry, almost 78% of such projects have turbine capacity of 2 MW or below and have the potential of repowering. The states which have the highest potential to go for repowering include Tamil Nadu and Gujarat

which account for 47% of such capacity. Hence, because of repowering of old plants, demand for better turbines will be boosted. Additionally, decommissioned wind turbines also have the potential to offer a good salvage value, particularly for steel components. This also provides economic benefits to the developer.

Figure 39: Wind re-powering potential



Source: MNRE

New business model structures (Hybrid, Peak Power, RTC, Firm Power)

Background of new business models in the renewable market

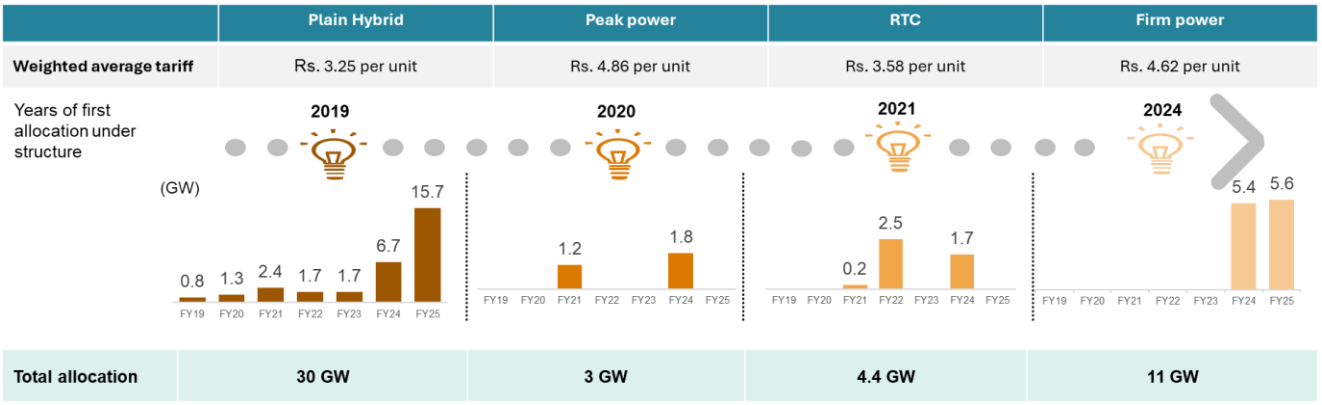
To improve the quality of power supplied to off-takers, nodal authorities are now issuing tenders for solar and wind projects with enhanced features. These tenders aim to address the mismatch between renewable energy supply and demand needs. A key characteristic of such tenders is combination of multiple renewable energy sources, aimed at increasing supply, with some tenders mandating power supply during peak hours and the use of storage to ensure a stable supply.

While there are multiple combinations now issued in the market some key distinctive features are as follows:

1. Hybrid tenders- Plain hybrid tenders require simple blending of solar and wind resources to achieve higher PLFs compared to standalone solar and wind plants and inject power for more hours during the day, compared to either source on standalone basis.
2. Peak Power tenders- Peak power tenders demand injection of renewable energy during peak periods of power demand during the day, typically two to four hours per day.
3. RTC tenders- Round the Clock (RTC) tenders are designed to enable injection of renewable power asking for higher availability from the power sources.
4. FDRE tenders- Firm and Dispatchable Renewable Energy (FDRE) tenders require availability of firm and dispatchable of renewable power with multiple requirements across availability, peak timing supply and / or following of a particular load profile.

These new project structures improve synergy of the renewable energy sources and offer a PLF of 30-40%, higher than that achieved in standalone solar and wind energy plants. Further, usage of storage also enables an efficient supply of generation.

Figure 40: Summary of new project structures



Note: Weighted average tariff is average across all allocations.

Source: Crisil Intelligence

Over fiscal 2019-2025, nearly 48.4 GW of new project structures have been allocated. Nearly 62% of the allocations are focused on plain hybrid. This is because to tackle the challenges of intermittencies and leverage synergies, mainstream hybrid allocations began in fiscal 2019. Hybrid tenders require simple blending of solar and wind resources to achieve higher PLFs compared to those achieved on standalone basis

Tariffs are higher in case of firm power allocations which began from fiscal 2024. Nearly 11 GW of firm power tenders have been allocated till fiscal 2025, accounting for 23% of the total new project structure allocations. While the demand fulfilment criteria vary even within the firm power model, the focus on meeting higher and consistent generation has remained constant. The SECI driven firm power tenders mandated demand fulfilment across months while non-SECI focused on selectively hour fulfilment ratio. This has resulted in a higher tariff range of Rs 4-5/kWh.

Typically, meeting the higher generation capacity requirements of these tenders will necessitate either the inclusion of storage components or the installation of scaled up plants. This results in high capital cost.

Projects installed under these structures, will look to maximising their PLFs, using a combination of solar, wind, storage or all three. Although solar, while cheap, has its own intermittency issues. Incorporation of wind or storage component can help counter some of that, by providing generation during non-solar hours. Developers could prefer wind or storage component when looking to mitigate solar intermittency.

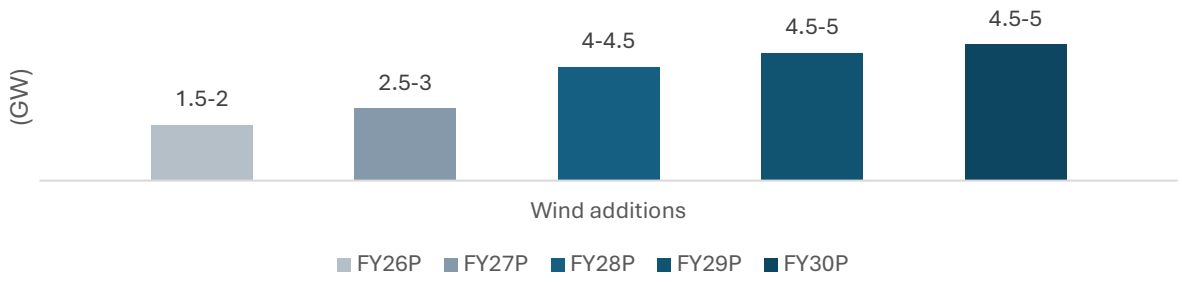
The successful deployment of these models in the future offers a promising outlook. Moreover, advancements in technology, particularly in storage, are likely to reduce costs even further in the long run, making implementation more viable.

Installation under new business models to gain traction in next five years

The sector is poised to witness a growth of capacity addition under new business models, including hybrid, RTC, peak power, and firm power. Crisil Intelligence estimates 18-19 GW additions under these new models over the next five years, from fiscal 2026 to fiscal 2030.The growth is also expected to be supported by various state government policies in this space.

For example, Gujarat state government has introduced a policy for allotting government waste/non-hazardous land for the development of Renewable Energy (RE) Parks, with the goal of setting up wind parks and wind-solar hybrid parks. The policy, which is active from 2019 to 2029, offers incentives for a period of 40 years, including 10 years for development and 30 years for operation. The policy allows for the development of parks with a capacity of 1,000 MW or more, with a total area sanctioned for 30,000 MW of renewable energy.

Figure 41: Wind capacity additions under new business model



Source: Crisil Intelligence

Renewable energy tariff outlook

Solar energy

Solar power prices are majorly influenced by the price of solar modules. Solar tariffs saw a rapid decline over fiscals 2016-2020, majorly due to declining module prices. Modules account for 50-55% of the capital cost of solar energy projects and these module prices are impacted by the commodities used to manufacture them i.e. polysilicon. Polysilicon prices had increased from approximately reached 38 USD/kg in August 2022 due to shortage of raw materials. However, since commissioning of polysilicon capacities in 2023 in China, polysilicon prices have dropped to 4 USD/kg in June 2025 due to an oversupply in the global market. Mono-crystalline module prices, declined significantly to USD 0.09/ Wp in June 2025 from USD 0.28 / Wp in August 2022, due to high inventory levels. Falling component prices and easing supply chain pressure has resulted in falling capital costs to Rs 32-37 million per MW. The solar tariffs have also fallen in line from Rs 2.7 / unit in fiscal 2023 to Rs 2.6 / unit in fiscal 2025. The government also levied of BCD and the ALMM policy mandate on imported produce. Currently, most parties in the ALMM are Indian manufacturers. Hence, after the imposition of ALMM, developers were compelled to procure domestically produced solar modules, which are costlier than their global counterparts. Even during the abeyance period of ALMM, the cost of solar module imports was high due to 40% BCD. Even though prices of solar cells and modules fluctuate significantly, they are currently lower in China than in India. Currently, domestic manufacturers use imported cells for solar module manufacturing. However, the government has proposed the imposition of ALMM on solar cells from April 2026, which means the prices of domestic modules are expected to be higher than those using imported cells. However, with significant cell capacity addition expected by fiscal 2027-28 the domestic module prices would remain below Rs 3.0 / unit. However, global supply chain scenarios, technology advancements (introduction of TopCon, HJT cells with high efficiency), domestic manufacturing capacity addition, infrastructure issues, land acquisition challenges, prices of commodities would be the

key monitorables over the medium term. The US investigated claims of involvement of forced labour in the production of China's Xinjiang province. It accounts for nearly 30-40% of global polysilicon production. It resulted in the US restricting imports from China's Xinjiang province over forced labour concerns and also forming strict traceability norms.

