Market Intelligence
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CRISIL
An S&P Global Company

NTPC Green Energy Limited

Strategic assessment of Indian power and renewable energy sector

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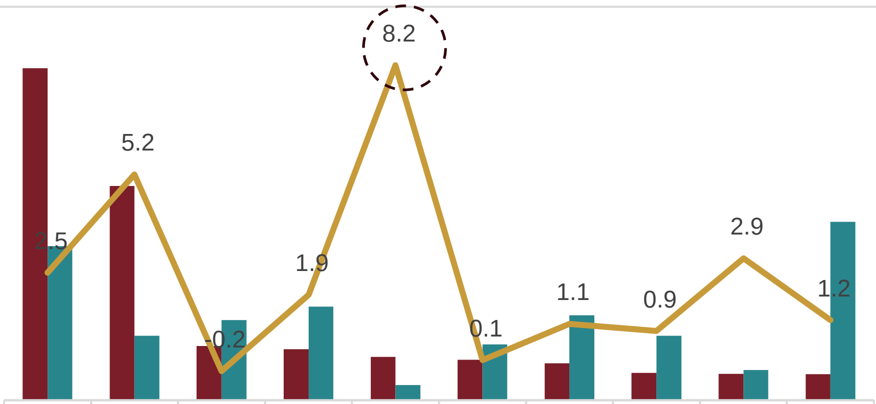
1 Macroeconomic overview

1.1 Economic indicators

India has become the fifth largest economy in the world in CY 2023, according to the International Monetary Fund's (IMF) World Economic Outlook (April 2024). As per IMF GDP Forecasts (July 2024), India's real gross domestic product (GDP) growth is estimated at 6.5% in 2025, the highest amongst the top 10 economies. Additionally, the World Bank has forecasted India's GDP to grow at 7% in fiscal 2025.

Figure 1: Comparison of India's economy with other major nations



	United States	China	Germany	Japan	India*	United Kingdom	France	Italy	Brazil	Canada
Nominal GDP (Tn USD) 2023	27.36	17.66	4.46	4.21	3.57	3.34	3.03	2.26	2.17	2.14
Per capita ele. consumption 2022 (MWh)	12.7	5.3	6.6	7.7	1.3	4.6	7	5.3	2.5	14.7
Real GDP Growth CY2023 (in %)	2.5	5.2	-0.2	1.9	8.2	0.1	1.1	0.9	2.9	1.2

**India Financial Year, Source: World Economic Outlook Database (April and July 2024) by IMF; IEA, CEA, CRISIL MI&A-Consulting*

In the last 10 years, Indian GDP has been growing consistently., Except for years affected by COVID-19, India's growth has been highest amongst the top 10 economies. With the receding risk of global recession, India has been identified as an economic growth center by various International Agencies as well as global rating firms.

Table 1: Historical growth of real GDP for major economies (figures in %)

Year	Brazil	Canada	China	France	Germany	India*	Italy	Japan	United Kingdom	United States
CY15	-3.5	0.7	7.0	1.1	1.5	8.0	0.8	1.6	2.2	2.9
CY16	-3.3	1.0	6.9	1.1	2.2	8.3	1.3	0.8	1.9	1.8
CY17	1.3	3.0	6.9	2.3	2.7	6.8	1.7	1.7	2.7	2.5
CY18	1.8	2.7	6.8	1.9	1.0	6.5	0.9	0.6	1.4	3.0
CY19	1.2	1.9	6.0	1.8	1.1	3.9	0.5	-0.4	1.6	2.5
CY20	-3.3	-5.0	2.2	-7.5	-3.8	-5.8	-9.0	-4.1	-10.4	-2.2
CY21	4.8	5.3	8.5	6.3	3.2	9.7	8.3	2.6	8.7	5.8
CY22	3.0	3.8	3.0	2.5	1.8	7.0	4.0	1.0	4.3	1.9
CY23	2.9	1.2	5.2	1.1	-0.2	8.2	0.9	1.9	0.1	2.5
CY24	2.1	1.3	5.0	0.9	0.2	7.0	0.7	0.7	0.7	2.6
CY25	2.4	2.4	4.5	1.3	1.3	6.5	0.9	1.0	1.5	1.9
CY26	2.1	1.9	3.8	1.6	1.5	6.5	0.2	0.8	1.7	2.0

Year	Brazil	Canada	China	France	Germany	India*	Italy	Japan	United Kingdom	United States
CY27	2.0	1.7	3.6	1.5	1.1	6.5	0.3	0.6	1.7	2.1
CY28	2.0	1.7	3.4	1.4	0.8	6.5	0.8	0.6	1.6	2.1
CY29	2.0	1.7	3.3	1.3	0.7	6.5	0.8	0.4	1.4	2.1

**India Financial Year, Source: World Economic Outlook Database (April-2024) by IMF; CRISIL MI&A-Consulting*

As per the World Economic Outlook released by IMF in July 2024, economic activity was surprisingly resilient through the global disinflation of 2022–23. IMF estimated global real GDP growth at 3.3% in 2023, is projected to continue at 3.2% and 3.3% in 2024 and 2025, respectively. As per July 2024 estimates of IMF, real GDP growth in India is projected to remain strong at 7.0% in 2024 and 6.5% in 2025, with the robustness reflecting continuing strength in domestic demand and a rising working-age population.

1.2 Overview of other demographic factors

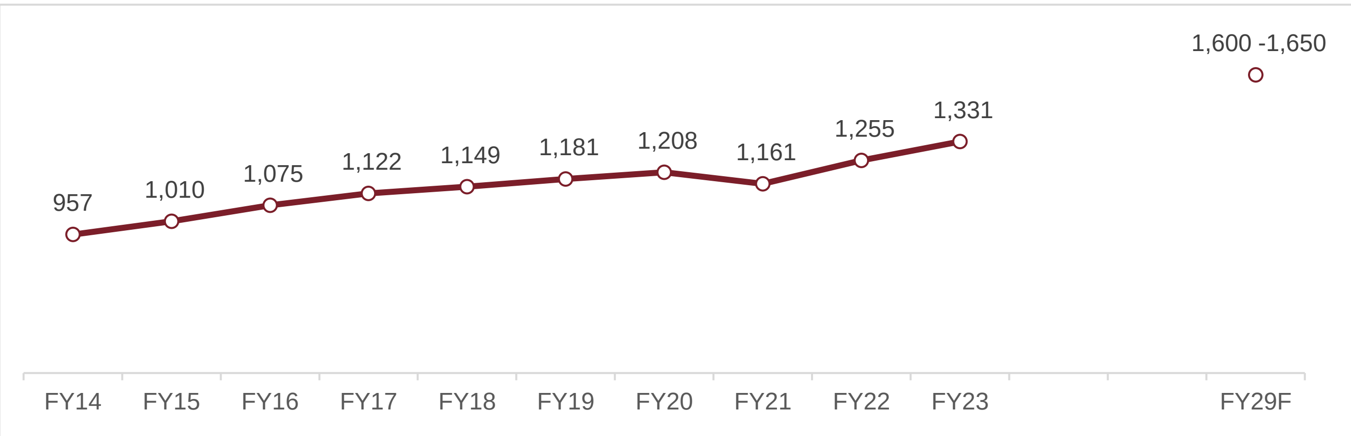
1.2.1 Per capita electricity consumption

India's electricity consumption per person rose to 1,331 kWh in fiscal 2023 (as per CEA's provisional data), from 957 kWh in fiscal 2014 at a CAGR of 3.73%, primarily led by increase in manufacturing activity, rising domestic consumption, rural and household electrification and extended hours electricity supply.

As seen in the Figure 1, despite this healthy increase, the per-capita electricity consumption remains significantly lower than other major economies. Developing countries, such as Brazil and China, have significantly higher per-capita electricity consumption than India. In CY2022, per capita electricity consumption of Brazil (2.5 MWh) was almost double of India's (1.3 MWh) per capita electricity consumption whereas the annual per capita electricity consumption of India was around 24% that of China (5.3 MWh) and around 10% of the United Staes (12.7 MWh).

Between fiscals 2023 and 2029, India's per capita electricity consumption is expected to grow at ~5-7% CAGR. Per capita electricity consumption is expected to gradually improve in the long term as well, as power demand picks up on the back of improvement in access to electricity, in terms of quality and reliability, rising per capita income, increasing EV penetration, railway electrification, on account of intensive rural electrification, resulting in realisation of latent demand from the residential segment, increased penetration of consumer durables. However, there are a few factors which could restrict the growth such as improved energy efficiency, focus on T&D loss reduction, sustainability targets and increasing share of services in GDP. Consequently, CRISIL MI&A-Consulting expects per capita electricity consumption to reach 1,600-1,650 kWh by fiscal 2029.

Figure 2: Per capita electricity consumption (in kWh)



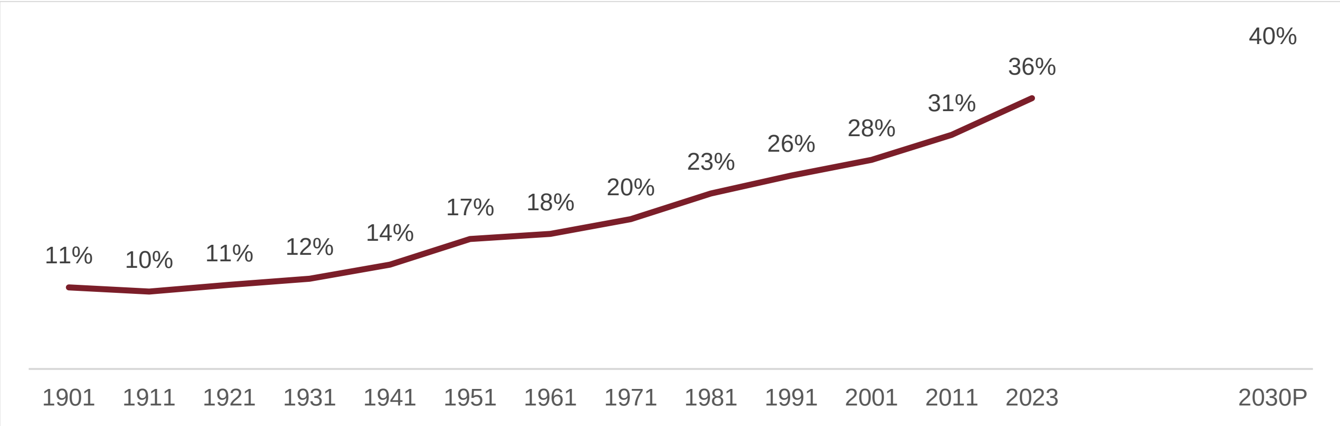
F: Forecast
Source: Central Electricity Authority of India (CEA), CRISIL MI&A-Consulting

1.2.2 Urbanization

Urbanisation is one of the big growth drivers, as it leads to rapid infrastructure development, job creation, development of modern consumer services, and mobilisation of savings.

The share of the urban population in India in overall population, which stood at ~31% in 2011, has been consistently rising over the years, and is expected to reach 40% by 2030, spurring increasing consumer demand.

Figure 3: Urban population as a % of total population of India



P: Projected

Source: Census 2011, Report of The Technical Group on Population Projections by Ministry of Health & Family Welfare (July 2020), World Bank; Economic Survey 2024, CRISIL MI&A Consulting

1.3 Outlook on Carbon Reduction Emission measures and corresponding developments

1.3.1 United Nations Climate Change Conference

COP 26

The 2021 United Nations Climate Change Conference (COP 26) was the 26th United Nations Climate Change conference, held at Glasgow, Scotland during Oct-Nov 2021 and a draft agreement was circulated with respect to climate change action. The draft agreement called on countries to phase out coal power and inefficient fossil fuel subsidies to reduce carbon emissions significantly in order to reach a goal of limiting global warming this century to 1.5 degree Celsius. The draft recognised that limiting global warming to 1.5 degrees Celsius would require rapid, deep and sustained reductions in global greenhouse gas (GHG) emissions, including reducing global carbon dioxide emissions by 45% by 2030 relative to the 2010 level and to net-zero levels around mid-century.

COP26 was a landmark event, as it saw a number of important decisions including

- A commitment to phase down coal power and to accelerate the transition to clean energy.
- A commitment to reduce methane emissions by 30% by 2030.
- A commitment to provide $100 billion per year in climate finance to developing countries.

India has submitted its updated first NDC working towards climate justice after COP26. Some of the key NDCs are

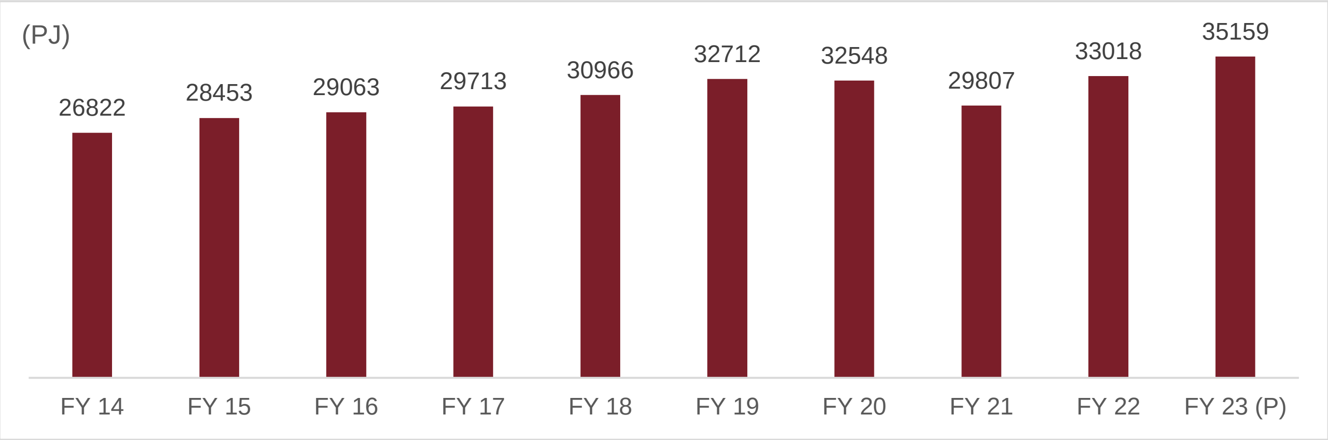
- To reduce Emissions Intensity of its GDP by 45% by 2030, from 2005 level
- To achieve about 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, with the help of transfer of technology and low-cost international finance including from Green Climate Fund (GCF)

- To create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030.

1.3.2 Total energy demand

Increased urbanisation and industrialization have necessitated the supply of clean energy. As per India Energy Statistics 2024, India has experienced a healthy growth in consumption of energy, a growth from 26,822 Petajoule (PJ) during FY 2013-14 to 35,159 Petajoule (PJ) in FY 2022-23 (P) at a CAGR of 3.05%. The total consumption of energy has increased from 33,018 PJ in FY 2021-22 to 35,159 PJ in FY 2022-23(P), an increase of 6.48%. Coal and Lignite together has registered the highest growth of close to 8.63% during FY 2022-23(P) over last year

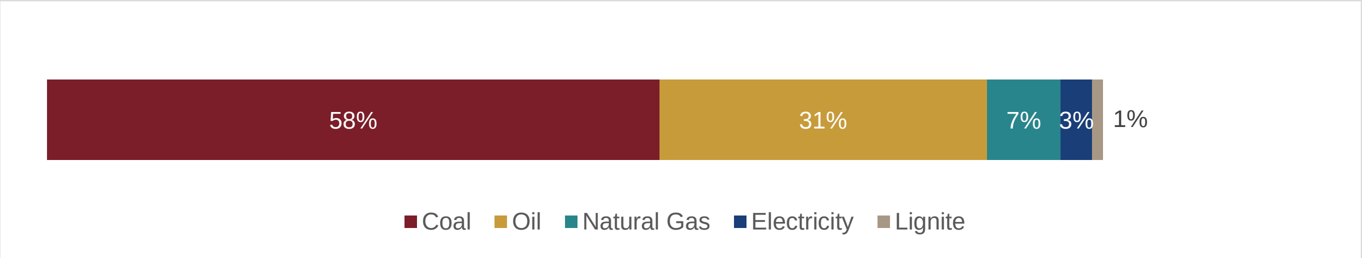
Figure 4: Trend of total consumption of Energy in India



(P) Provisional: 1 Petajoule= 23884.589 Tonnes of oil equivalent
Source: India Energy Statistics 2024 by MOSPI; CRISIL MI&A Consulting

The consumption of energy in petajoules from Coal and Lignite was highest which accounted for about 59% of the total consumption during FY 2022-23(P) followed by Crude Oil (31%) and Natural Gas (7%)

Figure 5: India-total primary energy demand met from



(P) Provisional: 1 Petajoule= 23884.589 Tonnes of oil equivalent
Source: India Energy Statistics 2024 by MOSPI; CRISIL MI&A Consulting

India's energy demand will continue to provide fuel for future economic growth and is bound to grow exponentially in the coming years. As per IEA, during 2020, India is the 3rd largest global energy consumer after China and the United States and in the Stated Policies Scenario, it is expected to overtake the European Union by 2030 to move up to third position.

2 Overview of the Indian Power Sector

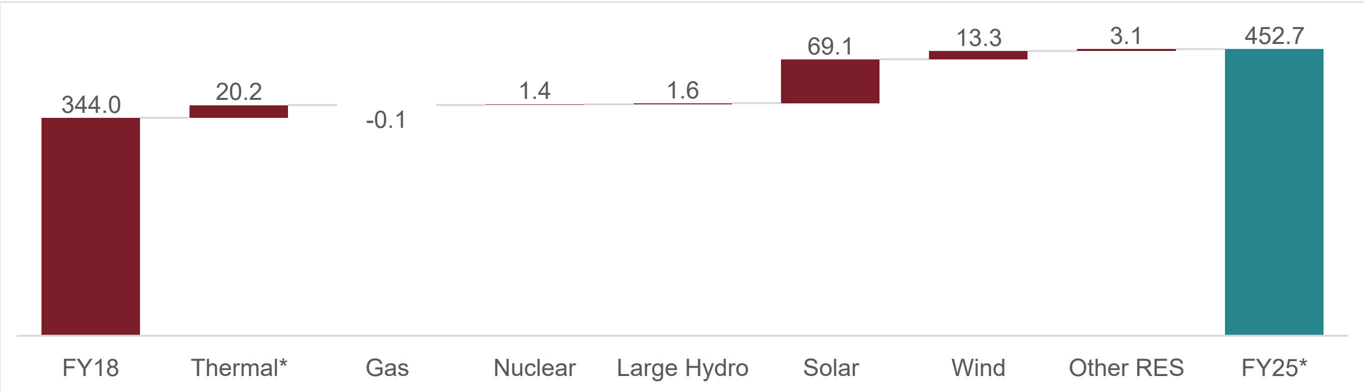
2.1 Review of power demand supply scenario

India witnessed robust growth in capacity addition over the past decade, led by delicensing of the power-generation business through the Electricity Act, 2003, followed by strong government thrust on RE through favourable policies and regulations.

2.1.1 Review of installed capacity and fuel mix

The total installed generation capacity as of September 2024 was ~453 GW, of which ~109 GW of capacity was added over fiscals 2018-25. The overall installed generation capacity has grown at a CAGR of ~5.0% over the same period.

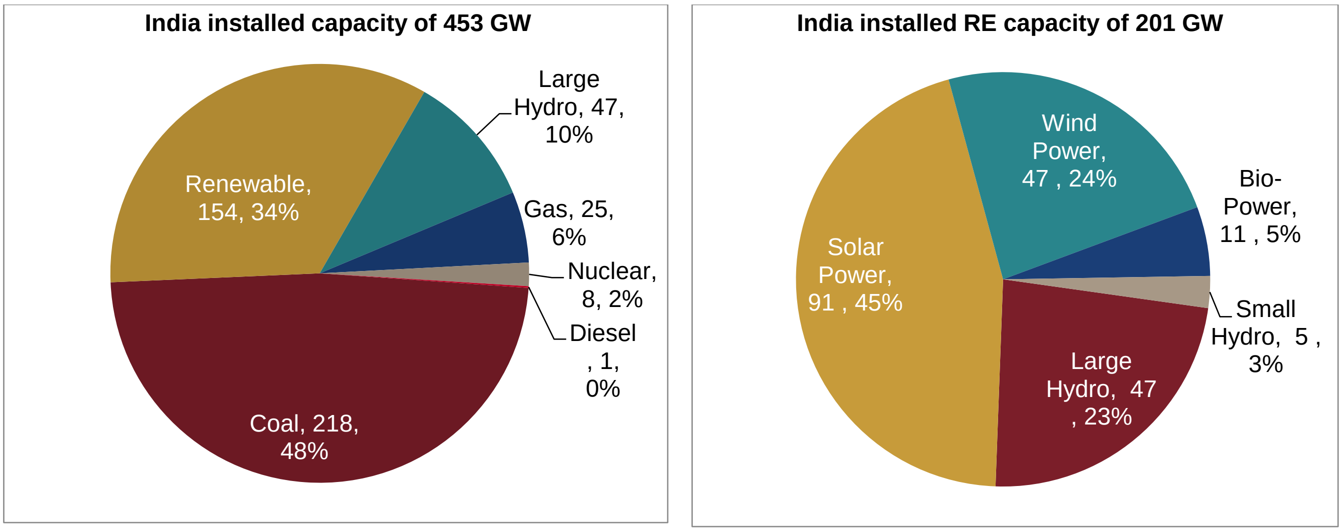
Figure 6: India Annual capacity additions and installed capacity (GW)



**FY25: As on 30 September 2024, Source: CEA, CRISIL MI&A-Consulting*

Coal and lignite-based installed power generation capacity has maintained its dominant position over the years and accounts for ~48% as of September 2024. In the last few years, RE has been the focused area for capacity additions which is evident from the fact that RE installations (including large hydroelectric projects), have reached ~201 GW capacity as of September 2024, compared with 114 GW as of March 2018, constituting about 45% of total installed generation capacity. This growth has been led by solar power, which rapidly rose to ~91 GW from 22 GW over the same period.