WSH projects

WSH projects have garnered significant interest in recent years, primarily driven by the increasing demand for reliable green power from both corporate consumers and discoms. MNRE also notified the national Wind-Solar Hybrid Policy in 2018 with an aim to reduce RE variability and improve grid stability. Additionally, various states including Gujarat, Andhra Pradesh, and Rajasthan have formulated their own WSH policies. In August 2023, the MoP issued tariff based competitive bidding guidelines for procurement of power from grid connected wind-solar hybrid projects. These guidelines are applicable to all upcoming wind-solar hybrid power projects of 10 MW and above capacity for intra-state transmission, and 50 MW and above for inter-state transmission, with or without energy storage. However, at least 33% of the total capacity must be from either wind or solar resources. The revised guidelines include revised bid capacity limits, revised timelines, restrictions on power procurement and penalties for delays. Some of the key advantages of hybrid projects include improved land and transmission infrastructure utilisation, reduced generation variability and complimentary generation profiles. Standalone solar and wind projects exhibit relatively low CUF. However, the amalgamation of these two technologies leads to a higher CUF, resulting in enhanced overall efficiency of the hybrid plant. Moreover, the cost of co-located solar and wind projects is lower compared to that of their respective standalone counterparts, making them economically attractive. Consequently, tenders conducted for such plain hybrid projects have yielded competitive tariffs, with prices ranging from Rs 3.25 / unit between fiscal 2019 to 2025. These factors collectively contribute to the growing allure and widespread adoption of WSH projects. Hybrid projects are well suited for a time-of-day tariff regime wherein during the morning/evening peak hours additional tariff is charged and during night (off peak) hours, rebate in tariff is provided. Since generation patterns of wind and solar are usually complementary, with wind power generation picking up after sunset and reaching peak generation late night. Thereby, the hybrid project can generate more revenue by selling power during evening peak hours when the tariff would be 10-20% higher than normal tariff.

Wind energy

Since wind prices are largely driven by commodity prices, they are expected to have an upward trajectory. Wind energy development cost is governed by Nacelle (34%) and BOS (21%) cost structure components. Steel is the major commodity with 31% share in overall wind energy development followed by cast iron (10%) and copper (4%). Renewable energy sources are expected to continue to be competitive compared to fossil fuels with improvement in technology, increased efficiency, and government support. The Crisil estimated capital cost increased to Rs 75-80 million/MW in fiscal 2023 over Rs 68-70 million in fiscal 2022 owing to rise in commodity prices, impacting project viability. However, with gradual cooling of global and domestic commodity prices in fiscal 2025, capital cost is estimated to have fallen to Rs 65-70 million/MW. Currently the two most prevalent choices of turbines available in the market are - 3 MW and 4 MW turbine with equipment and EPC. The prices are expected to continue

to stay elevated coupled with on-ground execution challenges. However, key commodity prices are expected to stabilise. The availability of type I wind sites in suitable locations is a cause for concern. There are other sites across states that would also be suitable for wind projects; however, they may be of lower wind density (Type 2 and 3 wind sites), may not have adequate linked grid infrastructure, or may have a paucity of contiguous land parcels. But due to lower availability of Type I wind sites in preferred locations along with congested transmission infrastructure has forced developers to move to type II wind sites. To avoid lower CUF at these sites developers are opting for high hub height wind turbines. Hence going forward, due to such reasons, the wind tariffs are expected to be in the range of Rs 3.6 – 3.9/unit to factor in the added execution challenges.

Outlook on cost of generation of multiple RE source vs cost of delivery

While the tariffs for ISTS connected plain vanilla solar and wind projects were observed between Rs 2.6/ unit and Rs 3.8/unit in fiscal 2025, the tariffs for plain WSH projects were in the range of Rs 3.2-3.6/unit. The weighted average tariffs for new age hybrid forms such as RTC, PPS and FDRE range between Rs 3.5-4.9/unit. Tariffs in Rajasthan, Maharashtra, Gujarat, Tamil Nadu and Karnataka are marginally lower than in other states due to availability of resources. The average CUF of solar projects can reach 25% or higher and for wind it could go upto 40% or higher in these regions.

O&M For wind sector in India

Evolution of O&M services in India

The LCOE of wind energy is significantly impacted by operations and maintenance (O&M) costs, prompting renewable energy producers to implement strategies to reduce these expenses and enhance service reliability. The O&M costs encompass five key categories: insurance, routine maintenance, repairs, spare parts, and administration, which tend to increase over time. However, advancements in technology have led to the development of approaches to mitigate these costs.

Initially, the industry relied on reactive maintenance, which often resulted in downtime and costly overhauls due to late fault detection. This approach led to higher service costs compared to early detection and repair. As the lifespan of generation plants increases, the cost of major repairs also escalates. In response, O&M service providers now offer solutions that minimize major repairs and replacements by adopting predictive maintenance techniques. Predictive maintenance involves collecting real-time performance data to monitor the health of the unit, resulting in a significant reduction in maintenance costs - a 65-70% decrease for onshore wind between 2010 and 2020, according to the International Renewable Energy Agency (IRENA).

Key components of wind turbine that require service include:

- Hydraulic Pitch
- Transformer
- Generators
- Gearbox
- Blades

- Grease oil and Lubricating Oil
- Electrical components
- Contactor/ Circuit Breaker/Relay
- Controls
- Safety
- Sensors
- Pumps/Motors
- Hub
- Heaters/ Coolers
- Yaw System
- Foundation/Tower/Mast
- Power Supply/Converter
- Services

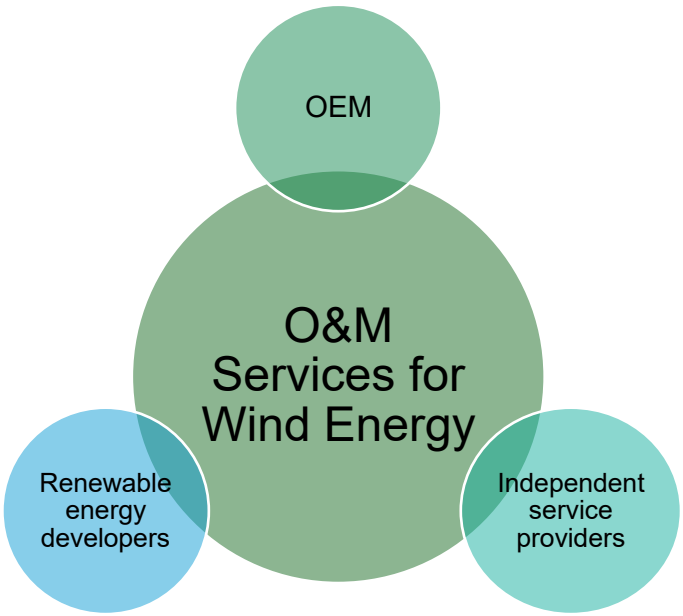
Wind O&M services value chain and active players

O&M value chain for wind plants

The wind O&M value chain encompasses a series of critical steps, including lifetime assessment, mechanical testing, inspection, and maintenance. Initially, the turbine's design and development phase involve assessing the harsh environmental conditions it will face, ensuring compliance, safety, and rigorous testing and validation. Advanced mechanical testing and scanning technologies can streamline quality control processes, reduce production costs, and expedite inspections. At the end of the turbine's lifespan, responsible decommissioning and disposal are crucial, with careful dismantling and redistribution of materials enabling the reuse of decommissioned turbines. To ensure long-term success, a proactive approach to maintenance and inspection is essential, involving preventive maintenance, failure analysis, and minimizing downtime to optimize overall performance.