Figure 7: Breakup of installed capacity as of September 2024 (GW, % share)

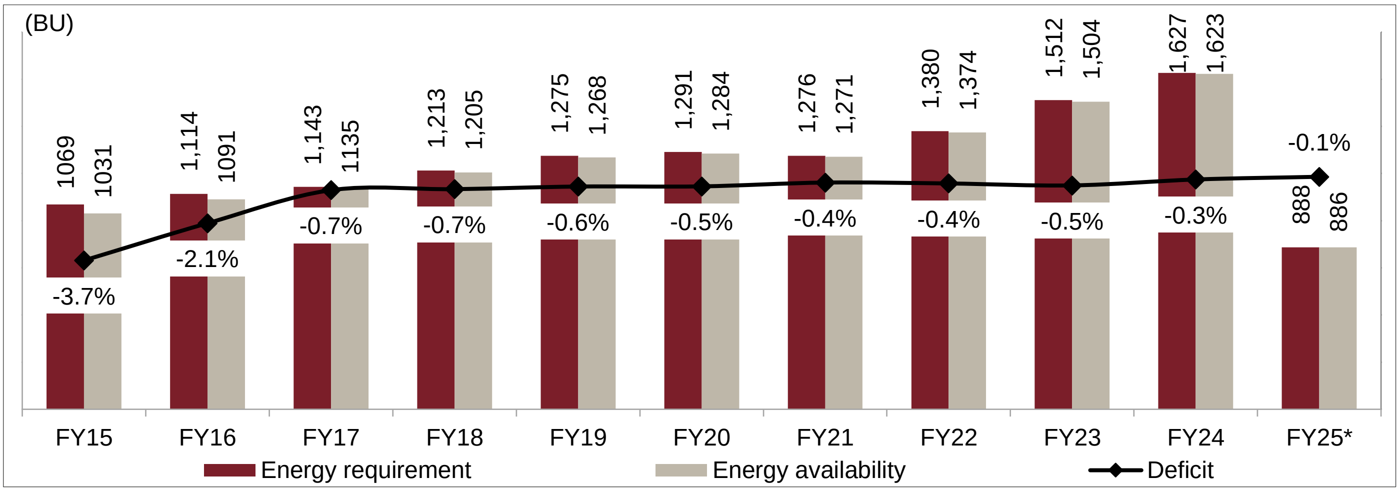


Source: CEA, CRISIL MI&A-Consulting

2.1.2 Historical trend in power demand and energy requirement

India's electricity requirement has risen at a CAGR of ~8.4% between fiscals 2021 and 2024, while power availability rose at ~8.5% CAGR due to strong capacity additions, both in the generation and transmission segments. As a result, the energy deficit declined to 0.5% in fiscal 2023 and further reduced to 0.3% in fiscal 2024 from 0.7% in fiscal 2018. Also, strengthening of inter-regional power transmission capacity over the past five years has further supported the fall in deficit levels as it reduced supply constraints due to congestion and lower transmission corridor availability. During fiscal 2025, the deficit was reduced to 0.1% as of September 2024.

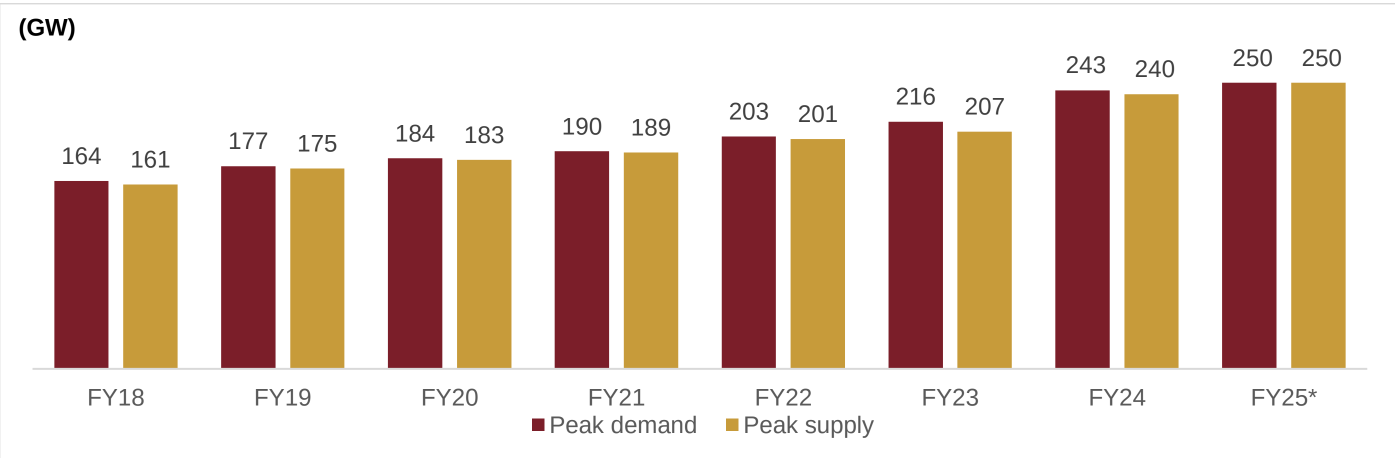
Figure 8: Aggregate power demand supply (in billion units, or BUs)



**FY25 as of September 2024; Source: CEA, CRISIL MI&A-Consulting*

Peak electricity demand in India has grown from 164 GW in fiscal 2018 to 243 GW in fiscal 2024 clocking an average growth rate of 6.8% in the past six years. In fiscal 2025 (as of September 2024) the peak demand further increased to 250 GW during the month of May 2024. Prior to the pandemic, electricity demand in India usually peaked in August-September, mostly covering the monsoon season. This spike in peak demand was primarily due to an increase in domestic and commercial load, mainly space cooling load due to high humidity conditions. However, during post pandemic years, annual peak demand occurred in the summer season (April-July), due to extreme heatwave conditions.

Figure 9: Peak power demand and supply position



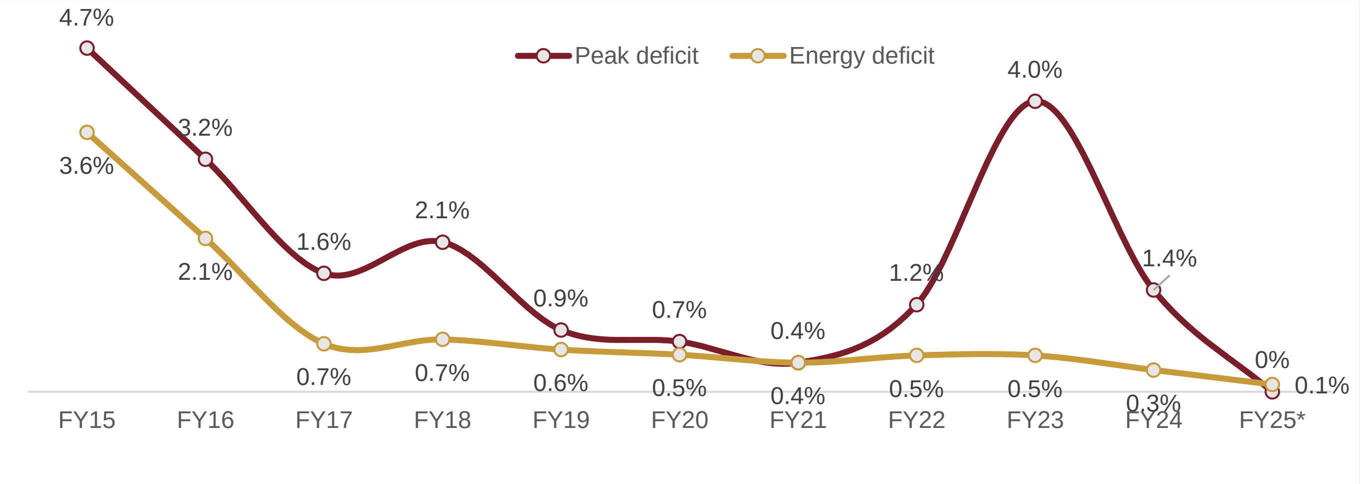
**FY25 as of September 2024; Source: CEA, CRISIL MI&A-Consulting*

2.1.3 Assessment of power deficit/surplus condition

On the back of strong growth in installed capacity, growth in energy availability outpaced demand growth. As a result, the gap between demand and supply narrowed, both in terms of energy as well as peak demand in the country. Peak demand shortage fell sharply to 1.4% in fiscal 2024, from 4.7% in fiscal 2015, whereas the energy shortage fell to 0.3% from 3.6% during the same period.

It is expected that the base deficit to persist, though remaining negligible at 0.3-0.5% over the medium-term, as deficit is expected in under-penetrated areas due to weak distribution infrastructure, with underserved populations expected to gradually come onto the grid in the long term.

Figure 10: Energy and peak demand shortage trend during the past 10 years



**FY25 as of September 2024; Source: CEA; CRISIL MI&A-Consulting*

2.2 Power demand supply outlook

2.2.1 Long term Demand drivers and constraints

Power demand is closely associated with a country's GDP. Healthy economic growth leads to growth in power demand. India is already the fastest-growing economy in the world, with an average GDP growth of 5.8% over the past decade. The trickle-down effect of government spending on infrastructure through the National Infrastructure Pipeline, expansion of the services industry, rapid urbanisation, and increased farm income from agriculture-related reforms are key macroeconomic factors that are expected to foster power demand. Significant policy initiatives such as 24x7 power for all, Sahaj Bijli Har Ghar Yojana (SAUBHAGYA) scheme to provide electricity connections to all households, green energy corridor to facilitate evacuation of RE power, green city scheme to promote the development of sustainable and eco-friendly cities, PLI scheme and low corporate tax rates among others are expected to further support power demand in the country.

Apart from macroeconomic factors, power demand would be further fueled by railway electrification, upcoming metro rail projects, growing demand for charging infrastructure due to increased adoption of electric vehicles, and higher demand from key infrastructure and manufacturing sectors. However, increasing energy efficiency, a reduction in technical losses over the longer term, and captive as well as off-grid generation from renewables would restrict growth in power demand.

Railway electrification and metro rail projects to drive a majority of incremental power demand

Indian Railways has planned to become a net zero carbon emitter by 2030. Therefore, the Government aimed to achieve 100% electrification by fiscal 2025. This leads to incremental power demand of around 23 BUs on average every year between fiscal 2025 to 2029. The power sector is poised to witness most of the incremental demand from railway electrification; however, lower energy consumption for electrification per kilometer due to energy efficiency improvements will partially offset the demand.

Metro rail has seen substantial growth in India in recent years, and the rate of growth is set to double or triple in the coming years with multiple cities seeking metro rail services to meet daily mobility requirements. As of May 31, 2024, around 712 km of metro rail is under construction and 1,878 km is proposed to be added. These developments are expected to add incremental power demand of 5-6 BUs every year on average between fiscal 2025 to 2029. Currently, metro rail projects constitute a marginal share of total incremental demand, but the share is expected to increase due to a large quantum of upcoming metro projects.

Further, EV charging requirements are likely to boost power demand over the medium term, with a gradual increase in the share of EVs in the vehicle population. CRISIL MI&A-Consulting projects that the adoption of EVs will boost power demand by 12-13 BUs annually on average over fiscals 2025 to 2029.

Declining T&D losses, an increase in off-grid/rooftop projects and open access transactions to drive power demand downward

T&D losses have been declining, and the reduction in losses is expected to continue further aided by a slew of government measures, primarily the Revamped Distribution Sector Scheme (RDSS). RDSS is a reform-based and result-linked scheme for improving the quality and reliability of power supply to consumers through a financially sustainable and operationally efficient distribution sector. Power demand is expected to be reduced by 20-25 BUs on average every year between fiscal 2025 to 2029 owing to lower T&D losses.

Further, with a boost to rooftop solar and the declining cost of renewable energy generation, decentralized distributed generation is expected to increase, reducing power demand from the grid. By fiscal 2029, 32-33 GW of rooftop capacities are expected to come onstream, resulting in a reduction of 2-3% in base demand.

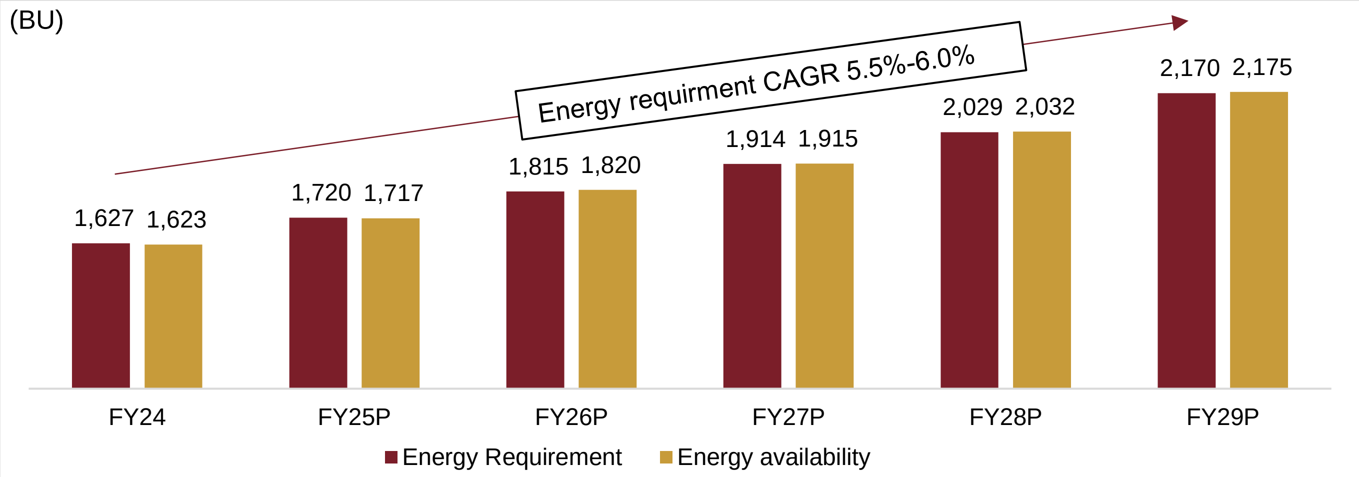
Captive consumption has been on a rising trajectory since fiscal 2013. The top four industries, namely iron and steel, sugar, aluminium, and steel account for 65% of the total captive consumption. Captive consumption is expected to maintain its growing trajectory going forward driven by increasing production in the mentioned industries. These industries are expected to add ~3-4 GW of captive capacity over the next five years, adding on average 290-300 BUs of demand over the period which may lead to a reduction in demand from the grid.

With higher tariffs and increasing operating expenses, commercial and industrial (C&I) consumers are opting for renewable energy through rooftops or open access to optimize the production costs. Thus, this segment opens up an avenue for more and more RE installations and provides an opportunity for RE players to expand their market.

2.2.2 Outlook on energy requirement and availability

Despite the high base of preceding three years, CRISIL MI&A-Consulting expects power demand to grow by 5.5-6.0% in the next five years which will be supported by infrastructure-linked capex, strong economic fundamentals along with expansion of the power footprint via strengthening of T&D infrastructure, coupled with major reforms initiated by the GoI for improving the overall health of the power sector, particularly that of state distribution utilities, are expected to improve the quality of power supply, thereby propelling power demand.

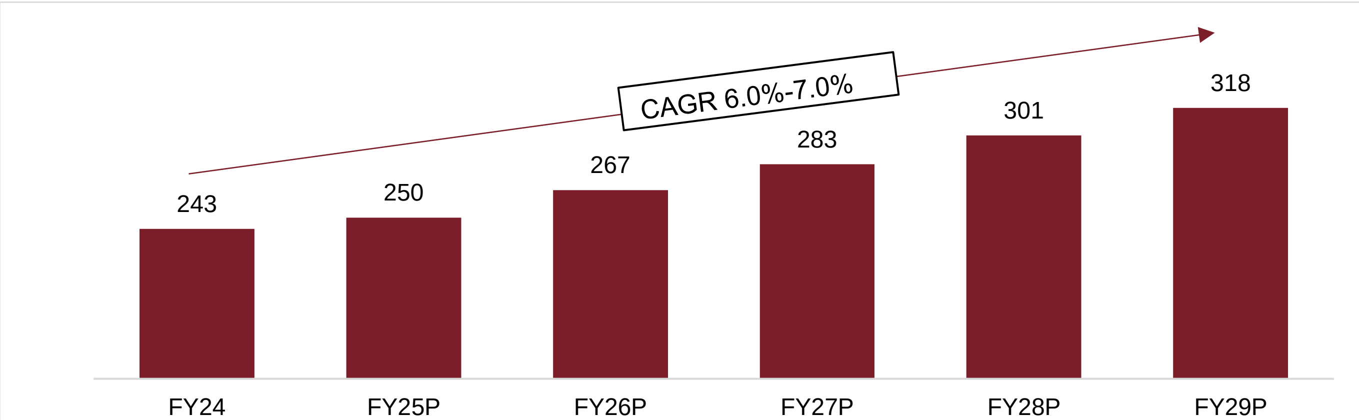
Figure 11: Energy demand outlook (fiscals 2025-29)



P: Projected, Source: CEA, CRISIL MI&A-Consulting

Peak demand is expected to grow at annual average 5-6% over fiscal 2024-29 to reach nearly 318 GW by fiscal 2029 with an expected persistent high temperatures, rising urbanization, economic growth and infrastructure push leading to higher power consumption.

Figure 12: Peak demand to increase by 75 GW between fiscals 2025 and 2029 to cross 300 GW



P: Projected, Source: CEA, CRISIL MI&A-Consulting

2.2.3 Capacity addition outlook

Capacity additions in the conventional power generation segment are projected to be around 32-35 GW from fiscals 2025 to 2029, driven by higher than decadal average power demand.

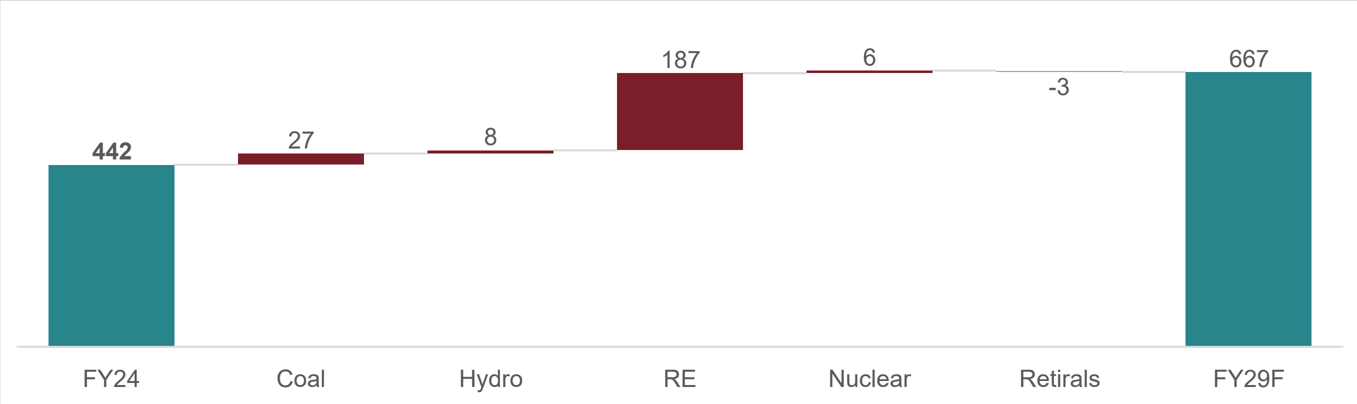
Nuclear power capacity additions of 5-6 GW are expected during the period as ongoing projects at Kakrapara, Kalpakkam, and Rajasthan are nearing completion.

CRISIL MI&A-Consulting expects 15-16 GW of hydro power installations including 7-8 GW pumped hydro storage projects (PSP) capacity additions over fiscals 2025-2029.

RE capacity addition of over 180-190 GW is expected to be installed between fiscal 2025-29 driven by various government initiatives, favourable policies, competitive tariffs, innovative tenders, development of solar parks and green energy corridors, etc. RE capacity is estimated to account for about 50% of the installed capacity of 660-670 GW by fiscal 2029.

BESS capacity additions, aimed at storing renewable energy during off-peak hours of power demand to support peak supply, are expected to be commissioned starting fiscal 2025, with 23-24 GW of BESS capacity likely to be added through fiscal 2029.