Types of players engaged in wind O&M

Figure 42: Value chain for O&M services



Source: Crisil Intelligence

1. OEMs- Typically O&M services for wind turbine generation (WTG) units are procured alongside the equipment itself, with contracts usually spanning 5 to 10 years with some offering 2 years of free O&M under warranty as part of comprehensive annual maintenance packages. Original Equipment Manufacturers (OEMs) are the primary providers of these services, offering guarantees, preventive maintenance, and corrective maintenance that can be extended beyond the initial contract period. Globally, OEMs are the preferred choice for O&M services (especially for WTGs) due to the convenience of sourcing spare parts or replacement equipment directly from them, which is often easier than dealing with third-party providers.
2. In-house capabilities- To optimise equipment performance, some large renewable energy developers have established in-house O&M capabilities, enabling them to directly manage the upkeep of their installed machinery. By setting up their own O&M units, these developers can exert greater control over operations, minimizing the risk of prolonged downtime and shutdowns. Several major renewable energy players have already begun to maintain some of their capacity in-house, leveraging the benefits of internalized O&M expertise. These renewable players extend their in-house capabilities to external parties also.
3. Independent service providers- O&M services are also offered by third-party service providers. This is usually taken at the time of warranty expiration of the Annual Maintenance Contracts (AMC) with the OEM or when the OEMs are not preferred with the equipment acquisition due to financial constraints.

India is rapidly emerging as a global leader in the renewable energy sector, with wind power playing a pivotal role in this transformation. As of June 2025, the country has already installed

~52 GW of wind energy capacity, and the growing fleet of aging wind turbines may present a challenge in terms of maintenance and operation. When turbines are near the end of their warranty periods, there is a rising demand for high-quality, affordable maintenance services, creating a lucrative opportunity for Independent Service Providers (ISPs).

ISPs are specialised companies that offer maintenance and repair services for wind turbines independently of the original equipment manufacturers (OEMs). Typically, some OEMs handle maintenance and servicing during the initial years of a wind turbine's life, but once the warranty expires, usually after 5-10 years, wind farm owners may seek flexible and cost-effective servicing options. This is where ISPs can provide competitive and technically efficient solutions, leveraging their expertise to optimize turbine performance and reduce downtime.

In India, several key players are actively operating in the ISP space, including Inox Green Energy Services, which manages 3.5 GW of wind assets and achieved a machine availability of 96.3% in fiscal 2025. Another player is Suzlon Services, a division of Suzlon Energy, which had an installed base of over 15 GW as of March 2025 and acquired Renom Energy Services, which had an asset under management of approximately 3 GW as of March 2025.

The growth of ISPs in India is driven by several key trends, including the aging of the country's wind turbine fleet, which requires ongoing maintenance beyond the OEM warranty period. The Indian government's initiatives to encourage repowering and replace outdated turbines with newer, more efficient models also present opportunities for ISPs with technical expertise. Furthermore, the adoption of new technologies, such as drones for inspections, artificial intelligence, and machine learning for predictive maintenance, and remote monitoring systems, is transforming the way turbines are maintained, enabling ISPs to identify faults before they occur, reduce costs, and improve overall energy output.

Another significant development is the trend of large renewable energy developers building their own in-house operations and maintenance teams. While this may reduce direct business for some ISPs, it also creates opportunities for collaboration, training, and support services. These in-house teams may partner with ISPs for specialized work, spare parts, and remote diagnostics, fostering a collaborative ecosystem.

Despite their rapid growth, ISPs in India also face several challenges, including a shortage of skilled manpower, particularly in remote locations where wind farms are typically situated. Environmental conditions, such as extreme heat, dust, and wind in regions like Rajasthan and Gujarat, also pose significant challenges, leading to faster wear and tearing on turbines. Delays in spare part supply, especially for imported components, can result in extended turbine downtime and higher costs for wind farm owners.

Looking ahead, the future of ISPs in India appears promising, with the country's installed wind energy capacity expected to reach 70-80 GW by fiscal 2030, according to Crisil Intelligence’s estimates. As some of the existing turbines are near the end of OEM warranties, there will be a demand for independent maintenance services. The introduction of new, high-capacity turbines will also create a new segment of high-tech servicing needs, including drone inspections, autonomous maintenance systems, and remote diagnostics. ISPs that invest in advanced technology, skilled manpower, and spare part localization will be well-positioned to capitalize on these opportunities. Ultimately, Independent Service Providers are poised to play

a vital role in India's wind energy journey, ensuring performance, reliability, and cost efficiency as the sector matures and scales. Companies that adapt quickly, build strong capabilities, and deliver consistent results will shape the next chapter of wind energy operations in India, driving growth and innovation in the renewable energy sector.

While wind turbines are often the focal point of attention, the Balance of Plant (BOP) infrastructure plays a crucial role in ensuring that turbine-generated electricity is transmitted to the grid safely and efficiently. In the Indian context, BOP encompasses all essential components of a wind project, excluding the turbine itself, including civil infrastructure, electrical systems, mechanical erection tools, grid interconnections, and digital control systems.

BOP infrastructure accounts for 20-30% of the total cost of a wind energy project, making it a significant component of the overall project expenditure. Key elements of BOP infrastructure include land, right of way, feeder, crane pad, hard stands, access roads, turbine foundations, substations, transformers, internal cabling, high-voltage transmission lines, switchgear, SCADA and automation systems, earthing and lightning protection, and remote operations systems. These systems work in tandem to enable real-time monitoring, protection, and maintenance of the wind farm, supporting both onshore and offshore projects.

The expansion of hybrid (wind-solar) projects and upcoming offshore developments, such as the 4 GW Tamil Nadu tender, have increased the demand for high-quality, scalable BOP solutions. These advanced projects require sophisticated civil and grid designs, more complex SCADA systems, and integration with transmission networks under the Green Energy Corridor.

BOP works include civil, electrical, and mechanical components. Civil BOP works encompass access road construction, turbine pad preparation, and the building of control rooms and site offices. Electrical works range from medium-voltage cabling to the installation of substations, transformers, and interconnection with the central grid. Mechanical erection includes the use of high-capacity cranes, torquing tools, and laser alignment systems for precise installation.

Several Indian companies, such as KP Energy Ltd, Powerica Ltd, RS Windtech, and Windapex Energy, WindPlus, Kshema Power also deliver turnkey BOP services.

BOP work is concentrated in India's high-wind states, including Gujarat (Bhuj, Kutch, Dwarka), Tamil Nadu (Tirunelveli, Coimbatore), Maharashtra (Satara, Beed), and Rajasthan (Jaisalmer), with emerging projects in Andhra Pradesh and Karnataka. Gujarat and Tamil Nadu, with their vast renewable energy parks and robust wind corridors, are particularly active markets for BOP contractors.

Costs vary depending on project size, terrain, and complexity. Transmission infrastructure (switchyards and lines) adds another 20% to 25%, with SCADA and automation systems contributing around 10%. Transportation, erection tools, and workforce costs round out the rest.

The market dynamics are rapidly evolving, with India focusing on localisation of critical components under the "Make in India" initiative, thereby reducing reliance on imported transformers, protection systems, and cabling. Government-backed tenders now mandate hybrid and storage-ready projects, driving BOP diversification. The push toward digitized

operations have made SCADA, remote monitoring, and predictive maintenance integral parts of BOP contracts.

Despite growth, the BOP sector faces several challenges, including grid connectivity delays, land acquisition bottlenecks, terrain-based construction risks, and high capital costs. However, with the Ministry of New and Renewable Energy (MNRE) aiming to auction at least 10 GW of wind power annually through fiscal 2028, the sector presents significant opportunities. Modern trends like modular precast foundations, containerized substations, and offshore BOP adaptations are redefining how wind energy infrastructure is planned and executed.

The combination of government support, technological advancements, localized supply chains, and digital O&M integration ensures that India's BOP ecosystem will not only support domestic wind growth but may also serve emerging markets. In this landscape, BOP is no longer just supportive—it is strategic, driving performance, scalability, and sustainability for the future of India's wind energy mission.

Multi Model Spares

India's wind energy sector, with ~52 GW of installed capacity as of June 2025, is rapidly maturing, and with it, an opportunity in the multi-model spares business has emerged. As the turbine fleet ages, particularly in states like Tamil Nadu, Gujarat, and Maharashtra, the demand for compatible, cost-effective spare parts across different turbine models is growing sharply. This shift is giving rise to an aftermarket ecosystem that caters to diverse turbine platforms, some of which are no longer supported directly by their OEMs.