Figure 13: All India installed estimated capacity addition by fiscal 2029 (in GW)



RE includes solar, wind, small hydro, and other renewable sources
Source: CEA, CRISIL MI&A-Consulting

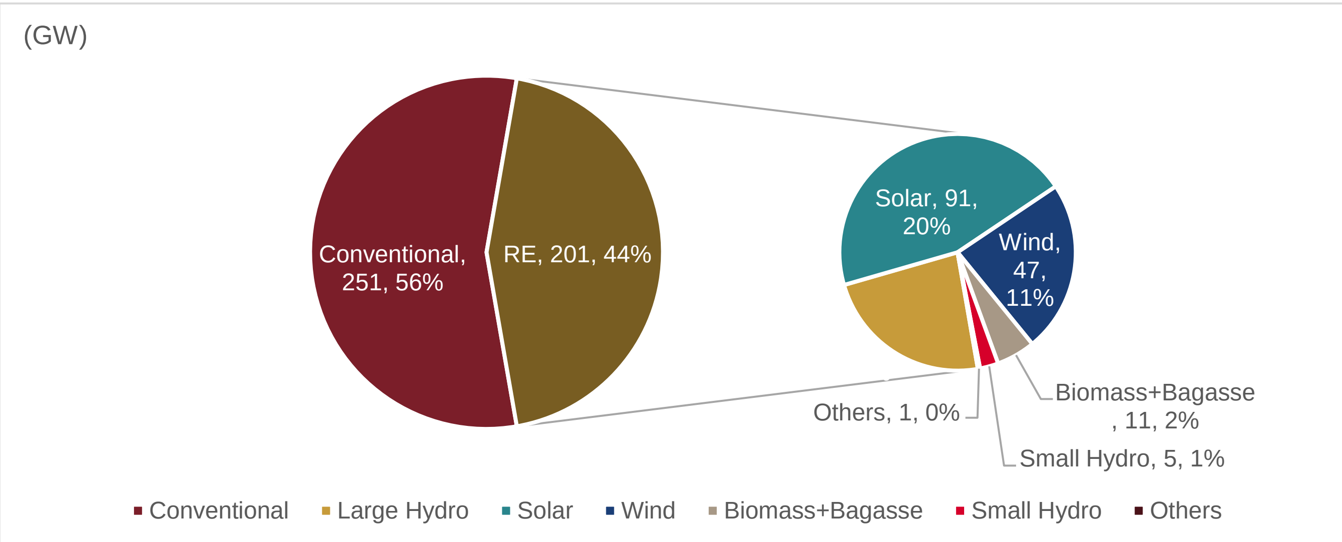
2.3 Overview of Renewable Energy sector in India

Renewable sources are a clean source of energy as they do not burn like fossil fuels, preventing the release of pollutants into the air. Increasing use of RE would help avoid carbon emissions, and thereby, restrict global warming. Further, the wide availability of these resources makes them less susceptible to depletion unlike conventional sources of energy. While there are multiple renewable sources that can be utilised, including solar, wind, small hydro, biomass, and bagasse remain key sources.

2.3.1 Installed Renewable energy capacity in India

Renewable energy installations (incl. large hydro) have increased to ~201 GW as of September 2024, as compared with ~63 GW as of March 2012 (source: MNRE), led by various central and state-level incentives. As of September-2024, installed grid connected RE generation capacity (incl. large hydro) in India constituted ~45% of the total installed generation base in India. This growth has been led by solar power, which has grown to ~91 GW from merely ~0.09 GW over the discussed time period (i.e., from March 2012).

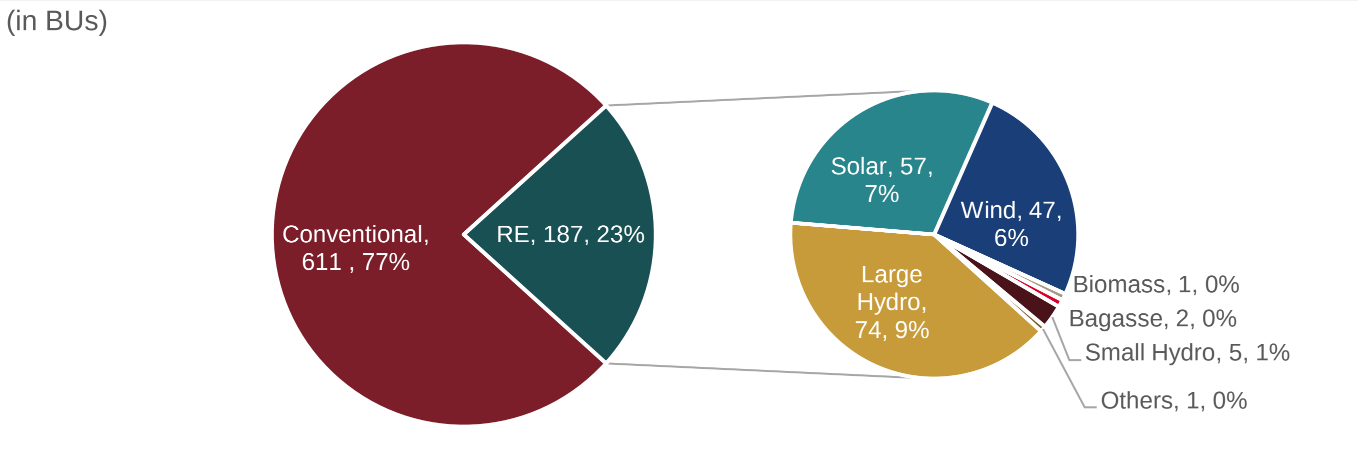
Figure 14: India's RE (incl. large hydro) capacity was ~45% at the end of September 2024



Conventional: Coal, Gas, Lignite, and Nuclear
Source: MNRE; CEA, CRISIL MI&A-Consulting

However, owing to lower capacity utilisation factors, the RE penetration (incl. large hydro) in terms of energy generation was at ~187 BUs for fiscal 2025 (as of Aug-2024).

Figure 15: India's RE (incl. large hydro) penetration was about 23% at end of August 2024



At CEA, generation lags data lags compared to installed capacity data.
Conventional: Coal, Gas, Lignite and Nuclear
Source: MNRE; CEA, CRISIL MI&A-Consulting

Some of the key players in thermal (coal), hydro, solar and wind energy and their share in respective energy segment is summarised in following table.

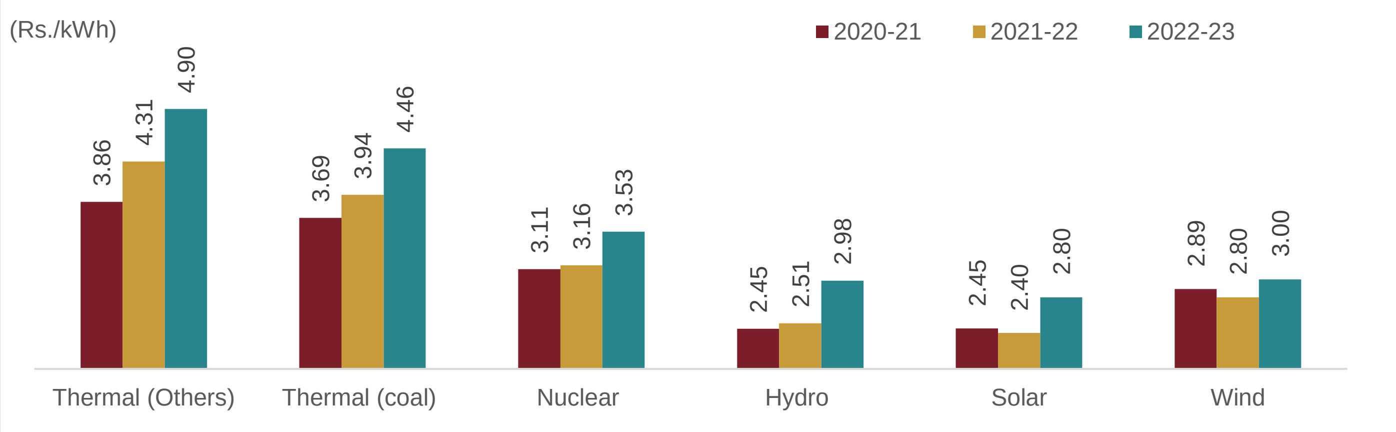
Table 2: Key players and their share in installed capacity

Player	Thermal (Coal + Lignite)	Player	Large Hydro	Player	Solar	Player	Wind
NTPC	29%	NHPC	15%	Adani Green	8%	Adani Green	3%
Adani Power	7%	BBMB	6%	ReNew	6%	ReNew	10%
Tata Power	4%	SJVNL	4%	Tata Power	4%	Tata Power	2%
DVC	3%	NHDC	3%	NTPC	4%	Sembcorp	4%
Reliance Power	3%	NEEPCO	3%	Avaada	3%	JSW	5%
Jindal Power	2%	THDC	3%	Azure	3%	Continuum	3%
JSW	2%	JSW Energy	3%	Acme	2%	Apraava	2%
NLC	2%	NTPC	2%	Greenko	2%	Greenko	7%
Jaypee Group	1%	Tata Power	1%	Sembocrp	1%	Torrent	2%
Total (MW)	**2,17,650**		**46,928**		**90,762**		**47,363**

Source: CEA, Company websites, Industry, CRISIL MI&A Consulting

Further, the following figure summarises the weighted average rate of sale of power for different sources of power generation.

Figure 16: Weighted average rate of sale of power

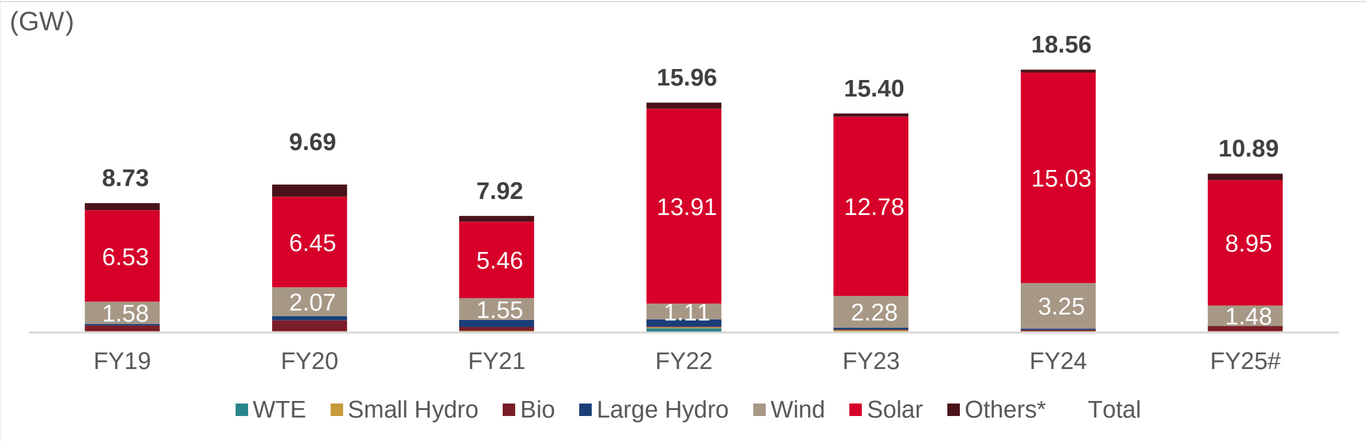


For solar and wind power, the weighted tariffs discovered in the bidding for the respective year
Source: CEA, Sansad website, Industry, CRISIL MI&A Consulting

2.3.2 Overview of RE capacity additions

With the increased support of the Government and improved economics, the RE sector has become attractive from an investor's perspective. During fiscals 2018 to 2024, India added around 76 GW of RE (incl. large hydro) capacities. The installed RE (incl. large hydro) capacity has grown from 114 GW in fiscal 2018 to 201 GW in fiscal 2025 (as of September 2024) at a CAGR of ~9%. Solar segment led the capacity additions with cumulative additions of ~69 GW followed by wind ~13 GW during the same period. The other RE sources added ~5 GW during the same period.

Figure 17: Historical RE Capacity additions in India

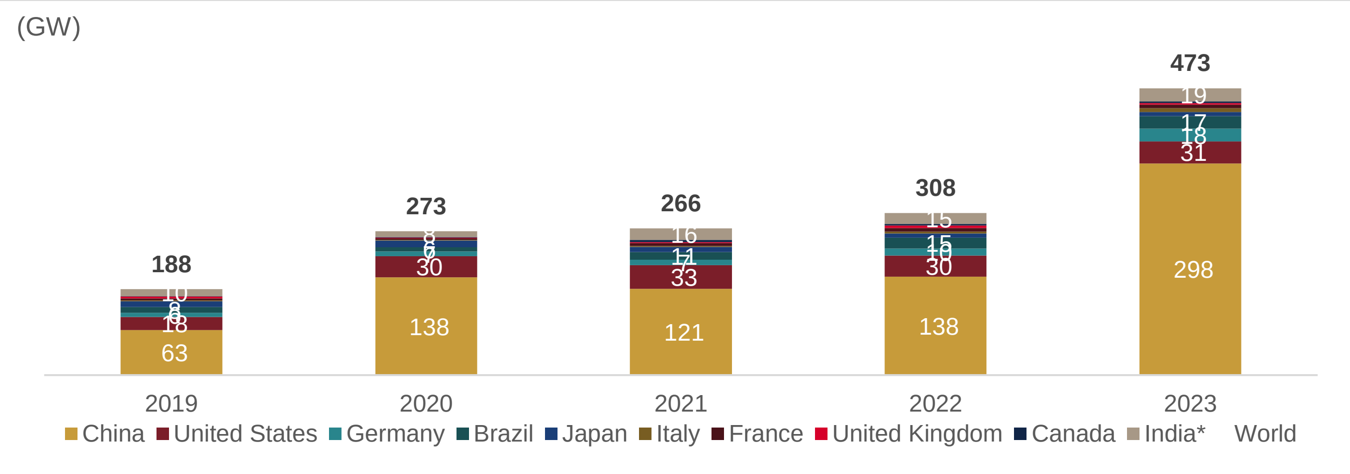


*# As of September 2024; *Others include small-hydro, biomass and waste-to-energy*
Source: CEA, MNRE, CRISIL MI&A Consulting

2.3.3 RE Capacity additions in India compared to major economies

Globally, India ranks fourth in total RE capacity, wind as well as solar installations. India has become the second largest RE market in the Asia Pacific region after China. As per IRENA RE capacity statistics 2024, during 2023, China added ~298 GW of RE capacity followed by USA with ~31 GW of RE capacity. During the same period, Germany added around 18 GW whereas Brazil added 17 GW of RE capacity. As per MNRE, India added ~15 GW during the fiscal 2023. Thus, as against the 63% of the global RE capacity added by China, India added around 3% during the fiscal 2023.

Figure 18: China is leading in global RE capacity additions



Source: MNRE, IRENA, CRISIL MI&A Consulting

2.3.4 RE Consumption in key Indian states

With declining tariffs and government push for RE, most of the RE states have added significant RE capacity and are also purchasing RE power to meet the energy demand. However, the RE penetration in Indian states varies substantially from state to state. In the Top 10 RE Rich States, the RE penetration is higher than national average. The following table summarises the share of RE consumption in total power consumption. The share of RE in most of the States is increasing.

Table 3: Trend of RE consumption in total electricity consumption in key States

State	FY19	FY 20	FY 21	FY 22	FY 23
Andhra Pradesh	34%	37%	32%	29%	26%
Chhattisgarh	5%	6%	9%	8%	14%
Gujarat	13%	15%	16%	18%	18%
Haryana	16%	18%	17%	19%	24%
Karnataka	31%	39%	44%	42%	43%
Madhya Pradesh	14%	17%	19%	16%	22%
Maharashtra	13%	14%	15%	17%	18%
Rajasthan	25%	27%	25%	25%	31%
Tamil Nadu	14%	15%	17%	15%	16%
Telangana	15%	19%	17%	20%	22%

Note: As per the ICED database, a large capacity of Solar Park in AP is discontinued from 20-21 onwards,
Source: India Climate Energy Dashboard (NITI Aayog); CRISIL MI&A Consulting

2.3.5 Availability of finance and evolution of funding mechanisms

To facilitate growth of renewable energy and, in particular, the solar power sector, the GoI has provided several measures to facilitate finance availability to developers. Some of these steps taken are as follows:

- *Funding from lending institutions such as PFC, IREDA, REC and PFS:* Government financial institutions such as Power Finance Corporation (PFC), PTC India Financial Services Limited (PFS), Rural Electrification Corporation (REC) and IREDA are financing many solar projects. As of March 2024, for PFC, the renewable energy portfolio crossed Rs. 600 billion (25% increase Rs. 602.08 billion as on 31.03.2024 vs Rs. 481.98 billion as on 31.03.2023). For the Quarter ended 30th June 2024, the PFC has sanctioned Rs. 598.44 billion loans to RE incl. large hydro against Rs. 497.07 billion on Quarter ended 30th June 2023. As of March 2024, for fiscal 2024, REC has sanctioned Rs. 1365.16 billion loans to RE incl. large hydro. For the half year ended 30th September 2024, the REC has sanctioned Rs. 603.91 billion loans to RE incl. large hydro against Rs. 499.29 billion on half year ended 30th September 2023. Further, IREDA sanctioned loans amounting to Rs. 373.54 billion and disbursed loans worth Rs. 250.89 billion during the fiscal 2024. This has led to a significant growth of 26.71% in the loan book, which stood at Rs. 596.50 billion. For the H1 of fiscal 2025, the IREDA sanctioned Rs. 178.60 billion and disbursed Rs. 97.87 billion.

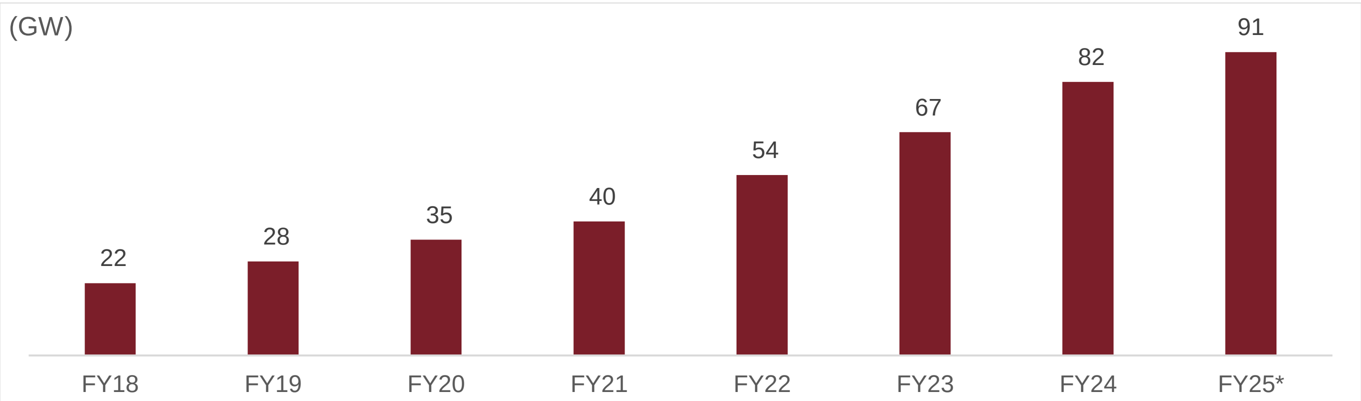
- *Green bond / masala bonds market:* A green bond is like any other bond; however, it invests the proceeds to support green investments including renewable energy projects. The tenure of the bonds typically ranges from 18 months to 30 months. India is the second country after China to have national-level guidelines for green bonds; in India's case, they were published by SEBI. The green bonds may be issued by the national government; multilateral organisations such as Asian Development Bank, the World Bank or the Export-import (EXIM) bank of the country; financial institutions; and corporations.
- *Pension funds / endowment funds*: Pension / endowment funds are expected to play a key role in financing solar 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 (ISA):* The Central government channelises the funds available from multilateral banks and financing institutes such as World Bank and KfW. The Central government or its representative gets the funds, and it further gets allocated/allocated 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. For instance, State Bank of India (SBI) has also received ~US$625 million of soft loans with a long tenure of 20 years from the World Bank at a concessional rate to support viable grid-connected rooftop solar PV projects. On the same lines, KfW Germany provided a 1-billion-euro loan through IREDA for funding solar projects. Further, European Investment Bank has signed a long-term loan of 150 million euros with IREDA to finance clean energy projects in India.

  The ISA, an association of solar-resource-rich countries, launched by the governments of India and France, aims at mobilising $1,000 billion in funds by 2030.

2.4 Overview of solar sector in India

In the renewable energy basket (including large hydro) as of September 2024, solar energy accounted for a share of 45%. Growth in the solar power sector over the last five years has been robust. As much as ~69 GW capacity was added in the segment over fiscals 2018-25 (as of September 2024), registering a CAGR of ~24.7%, although on a low base.

Figure 19: Trend in cumulative solar capacity installation in India



**FY25 as of September 2024, Source: MNRE, CEA, CRISIL MI&A-Consulting*

The GoI imposing solar RPOs across Indian states in 2011, coupled with the sharp drop in capital costs, led to most states releasing solar polices. This resulted in a spur in solar sector investments. Till fiscal 2012, only Gujarat and Rajasthan had state solar policies. After the success of Gujarat's solar policy, other states such as Andhra Pradesh, Tamil Nadu, Karnataka, Madhya Pradesh, and Telangana introduced their respective solar polices.

The National Institute of Solar Energy estimated the country's solar potential at 748 GW, assuming solar PV modules cover 3% of the geographical surface. India is a perfect location for solar energy because of its location. It has 300 days of sunshine each year, with daily peak electricity use being in the evenings and a seasonal peak in the summer.

The daily average Global Horizontal Irradiance (GHI) in India is around 5 kWh/m^2 in north-eastern and hilly areas to about 7 kWh/m^2 in western region and cold desert areas. The annual GHI varies from 1600 – 2200 kWh/m^2. States like Gujarat, Rajasthan, Madhya Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu offers more solar irradiance as compared to other parts of India which makes them desirable for installing solar projects.