The multi-model spares business involves the supply, repair, refurbishment, and replacement of critical components such as gearboxes, generators, blades, control panels, hydraulic pitch systems, yaw motors, and SCADA modules across various wind turbine models. With wind farms operating on legacy turbines, which are either obsolete or have limited OEM service availability, independent players can step in to meet the demand. These multi-model spares companies offer spare parts not just for one manufacturer but for multiple turbine types, often across a wide range of vintages and capacities.

The demand surge is driven by several key factors:

1. Aging Turbine Fleet: Nearly 21 GW of India's wind fleet is at least 10 years old, creating an addressable market for third-party spares and repairs.

2. Shift to Flexible Service Models: The market is witnessing a shift from traditional OEM-bound service models to flexible and cost-efficient operations and maintenance frameworks, where independent service providers and spare part vendors offer tailored solutions to wind asset owners.

3. Government Policy: Government policy, including Make in India and localization incentives, encourages domestic production of key components like bearings, electronic boards, slip rings, and brake systems, reducing dependency on imports, shortening lead times, and improving affordability for wind farm operators.

Several companies, such as NUTECH Wind Parts, Spare in Motion, Wind Cluster of Denmark, WECS Renewables, Mija Wind Power – Denmark, Wind Sourcing - German, Pearce

Renewables - United States, and Powerica, operate through a wide network of component suppliers and workshops in Europe & India, manufacturing alternators compatible with multiple wind platforms.

India's spares manufacturing clusters in Coimbatore, Pune, Ahmedabad, and Noida are becoming vital hubs, supporting wind farm operators. With OEMs focused on newer turbine models, these repair shops and independent vendors may provide a crucial lifeline for older wind farms that still have years of productive life left.

Export of multi-model spares, particularly to countries using similar first-generation turbines, has become a secondary revenue stream for many Indian firms.

Market dynamics are also evolving with technology. Predictive maintenance, condition monitoring, and SCADA integration are transforming the way spare parts are used and managed. Wind farm operators increasingly rely on AI-driven analytics to identify component wear before failure, allowing service providers to supply or repair specific parts just in time.

However, the sector is not without challenges. Maintaining quality across multiple turbine models demands high levels of engineering expertise and testing capability. Intellectual property restrictions, lack of access to proprietary control software, and rising cases of counterfeit parts present additional risks. Moreover, transport and logistics bottlenecks for large components such as blades or hubs add cost and complexity, especially in remote wind farm locations.

Despite these challenges, India's multi-model wind spares business presents opportunities. With ongoing repowering initiatives, hybrid projects, and offshore wind on the horizon, the need for flexible, compatible, and localized spare part solutions will only increase. Firms that invest in localized production, responsive supply chains, skilled technical staff, and digital integration will be best positioned to serve this evolving market. As wind energy transitions from growth to optimization, the multi-model spares business will form a critical backbone of India's long-term renewable energy success.

Review of wind O&M services market

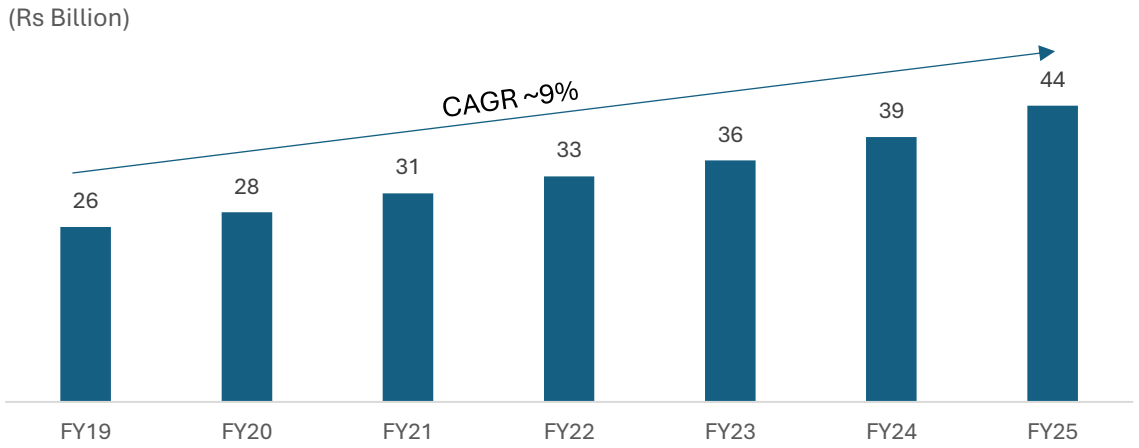
O&M services for wind energy are dominated by the equipment manufacturers in the country. Wind plant O&M costs could vary depending on the scope of the contract. The type of services offered as a part of O&M contracts include:

1. Supply of equipment
    - Large equipment supply
    - Sundry or small equipment supply
    - Consumables
2. Repair services
    - Regular repair and maintenance
    - Major repair or overhaul
    - Equipment replacement

The wind energy O&M market grew at a healthy CAGR of ~9% between fiscal 2019-2025, with installed base reaching from 36 GW to 50 GW over the same period. This has also positively

impacted the demand of O&M services which grew from ~Rs 26 billion in fiscal 2019 to ~Rs 44 billion in fiscal 2025.

Figure 43: Wind O&M growth between fiscal 2019-2025

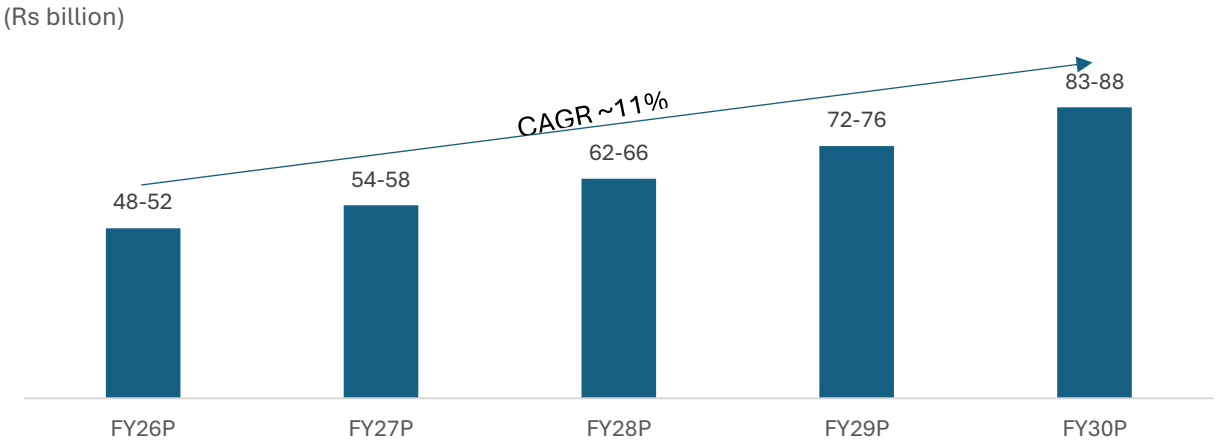


Note: Capacity addition from a particular year have been considered for O&M in the next year, e.g. wind capacity due for service in fiscal year 2019 would be installed base of fiscal 2018, while capacity added in fiscal year 2019 would become due for service in fiscal year 2020.

Source: Crisil Intelligence

Outlook of wind O&M service market

Figure 44: Wind O&M market size growth between fiscal 2026-2030



Note: Capacity addition from a particular year have been considered for O&M in the next year, e.g. wind capacity due for service in fiscal year 2026 would be installed base of fiscal 2025, while capacity added in fiscal year 2026 would become due for service in fiscal year 2027.

Source: Crisil Intelligence

Crisil Intelligence expects the wind capacity addition to be in the range of 25-27 GW between fiscals 2026-2030. The growth will be driven by hybrid capacity allocation along with existing standalone wind pipeline. As a result of this, the demand for O&M services is expected to be in the range of Rs 83-88 billion in fiscal 2030, growing at a CAGR of ~11% between fiscals 2026-2030.

Key technological advancements in O&M

Predictive vs reactive maintenance

Critical components of wind turbines, such as nacelles, turbines, generators, hydraulics, and electronics, require continuous monitoring to ensure seamless operation. Historically,

maintenance was only performed when equipment failed or showed signs of operational issues, resulting in prolonged shutdowns and reduced generator availability. In contrast, predictive maintenance uses historical data to forecast component failures before they occur, addressing the drawbacks of reactive maintenance. By adopting predictive maintenance, wind energy operators can reduce operational costs by minimizing equipment wear and tear, leading to a significant decrease in replacements and major repairs over the years.