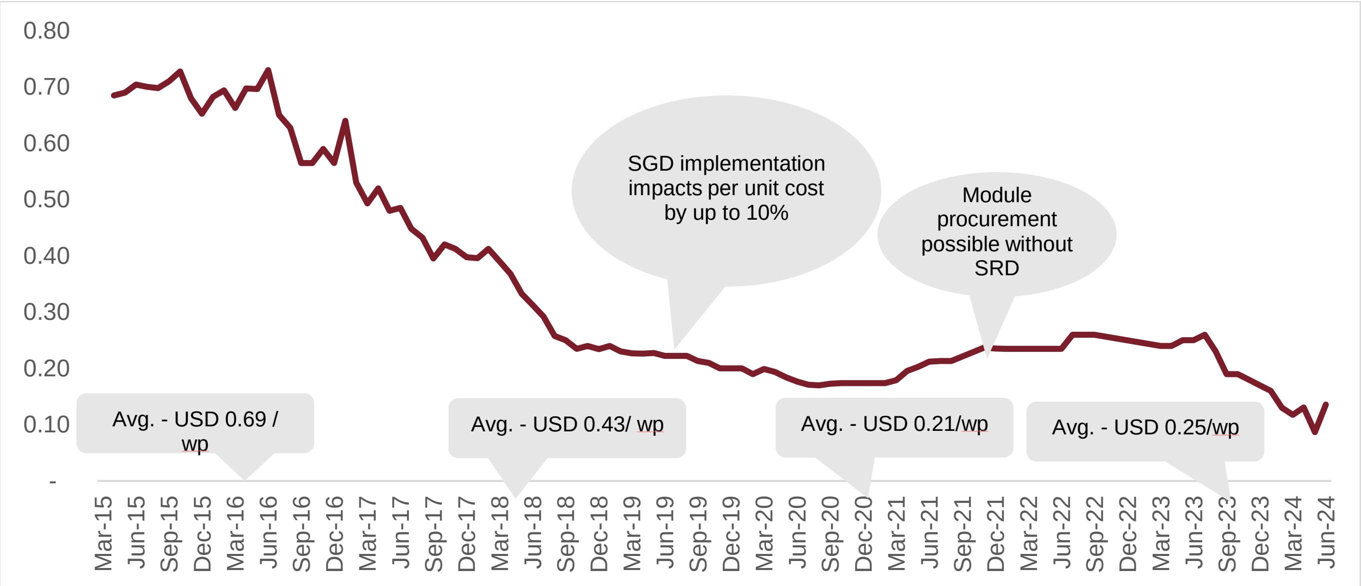
2.4.1 Growth drivers for Solar sector in India

2.4.1.1 Declining module prices and tariffs

The global average solar module price, which constitutes 55-60% of the total system cost, crashed 73% to $0.47 per watt-peak in 2016 (average for January-December) from $1.78 per watt-peak in 2010. In fact, prices continued to decline to $0.22 per watt-peak by end-August 2019, owing to technology improvement, scale benefits and a demand-supply gap in the global solar module manufacturing industry.

CRISIL MI&A Consulting expects that post the reapplication of ALMM; the domestic module prices are expected to inch up on a quarterly basis as demand for domestic module grows. However, the fall in cell prices will mean that the domestic prices will still be 10-15% down on year in fiscal 2025 to Rs 0.21-0.23/wp. On the other hand, the international module prices are expected to register a higher fall of 20-25% owing to oversupply.

Figure 20: Module prices declined over 85%% from fiscal 2015 to 2024 (USD/Wp)



Source: Industry, CRISIL MI&A-Consulting

2.4.1.2 Fiscal and regulatory incentives

The Indian government has been offering a variety of incentives to encourage the development of solar power plants.

PM *Surya Ghar Muft Bijli Yojna*: For further sustainable development and people's well-being, the Central Government in February 2024 launched the PM *Surya Ghar: Muft Bijli Yojna*. This scheme has a proposed outlay of Rs. 750 billion and aims to light up 10 million households by providing up to 300 units of free electricity every month.

***CPSU Scheme*:** The Central government introduced the CPSU scheme Phase I in 2015 to promote the set-up of 1,000 MW grid-connected solar PV power projects by CPSUs and government organisations with Viability Gap Funding (VGF). Further, the Central Government in March 2019, approved implementation of CPSU Scheme Phase-II for setting up grid-connected Solar PV Power Projects by Central and State PSUs, Government Organisations, with VGF support of Rs 85.8 billion, for self-use or use by Government/ Government entities, either directly or through Discoms. The maximum permissible VGF was initially two tranches and was kept at Rs 7 Mn/MW which was subsequently reduced to Rs 5.5 Mn/MW for third tranche. Under this Scheme, the Government has so far sanctioned about 8.2 GW capacity of solar PV power plants to various entities. Ability of CPSUs to execute the scheme at ground level and consumer awareness will play key roles in success of the Scheme.

Annual Bidding Trajectory:

MNRE has prescribed an annual bidding trajectory for RE power bids to be issued by Renewable Energy Implementation Agencies (REIAs). Bids for 50 GW per annum RE capacity, with at least 10 GW per annum Wind power capacity, are to be issued each year from 2023-24 to 2027-28. This is expected to help in achieving the targets specified for 2030. Bids of 35.51 GW have been issued by four REIAs (SECI, NTPC, NHPC & SJVN) in fiscal 2024 till December 2023.

National Solar Mission

Central-level allocations under NTPC Vidyut Vyapar Nigam Limited (NVVN) Batch II, Jawaharlal Nehru National Solar Mission (JNNSM) Phase II Batch III and IV have been almost entirely commissioned.

Operational support to execute solar projects

Apart from providing incentives, the government has lent significant support to the solar power sector for execution of projects.

Solar parks and ultra mega solar power projects: One of the most important initiatives by the GoI has been setting up of solar parks in the country. To overcome the land and transmission related challenges, the scheme for "Development of Solar Parks and Ultra-Mega Solar Power Projects" was rolled out in December 2014 with an objective to facilitate the solar project developers to set up projects expeditiously.

As per the available information, Solar Parks / UMREPPs of aggregate capacity of 39284 MW have been envisaged for development in the country as on 30th September, 2024. Of these, the capacity of 10931 MW has already been commissioned while 8983 MW capacity is under construction and 19370 MW is under award/tendering process.

2.4.1.3 Favourable technology

Solar power is becoming increasingly attractive due to falling module prices and improving efficiency resulting from excess manufacturing capacity in China and technology advancements, respectively.

On the project development front, developers are exhibiting heightened preference for bifacial modules that typically have higher efficiency relative to mono-facial modules and are compatible with tracker technology. In 2023, the share of bifacial variant in module imports increased from 8% in Q1 2022 to 37% in Q4 2023. On the other hand, multi-crystalline modules are being phased out due to lower efficiency and higher degradation rate – share of import volume was negligible in 2023.

Currently, the solar PV market is dominated by monocrystalline silicon technology. Within monocrystalline technology, Mono PERC is an advanced version that employs dielectric passivation film on the rear surface of the cells which increases the efficiency levels. These cells are currently leading the market due to higher efficiency, cover less space, higher output in low light conditions and are available at competitive pricing.

In addition to process improvements, the development of new solar cell designs is essential for achieving further efficiency gains while simultaneously reducing material intensity and manufacturing costs. The p-type to n-type migration is currently underway and paving the way for new technologies – by end of 2023, n-type technologies including TOPCon, heterojunction (HJT) and back contact represented 42% of China's total module manufacturing capacity (7% in 2022).

In addition, there are ongoing considerations for mass manufacturing of multilayer and tandem silicon-perovskite or silicon-CdTe hybrid solar panels. These innovative solutions have the potential to significantly increase cell efficiency, surpassing the 30% mark, while maintaining competitive production costs and promise to make solar power an even more compelling and sustainable energy solution in the years to come.

2.4.1.4 Green Hydrogen and green ammonia push

India has announced a target of energy independence by 2047 and a net-zero by 2070. Green Hydrogen is expected to play a substantial role in achieving these goals. The production of Green Hydrogen using renewable energy sources like solar, wind, and hydropower can provide energy security, reducing dependence on fossil fuels and ensuring a stable and reliable source of energy. Hence, India has launched the National Green Hydrogen Mission with an outlay of Rs. 197.44 billion with a target of 5MMT production capacity of Green Hydrogen per annum. Green hydrogen push from the government will likely push for the installation of solar energy for consumption.

In July 2023, SECI has issued a tender for selection of green hydrogen producers for setting up 450,000 TPA production facilities for green hydrogen in India under the SIGHT Scheme (Mode-1-Tranche-I). Moreover, in July 2024, MNRE notified guidelines under SIGHT Scheme (Mode-1-Tranche-II) with a capacity of 450,000 TPA. SECI has already issued a tender for Tranche-II which is expected to be concluded soon. The Government of India has already initiated pilot scheme for use of hydrogen in shipping, steel and transport sector.

The Green Hydrogen Mission will have wide ranging benefits- creation of export opportunities for Green Hydrogen and its derivatives; Decarbonisation of industrial, mobility and energy sectors; reduction in dependence on imported fossil fuels and feedstock; development of indigenous manufacturing capabilities; creation of employment opportunities; and development of cutting-edge technologies.

2.4.2 Outlook on Solar capacity additions in India

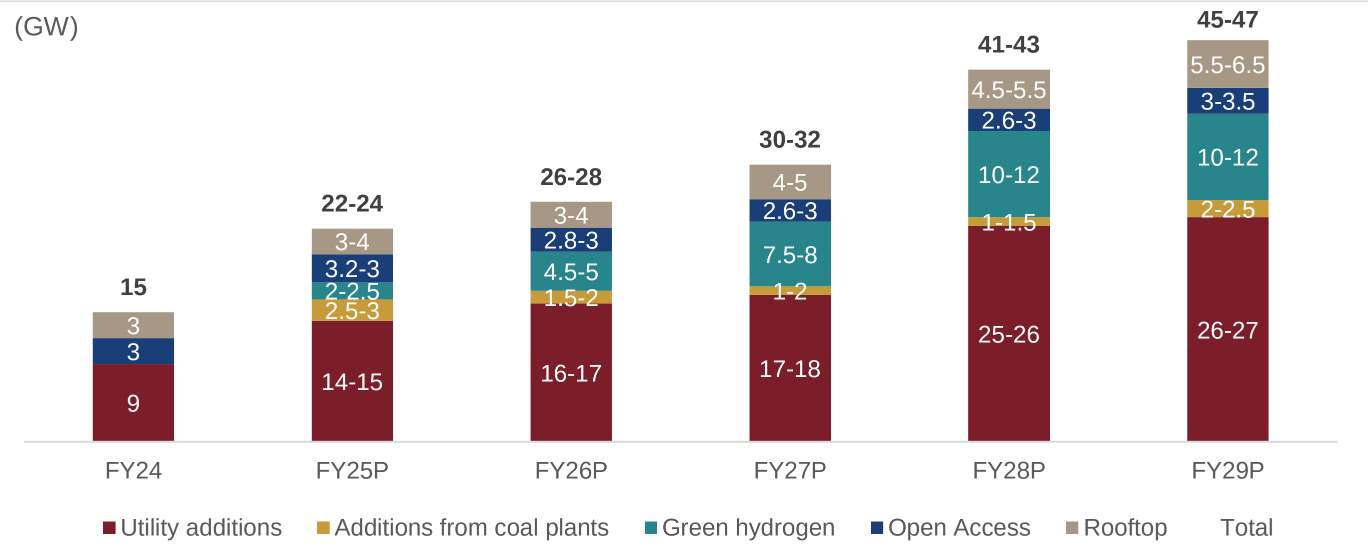
Solar sector growth in India primarily spurred by robust government backing, demonstrated through an aggressive tendering strategy. Some of the key catalysts include technological advancements, affordable financing, supportive policies, thrust on go-green initiatives/sustainability targets, cost optimisation due to increased grid electricity tariffs, subsidy initiative (specially in rooftop solar) and various incentives such as ISTS charge waiver.