However, relying solely on historical data can lead to unnecessary maintenance costs, as some assets may be flagged for maintenance despite being in good working condition. To mitigate this, an additional layer of technological intervention is needed to analyse, prioritize, and segregate maintenance activities, thereby minimizing unnecessary expenses. Artificial intelligence (AI) and the Internet of Things (IoT) can play a crucial role in achieving this, particularly in large power plants with geographically dispersed assets. For instance, AI-powered predictive maintenance in solar parks can result in substantial savings on inspection and maintenance planning, while also facilitating capacity planning and expansion. Similarly, in wind energy, AI can forecast gearbox issues using vibration and temperature patterns and therefore predict the maintenance schedule in advance leading to lesser probability of turbine getting damaged. Furthermore, in distribution networks, precise asset mapping enables accurate identification and location of assets, streamlining maintenance and consumer addition processes.

Condition monitoring

Condition monitoring is a crucial component of predictive maintenance, enabling real-time monitoring of turbine and electrical system health. By predicting potential maintenance issues, site operators can schedule repairs and replacements only when necessary, avoiding unnecessary and costly up-tower maintenance. The primary goal of condition monitoring is to extend the lifespan of components by continuously tracking their health and setting strict maintenance thresholds. Although damage progression can be unpredictable, posing a risk of further damage to other drivetrain components, the system can provide valuable insights into failure rates for up to 20 years, along with predictive simulations. This enables operators to reduce energy costs significantly by minimizing major replacements and optimizing maintenance activities.

Impact of technology implementation

The wind energy sector is witnessing a rapid evolution of technology-driven solutions, with the adoption of AI-powered predictive analytics being a notable example. These solutions can analyse vast amounts of real-time operational data, detect underperformance, and identify potential failures using machine learning algorithms. One of the most advanced technological implementations in the industry is the digital twin, a virtual replica of a physical asset that enables remote interaction and monitoring by trained professionals. By leveraging digital twins, engineers can diagnose and troubleshoot issues remotely, reducing the need for on-site personnel and minimizing effort. Additionally, emerging applications such as demand response management, hybrid energy storage systems, and virtual power plants are being explored in the clean energy sector, driven by the integration of new technologies. The application of machine learning and artificial intelligence can also uncover hidden patterns, predict faults,

and highlight critical variables that might otherwise go unnoticed, further optimizing the performance and efficiency of wind energy systems.

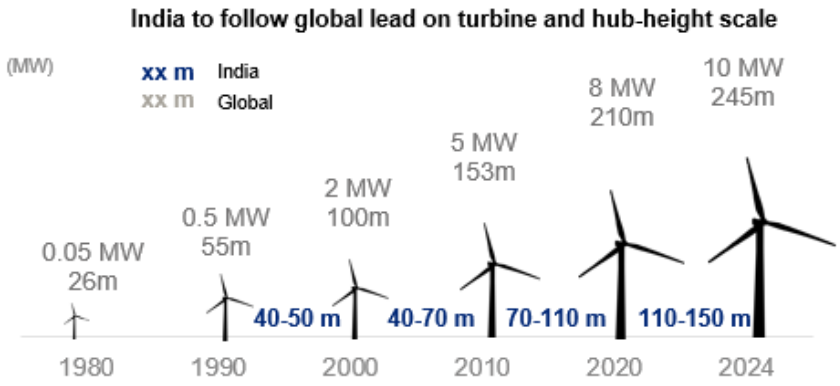
Challenges

1. Dependence on OEMs- In India, the O&M service space is dominated by the OEM players resulting in delays in accessing valuable data. This, along with spare parts unavailability, impacts power generation and revenues for plant owners. Some of the players have also seen a few cases of financial trouble in the past on the OEM side. Thus, the industry is leaning towards adoption of technologies to de-risk the operations. Further, the availability of spare parts is very specific to OEMs. There is also the issue of forecasting and scheduling resulting in the additional deviation settlement charges to be borne by the generator itself in case of unavailability of the system.

   Moreover, countries leading in the wind energy race such as US have a very buoyant service market with a lot of independent service providers providing services in addition to OEMs. This leads to higher competition among the service providers. gives greater visibility, saves resources, and improves the accuracy of prediction. Therefore, for third-party service providers (ISP) and Renewable Energy Developers (RED) in India, the cost of O&M services is expected to remain high until they reach economies of scale and have better/efficient spare part availability.

2. Slow adoption of new technologies as compared to USA, China and Europe- The Indian wind energy sector is hindered by the slow adoption of cutting-edge technologies like Artificial Intelligence (AI) and Machine Learning (ML), which limits its ability to capitalize on innovative solutions. However, this could change as ISPs and major developers increasingly enter the O&M space, going beyond mere performance monitoring of machines. Currently, the standard practices in the country's wind capacities, such as SCADA, are not as advanced as AI and ML, and therefore require upgrading to minimize the risk of equipment failure. The implementation of AI and ML is likely to gain momentum, enabling the sector to reap the benefits of these innovations and improve overall efficiency. Hence, we see that India is developing its technology, and the turbine size and capacity is doubling almost every decade. As the industry moves towards more advanced technologies, it is expected to reduce risk exposure and enhance the reliability of wind energy operations, ultimately contributing to the growth and development of the sector

Figure 45: Growth of turbines in India as compared to the world



Source: NIWE, GWEC, Crisil Intelligence

Threats and challenges

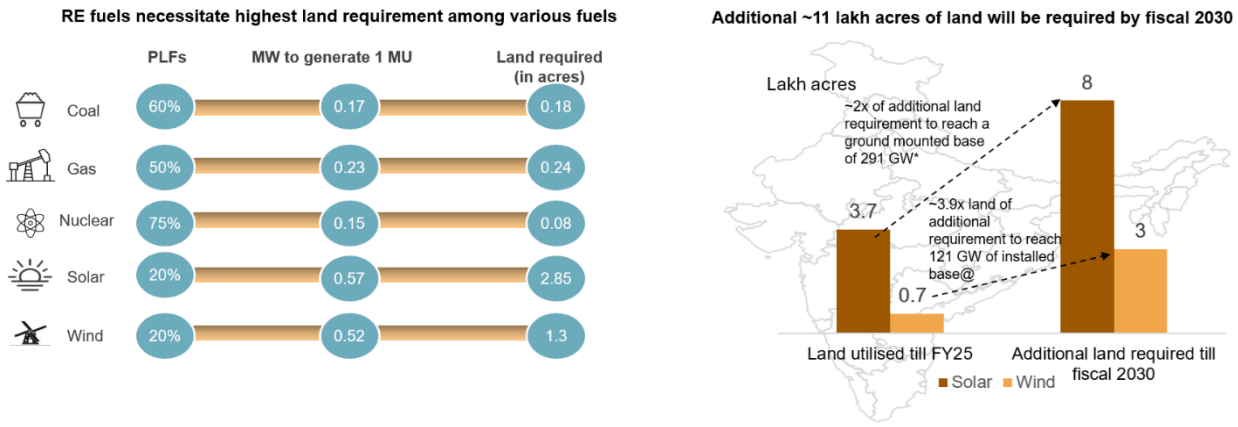
Policy risk

While any adverse shift in government policies, including reductions in incentives or changes in energy regulations, may impact revenue and profitability, the risk of a drastic regulatory overhaul remains low. This is supported by India's COP commitments, climate change goals, and continued government push for renewable energy. Notably, over the past five years, approximately 90 GW of RE capacity was added, compared to only ~18 GW of conventional capacity, indicating sustained policy support.

Land availability and geographical concentration

While 84% of wind capacity (fiscal 2025) is concentrated in Rajasthan, Gujarat, Maharashtra, Tamil Nadu and Karnataka owing to high wind speed. Land availability is one of the biggest concerns for RE because on an average, renewables require more land compared with fossils. The total land utilised for ground-mounted solar and wind projects was 4.5 lakh acres until fiscal 2025. As India moves towards achieving its 500 GW target by 2032, an additional 23 lakh acres of land parcel will be required.

Figure 46: Land availability a key monitorable for renewables



Land availability is one of the big concerns for renewable energy. On average, land requirement is the highest for renewable fuels compared to fossils. Solar energy requires a land parcel of 2.85 acres to generate 1 MU while wind requires 1.3 acres. This would necessitate an additional 11 lakh acre of land parcel by fiscal 2030 to achieve the government target

Source: Crisil Intelligence

Securing large, contiguous parcels of land remains a major challenge due to fragmented ownership and procedural delays. Multistakeholder involvement often slows down project timelines. While the 40 GW solar park scheme is a positive step, timely allocation and facilitation need to be ensured.

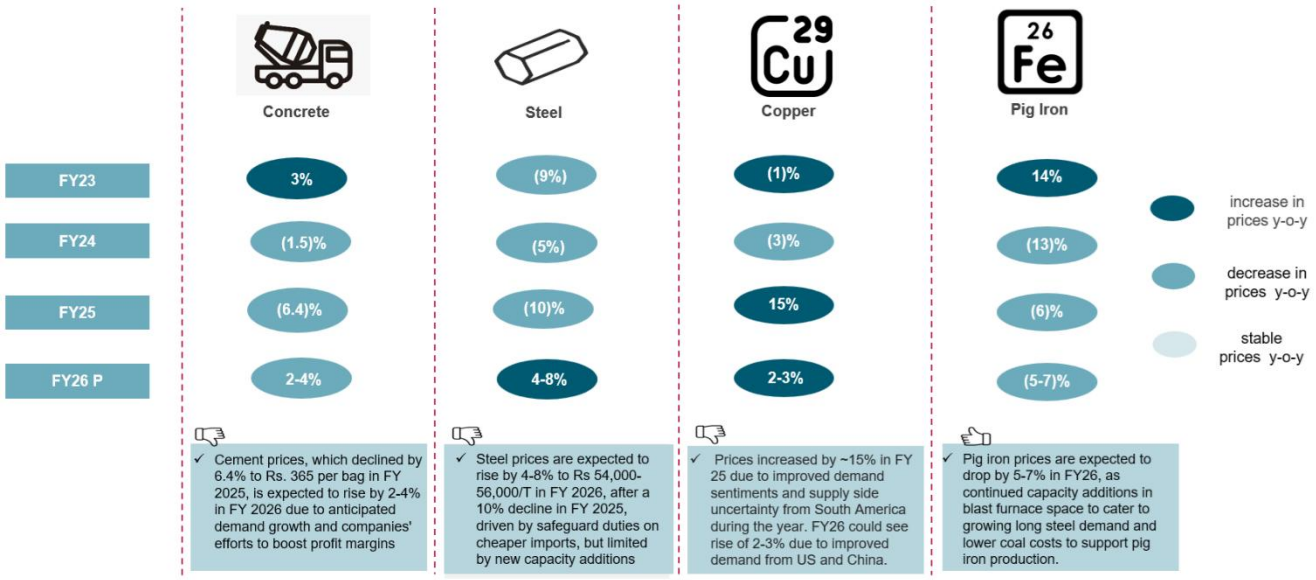
Capital cost volatility arising from input prices

Renewable projects are highly susceptible to global commodity prices. The variation in prices can substantially hamper returns when not hedged properly. Wind for example is highly susceptible to price changes for concrete and steel.

The main reason for the slowdown in wind capacity additions in the past fiscals was surging input prices, due to acceleration in commodity prices. A typical wind project prices fluctuate with fluctuation in prices for requires concrete, steel, copper and pig iron.

- A typical wind project requires ~300-500 MT/MW of concrete for setting the foundation of wind towers.
- Steel accounts for large portion of total turbine mass based on the technology employed.

Figure 47: Steel account for large portion of cost



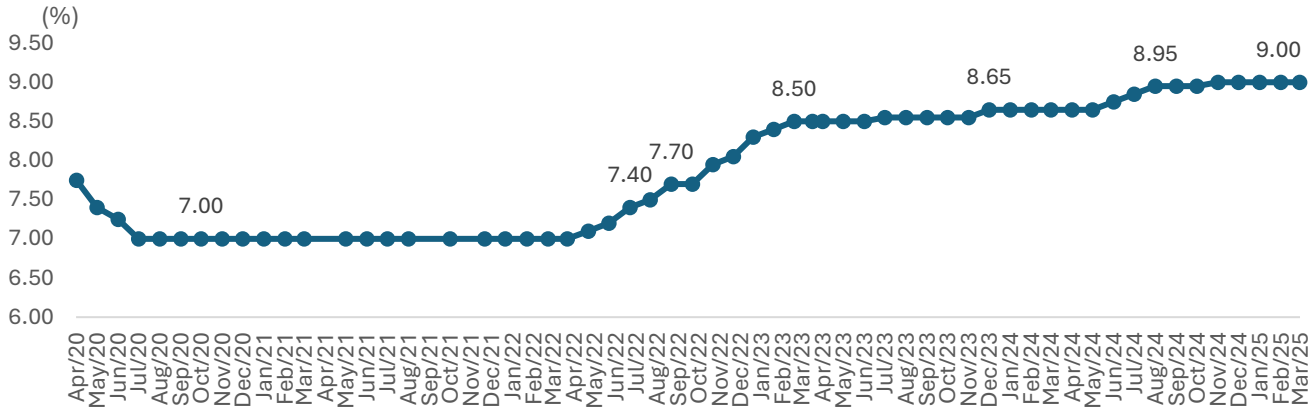
Note: Cement prices used as a substitute for concrete & price taken per 50kg bag, Steel prices refer to domestic steel HR IS2062 (2.5-8 mm) E-250 monthly average prices, copper prices are for copper cathode

Source: Crisil Intelligence

Availability of funds for projects

Given the capital-intensive nature of RE projects, cost of capital plays an important role. In the past, high domestic interest rates, lower re-payment tenure and inadequate and delayed capital subsidy increased the minimum tariffs required to achieve a healthy internal rate of return (IRR).

Figure 48: SBI MCLR continues to inch upwards



Source: SBI MCLR

The above graph shows the State Bank of India's (SBI) marginal cost lending rates (MCLR). Over fiscals 2019 and 2020, interest rates were higher due to several macro factors at play. However, with no changes in interest rate by RBI from the second quarter of fiscal 2021, the MCLR remained stable after a sharp decline. The low-interest rate regime reversed in fiscal 2023, due to a gradual increase in repo rates by RBI to increasingly tackle inflation. In fiscal 2024, the rates remained in the range of 8.5-8.65% with increase from 8.5% in November 2023 to 8.65% in December 2023. Rates rose to 8.85% in July and to 8.95% in September 2024. Further upwards revision was observed in November, rising to 9.0%, where it remains as of March 2025.

Traditionally, domestic lenders while keen to invest in clean energy, assess risks associated to the segment. Past incidents of renegotiation and delayed payments by counterparties had caused some concern among lenders. They also perceived risk due to the aggressive bidding seen previously. However, over the past two fiscals, with a push from the government to achieve nationwide clean energy targets and ESG-related targets for lenders themselves, traction has improved from domestic lenders, including PSUs, in funding to the segment.

In addition, even foreign fund raising has seen some impact with a rising interest rate regime limiting appetite for Indian green bonds at 4-6% coupon rates. This is also impacted by:

- A weaker rupee has also led to higher hedging costs adding cost pressure to any ECB or green bond issuance.
- Frequent policy changes and lack of clarity would also lead to hesitance among global investors to enter / fund the sector as previously. This is highly detrimental to the growth of the sector which requires significant equity over the coming years to continue supporting additions.

Renewable developers should ensure to access a broader spectrum of cheaper financing options in addition to prudent capital management to sustain over the long term. However, at present fund availability may be a concern for few projects where viability is sub-par or those facing project implementation.

Availability of transmission infrastructure

Large-scale, grid-connected renewable plants are usually located in far-flung areas devoid of transmission infrastructure. Thus, robust transmission planning to optimize costs, utilization levels and losses associated with transmission system, to transmit the power generated from the renewable plants to load centres (cities and industrial areas) is critical.

The industry had been raising concerns regarding connectivity for renewable projects. Taking the same into consideration, nodal agencies (PGCIL, SECI) have planned various schemes to alleviate grid congestion and improve connectivity to RE projects. Schemes such as Green Energy Corridor (GEC) and Renewable Energy Zones (REZ) were launched.

The GEC Phase-I was aimed at developing specific evacuation corridors for renewable energy in key renewable rich states. Government has planned to integrate renewable energy into the national grid by setting up inter-state and intra-state schemes for evacuation of power from wind and solar projects, termed as 'green energy corridors'. The interstate component of the scheme was completed in March 2020 while the intra-state level is near completion. A total of 9,135 ckm of transmission lines have been constructed under the intra state scheme as of June 2024 (as per last available information). While, the GEC Phase-II, approved in March 2022, aims to integrate ~19 GW of renewable energy.

However, grid stability and maintenance charges are going to be a key risk going forward for renewable energy projects. As of March 2025, total installed renewable energy capacity was ~172 GW (comprising solar, wind, bio energy and small hydro) out of total ~475 GW power generation capacity in India. However, based on the units supplied, renewable energy's share amounts to only ~15% of total power supplied in fiscal 2025. Its share is expected to rise to 25-30% in generation by fiscal 2030. This may result in grid instability due to variable nature of generation of power from renewable energy sources. Hence, renewable generation may have to be backed down to maintain grid stability.

To address the issue of grid variability, the government has started taking measures such as planning and deploying electricity generation reserves; augmenting transmission infrastructure; creating technical standards and regulations for renewable energy generators; introducing features such as low-voltage ride through (LVRT) and high-voltage ride through (HVRT); setting frequency thresholds for disconnection from the grid; and finalising regulations for active and reactive power generation. Further, the government is planning ancillary services to support electricity grids. These services, regulations and charges will be partly shared between generators as their direct costs and by consumers as pass-through costs.

Moreover, under/over injection of power beyond the limits of forecasted schedule will attract penalties, which will hike grid maintenance charges. Most states have released Forecasting and Scheduling Regulations. This adds to operating costs for developers.

CERC (Sharing of Inter-state transmission and losses) Regulations, 2020 allows waiver off inter- state transmission charges (ISTS charges) for renewable energy capacities installed by 30 June 2025. However, renewable capacities commissioned after 30 June 2025 will be subject to ISTS charges which might put them in a disadvantageous position with regards their participation through open access route. However, the treatment of ISTS charges (INR

0.40-0.60 per kwh at present) to be levied on power purchased through exchanges from projects commissioned post June 30, 2025, is not clear and guidelines from CERC will be a key monitorable.

Additionally, the state governments are also taking major steps to improve transmission infrastructure availability in India. For example, Gujarat Energy Transmission Corporation Limited (GETCO) has taken various proactive measures to boost renewable energy connectivity in the state. GETCO is first State Transmission Utility (STU) to install 220 kV ±125 MVAR STATCOM at its 220 kV Timbdi substation for quality and reliable power, introduced 765 kV system for bulk power transmission, deployed of the world's largest WAMS project in terms of PMUs reporting at a single control room and monitoring the population of transmission elements. In the coming years, GETCO has planned to invest Rs. 1 Lakh Crore up to fiscal 2030 to upgrade and expand the transmission infrastructure in Gujarat.

RPO Enforcement and Compliance

Compliance with Renewable Purchase Obligations (RPO) remains uneven across states, with limited enforcement for discoms, open access, and captive users. Uniform application of penalties and strict monitoring will be crucial for improving RPO compliance and ensuring a level playing field

Cost Volatility and EPC Margins

Renewable players are experiencing cost pressures due to fluctuations in module prices, commodity rates, exchange rates, and freight charges. These variables affect project costs and may compress EPC margins, especially when fixed-price contracts restrict cost pass-through to project SPVs.

Market Competition and External Factors

Intense competition, both from established and new players, poses challenges to market share and pricing. Additionally, external risks such as extreme weather events and climate change can disrupt project operations. Economic downturns may also reduce funding availability and increase the cost of capital, thereby slowing RE capacity expansion.

Competition of wind energy with other renewables

Renewables benefit from record-high crude oil and petroleum product prices in 2008, as well as continued advancements in wind turbine technology, which have driven down the cost per kilowatt hour of wind-generated power. However, a decline in global prices for oil, gas, coal, other petroleum products or solar modules could make alternative sources of energy more attractive and reduce demand for wind farms. In particular, the local manufacturing of solar modules on a large scale has driven down the cost of solar power, making it increasingly cost-competitive and sometimes preferred over wind

Operational constraints

As more turbines are installed close to each other, the wind flow reaching downstream turbines may be disrupted by upstream units, leading to what is known as the 'wake effect'. This effect results in turbulence and reduced wind speeds for turbines located behind others, which can cause a measurable decline in energy generation.

Module 5: Player profiles

Some of the key players operating in the renewable energy sector are NTPC Green Energy (5,902 MW operational solar and wind as of 2025), Adani Green Energy Limited (14,243 MW of contracted operational solar and wind as of fiscal 2025), Acme Solar Holding Limited (2,705 MW operational solar as of fiscal 2025). These players also have a sizeable quantum of capacity under consideration/development.

Table 11: Operational KPIs of key players in the industry

Operational KPIs	NTPC Green Energy Limited			NTPC RE Group^	Adani Green Energy Limited			Acme Solar Holdings Limited		
	FY25	FY24	FY23	FY23	FY25	FY24	FY23	FY25	FY24	FY23
Operational capacity (MW)	5,902	2,925	2,611	2,611	14,243	10,934	8,086	2,705	1,340	1,459
Contracted capacity (MW)	17,277	11,571	6,250	6,250	NA	11,019*	10,449*	4,265	4,030	1,900
Solar average CUF (%)	24%	24%	27%	23%	25%	25%	25%	26%	24%	22%
Wind average CUF (%)	21%	20%	16%	24%	27%	29%	25%	NA	NA	NA
Average plant availability (%)	NA	NA	NA	NA	NA	NA	NA	100%	99%	99%

Note:

1. Contracted capacity represents the sum of capacity where PPA has been signed, and the LOA has awarded but PPA has not signed. These projects are not operational.
2. *Adani Green Energy Limited's Contracted capacity is under execution contracted AC capacity. The CUF for solar and wind does not include hybrid capacities.
3. NA indicates lack of data availability in public domain.
4. ^ Based on Special Purpose Carved-out Combined Financial Statements for Fiscal 2023, which includes the carved-out business in respect of RE Assets (part of the standalone financial statements of NTPC Limited until February 28, 2023)

Source:

1. Adani Green Energy Limited's numbers have been sourced from company investor presentations.
2. ACME Solar Holdings Limited Q4 FY25 numbers are sourced from company investor presentations while FY24 and FY23 numbers are sourced from its DRHP
3. NTPC Green Energy Limited numbers are sourced from its Q4 FY25 investor presentations and DRHP

Table 12: Operational KPIs of Powerica Limited

Powerica – Operational KPIs	FY25	FY24	FY23
Operational capacity (MW)*	279.55	279.55	305.95
Contracted capacity (MW)**	100	0	0
Solar average CUF (%)	NA	NA	NA
Wind average CUF (%)	26.78%	28.36%	26.09%
Average plant availability (%)	98.30%	98.80%	98.68%

Note:

1. * Operational capacity for fiscal 2023 includes capacity of 26.4 MW pertaining to two wind power projects sold by the company during in fiscal 2024
2. ** Contracted capacity (MW) represents the aggregate megawatt rated capacity of wind power plants as of the reported date, for which the Power Purchase Agreements have been signed with customers but not yet operational.

Source: Company

Financial parameters

The following table summarises the financial profile of some of the large, listed entities in the renewable energy sector.

Table 13: Financial KPIs of key players in the industry

KPIs	NTPC Green Limited			NTPC RE Group	Acme Solar Holdings			Adani Green Energy Limited		
	FY25	FY24	FY23	FY23	FY25	FY24	FY23	FY25	FY24	FY23
Revenue from operations	2,210	1,963	170	1,450	1,405	1,319	1,295	11,212	9,220	7,776
Total income	2,466	2,038	171	1,458	1,575	1,466	1,361	12,422	10,521	8,617
EBITDA	1,916	1,744	151	1,310	1,235	1,089	1,173	9,321	7,607	4,990
EBITDA margin	86.69%	88.86%	89.21%	90.34%	87.92%	82.56%	90.55%	83.13%	82.51%	64.17%
PAT	474	343	171	456	251	698	-3.17	2,001	1,260	973
PAT margin	19.23%	16.83%	100.35%	31.32%	15.92%	47.59%	-0.23%	16.11%	11.98%	11.29%
Net debt to Equity	0.78	1.98	1.09	1.09	1.66	2.66	3.79	3.31	3.11	6.92
Net debt to EBITDA	7.55	7.07	35.31	4.08	6.08	6.34	6.24	8.02	7.14	10.19
Return on equity	3.83%	6.17%	NA	13.35%	7.07%	30.87%	-0.16%	10.00%	10.16%	19.53%
ROCE	5.22%	7.56%	NA	7.47%	10.23%	9.79%	8.24%	9.55%	10.84%	8.20%
Receivable days	85	131	700	82	99	116	197	50	53	104
Payable days	15	12	220	26	58	20	18	13	13	18
Inventory days	5	5	20	2	1	0	0	3	12	2

Note:

1. The financials of the above companies are considered on a consolidated basis
2. The fiscal 2024 and 2025 financials for NTPC Green Energy Limited are sourced from its BSE filings of “Results for the quarter and year ended 31.03.2025”. The financials for fiscal 2023 are sourced from its Red Herring Prospectus dated November 12, 2024
3. ^The restated consolidated financial information for fiscal 2023 for NTPC Green Energy Limited comprises operating result for 31 days from February 28, 2023, after transfer of the RE Assets and equity shareholding in NREL from NTPC Limited to NTPC Green Energy Limited and thus NTPC RE Group financials are also provided. The financials are not annualised for calculation. Refer to note 4.
4. * Based on Special Purpose Carved-out Combined Financial Statements for Fiscal 2023, which includes the carved-out business in respect of RE Assets (part of the standalone financial statements of NTPC Limited until February 28, 2023). The financials are not annualised for calculation
5. The fiscal 2024 and 2025 financials for Acme Solar Holding Limited are sourced from its BSE filings of “Financial results for the quarter and year ended March 31, 2025”. The financials for fiscal 2023 are sourced from its Red Herring Prospectus dated October 29, 2024
6. The fiscal 2024 and 2025 financials for Adani Green Energy Limited are sourced from its annual report for fiscal 2025. The financials for fiscal 2023 are sourced from its annual report for fiscal 2023
7. Revenue from operations = Revenue from operations for the year or period reported by the companies in the filings
8. Total income = Revenue from operations + Other income for the year or period
9. Earnings before Interest, Tax, Depreciation and Amortisation (EBITDA) = Profit before exceptional items and tax + Finance cost + Depreciation and amortisation - Other income for the year or period
10. EBITDA margin = EBITDA / Revenue from operations for the year or period

11. Profit after tax (PAT) = Profit after tax for the year or period
12. PAT margin = PAT / Total income for the year or period
13. Net debt = Long term borrowings + Short term borrowings - Cash and cash equivalent - Other bank balances
14. Equity = Total equity for the year or period
15. Net debt to Equity = Net debt / Equity
16. Net debt to EBITDA = Net debt / EBITDA for the year or period
17. Return on Equity = PAT / (Average of current fiscal year and previous fiscal year)
18. CY = Current fiscal year. PY = Previous fiscal year
19. Capital employed = ((CY Total equity + CY Long term borrowings + CY Short term borrowings + CY Deferred tax liabilities (net) – CY Cash and cash equivalents – CY Bank balances – CY current investments) + (PY Total equity + PY Long term borrowings + PY Short term borrowings + PY Deferred tax liabilities (net) – PY Cash and cash equivalents – PY Bank balances – PY current investments))/2
20. Return on Capital Employed = (Profit before exceptional items and tax + Finance cost) / Average Capital Employed of current fiscal year and previous fiscal year
21. Receivable days = Current trade receivables / Revenue from operations * 365
22. Payable days = Current trade payables / Revenue from operations * 365
23. Inventory days = Current inventory / Revenue from operations * 365
24. NA stands for ‘Not Available’ in the public domain

Source: Company filings, Crisil Intelligence

While the other companies are primarily focused on Independent Power Producer (IPP) activities, Powerica operates as both an IPP and as an Engineering, Procurement, and Construction (EPC) segment.

The company was one of the winners in SECI's 1,350 MW Wind Tranche XVI, winning a 50 MW wind energy project at a tariff of Rs 3.70 per unit. The tender included projects in Gujarat, Karnataka, and Rajasthan.

They also won a 50 MW wind power project in SECI's 500 MW auction ISTS wind power projects (Tranche-XVII), where they secured it at a tariff of Rs 3.81 per unit.

In all, the company has an under-construction IPP pipeline of 104 MW, comprising two projects, which will take the total generation capacity of 383.55 MW.

The weighted average PLF for the operational fleet is in the range of 26% to 28.5% yearly. The average plant availability of 98.60% to 98.84% between fiscal 2023 to 2025.

Powerica has a 586 MW wind Balance of Plant (BOP) pipeline under work in progress for other IPPs. Additionally, the company is developing land suitable for 50 MW and 150 MW solar projects at Khambaliya, Gujarat and Beed, Maharashtra respectively.

Furthermore, as part of its EPC activity, Powerica is developing a 7.2 km, 400 kV transmission line and a 220/400 kV substation for third-party clients.

The wind energy segment is expected to add 25-30 GW of additions between fiscal 2026-2030, which is ~2 times the additions between fiscal 2021-2025. As of June 2025, at least a quarter of the pipeline is expected to be in the southern and western regions, due to the presence of high tier-I sites. Powerica's major operations are also in the same regions.

Table 14: Financial KPIs of Powerica Limited

Financial KPIs	Units	Powerica Limited		
		FY25	FY24	FY23
Revenue from operations	Rs crore	2,653	2,210	2,378
Total income	Rs crore	2,711	2,357	2,422
Revenue from operations - Generator set business	Rs crore	2,255	1,907	1,969
Revenue from operations - wind power business	Rs crore	398	303	409
Generator set business - Percent of total revenues from operations	%	85.00%	86.30%	82.79%
Renewable business - Percent of total revenues from operations	%	15.00%	13.70%	17.21%
EBITDA	Rs crore	346	362	333
EBITDA from generator sets business*	Rs crore	188	245	205
EBITDA from wind power business*	Rs crore	164	143	164
EBITDA Margin	%	13.03%	16.40%	14.01%
PAT	Rs crore	176	226	106
PAT Margin	%	6.49%	9.59%	4.39%
Net debt to Equity	Times	0.24	0.16	0.31
Net debt to EBITDA	Times	0.75	0.40	0.74
Return on Equity	%	17.53%	26.50%	Refer to note 14
Return on Capital Employed	%	27.02%	43.47%	Refer to note 18
Receivable days	Days	55	53	40

Payable days	Days	36	50	36
Inventory days	Days	28	45	31

Note:

1. The financials are considered on a consolidated basis which includes the company's diesel generator (DG) set business vertical and are not solely corresponding to the renewable energy business.
2. *Information received from the company.
3. Revenue from operations = Revenue from operations for the year or period reported by the companies in the filings
4. Total income = Revenue from operations + Other income for the year or period
5. Earnings before Interest, Tax, Depreciation and Amortisation (EBITDA) = Profit before exceptional items and tax + Finance cost + Depreciation and amortisation - Other income for the year or period
6. EBITDA margin = EBITDA / Revenue from operations for the year or period
7. Profit after tax (PAT) = Profit after tax for the year or period
8. PAT margin = PAT / Total income for the year or period
9. Net debt = Long term borrowings + Short term borrowings - Cash and cash equivalent - Other bank balances
10. Equity = Total equity for the year or period
11. Net debt to Equity = Net debt / Equity
12. Net debt to EBITDA = Net debt / EBITDA for the year or period
13. Return on Equity = PAT / (Average of current fiscal year and previous fiscal year)
14. The return on equity for fiscal 2023 is not calculated as the closing total equity for fiscal 2022 is not available since the restated consolidated financial information has not been prepared
15. CY = Current fiscal year. PY = Previous fiscal year
16. Capital employed = ((CY Total equity + CY Long term borrowings + CY Short term borrowings + CY Deferred tax liabilities (net) – CY Cash and cash equivalents – CY Bank balances – CY current investments) + (PY Total equity + PY Long term borrowings + PY Short term borrowings + PY Deferred tax liabilities (net) – PY Cash and cash equivalents – PY Bank balances – PY current investments))/2
17. Return on Capital Employed = (Profit before exceptional items and tax + Finance cost) / Average Capital Employed of current fiscal year and previous fiscal year
18. The return on capital employed for fiscal 2023 is not calculated as the closing consolidated restated financial statements are not available for fiscal 2022
19. Receivable days = Current trade receivables / Revenue from operations * 365
20. Payable days = Current trade payables / Revenue from operations * 365
21. Inventory days = Current inventory / Revenue from operations * 365
22. NA stands for 'Not Available' in the public domain

Source: Company, Crisil Intelligence

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