CRISIL MI&A-Consulting expects 137-142 GW of solar capacity additions over fiscal 2025-2029. This will be driven by additions under:

- **NSM**: The entire NSM Phase II Batch II Tranche I of 3,000 MW has been commissioned. Under NSM Phase II, Batch III, and Batch IV, SECI through its state specific VGF has tendered out ~7 GW of capacities, most of which has been completed.
- **Other central schemes**: SECI has also started tendering projects outside the JNNSM Batch programme. It has initiated the ISTS scheme, wherein projects are planned for connection with the ISTS grid directly. Under this, SECI has already tendered and allocated ~35 GW (including hybrid).
- **State solar policies**: ~24 GW of projects are under construction and are expected to be commissioned over the fiscal 2025-2029. Based on tendered capacities by states at the end of June 2024, a further ~24 GW capacity of solar projects is expected to be up for bidding over the same duration.

- **PSUs**: The CPSU programme under JNNSM has been extended to 12 GW in February 2019. The government is also encouraging cash-rich PSUs to set up renewable energy projects. Group NTPC (NTPC Limited) has commissioned 4,013 MW as on 30.09.2024. It has a target of installing ~60 GW of renewable energy capacities by fiscal 2032. Similarly, NHPC Limited had allocated 2 GW of projects in 2020, while the Indian Railways has committed to 20 GW of solar power by 2030. Other PSUs such as NLC India Limited, defence organizations, and governmental establishments are also expected to contribute to this addition.
- **Rooftop solar projects**: CRISIL MI&A-Consulting expects 20-22 GW of rooftop solar projects (under the capex and opex mode) to be commissioned by fiscal 2029, led by PM Surya Ghar Yojana and industrial and commercial consumers under net/gross metering schemes of various state.
- **Open-access solar projects**: CRISIL MI&A-Consulting expects 13-15 GW of open-access solar projects (under the capex and opex mode) to be commissioned by fiscal 2028, led by green energy open access rules 2022, sustainability initiatives/RE 100 targets of the corporate consumers, better tariff structures and policies of states such as Uttar Pradesh and Karnataka, which are more long term in nature.
- **Push for Green hydrogen**: Production for green hydrogen is expected to start from fiscal 2026 with production of 0.5-1 million tonnes of production. The government has set the target production of 5 million tonnes of green hydrogen by 2030. As per announcement, we expect 2.0-2.2 MTPA of green hydrogen to commission which can lead to further upside of solar capacity of 32-37 GW, by fiscal 2029. However, developers may tie-up via grid / open access and not go to the captive route generation under this segment will remain a monitorable.

Figure 21:Year wise expected solar capacity addition



Source: CRISIL MI&A-Consulting

Also, the global conglomerate such as Amazon, Microsoft has set their sustainability goals and procuring more and more renewable energy in India to set off their global GHG emission. This also provides a lucrative opportunity for IPPs to sign PPAs for RE capacity.

The European Unions' (EU) Carbon Border Adjustment Mechanism (CBAM) is the EU's tool to put a fair price on the carbon emitted during the production of carbon intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries. The CBAM is expected to have a significant impact on solar capacity additions in non-EU countries. With increasing adoption of solar energy, CBAM is expected to contribute to overall growth of the market. The CBAM is expected to drive the renewable energy demand for energy intensive industries who export their products in European markets in order to follow their norms regarding carbon emission and avoid imposition of penalties for non-adherence to such rules & regulations.

2.4.3 Progress on T&D infrastructure, interregional transmission capacity

2.4.3.1 Market review

Robust generation capacity addition over the years and government's focus on 100% rural electrification through last mile connectivity has led to extensive expansion of the T&D system across the country. The total length of domestic transmission lines rose from 413,407 circuit kilometres (ckm) in fiscal 2019 to 485,544 ckm in fiscal 2024.

There has been strong growth in the transmission system at higher voltage levels and substation capacities. This is a result of increased requirement of the transmission network to carry bulk power over longer distances and at the same time optimise the right of way, minimise losses and improve grid reliability.

The total transmission line length (above 220 kV) has increased at 3.3% CAGR from fiscal 2019 to fiscal 2024. This increase can also be attributed to an increase in the commissioning of the 765-KV lines, growing at a CAGR of ~6% over the same period. 765 kV lines have higher transfer capacity and lower technical losses thereby reducing the overall number of lines and rights of way required to deliver equivalent capacity. Performance in a transmission line improves as voltage increases and as 765 kV lines use one of the highest voltage levels, they experience comparatively lesser amount of line loss. 800 kV lines have also shown strong growth momentum, rising at 9.5% CAGR over the last 5 fiscals, majorly owing to strong investments by the central sector.

Inter-regional power transmission capacity of the National Grid has grown strongly from 99,050 MW in fiscal 2019 to 118,740 MW in fiscal 2024, at a CAGR of 3.7%. Subsequently, transformation capacity rose from 899,663 MVA in fiscal 2019 to 1,251,080 MVA in fiscal 2024, growing at a CAGR of ~6.8%.

2.4.3.1.1 Plans to increase grid infrastructure

Report on “Transmission System for Integration of over 500 GW RE Capacity by 2030” published by CEA portrays the broad transmission system roadmap for reliable integration of 537 GW RE capacity by the year 2030.

The length of the transmission lines and sub-station capacity planned under ISTS for integration of additional wind and solar capacity by 2030 has been estimated as 50,890 ckm and 433,575 MVA respectively at an estimated cost of Rs 2442 billion.

The present inter-regional transmission capacity is 118,740 MW. With the additional inter-regional transmission corridors under implementation/planned, the cumulative inter-regional transmission capacity is likely to be about 150,000 MW in 2030

Furthermore, central government has planned to achieve 500 GW capacity from non-fossil fuel-based energy sources by 2030. Solar and wind will pay a more role in achieving the said target. The share of renewable energy (incl. hydro and energy storage) in the installed capacity mix is expected to reach ~62% in fiscal 2029 from ~43% in fiscal 2024.

Such multifold expansion plans also require large scale development in transmission sector. This is mainly because large scale grid connected solar and wind plants are usually located in the far-flung areas, where there is limited existing transmission infrastructure. Moreover, renewable energy is not well distributed across states and is in-firm in nature. Robust transmission planning is required to optimize the high costs, utilization levels and losses associated with transmission system to transmit the power generated to load centres is critical.

For enabling growth of RE capacity, areas which have high solar and wind energy potential, needs to be connected to ISTS, so that the power generated could be evacuated to the load centres.

MNRE/SECI have identified REZs totaling 181.5 GW for likely benefits by the year 2030. These REZ’s are in eight states as detailed below:

2.4.4 Cost competitiveness and other advantages of solar power

The sun is the most abundant source of energy on the planet, and it is completely replenishable. Solar energy plants do not pollute the environment and take less time to build than wind and hydroelectricity power plants. Solar energy plants can be set up anywhere, especially in country like India where sunshine is almost available for more than 8-10 months across country.

With Energy storage solutions, solar can become an affordable energy option for round the clock supply.

Table 4: Comparison of solar with different energy sources

Parameter	Solar	Wind	Hydro	Biomass	Coal
Utilization Factor	~20-25%	~25%-30%	~40-45%	70-80%	80-85%
Clean energy	Yes	Yes	Yes	No	No
Time to construct	Less	Moderate	More	Moderate	More
Initial Cost	Moderate	High	Very high	High	High
O&M Cost	Low	High	Low	Moderate	Moderate
Impact of environment	Low	Medium	High	Medium	High
Water requirement for cleaning/cooling purpose	Low	NA	NA	Medium	High

Source: Industry, CRISIL MI&A Consulting

2.4.5 Key challenges/bottlenecks in solar power development

Notwithstanding the high potential of solar energy, it is mired with some challenges. Overcoming these challenges will be critical for the successful implementation of solar projects.

Availability of contiguous parcels of land: With rapid capacity additions and intense competition, it becomes imperative for developers to acquire land at competitive costs and in areas with high levels of solar irradiance. The 40 GW solar park scheme, which provides land to successful bidders for setting up of the projects, is facilitative in this aspect.

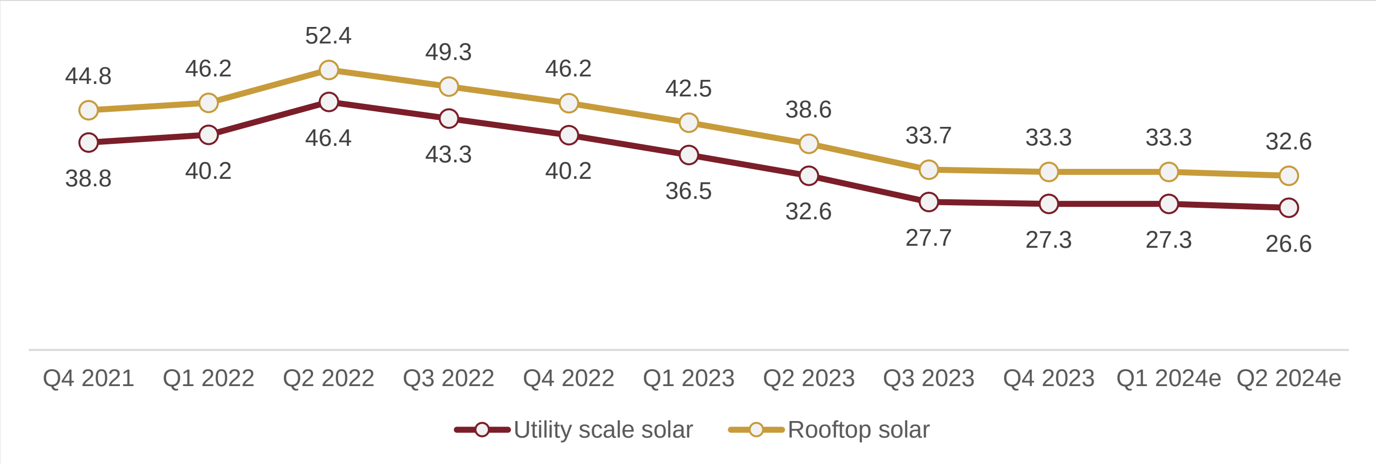
Adequacy of evacuation infrastructure: Grid integration of renewables is key to the sector's growth. Instances of delay in readiness of transmission infrastructure at solar parks have caused concern among developers. However, an aggressive roadmap to add an incremental ~100 GW via new schemes and existing available capacity to the grid should be adequate for the expected solar capacity additions' timely execution is critical

Availability of low-cost capital: With the emergence of several large players in the sector, scale, and experience have aided fund-raising to an extent, especially with the backing of several foreign investors. However, after factoring in the weak rupee, the conservative risk appetite of lenders, and other added cost pressures, it is imperative for developers to maintain prudent capital management over the long term. To mitigate these factors, developers have been tapping alternative/new routes to raise money from time to time.

Furthermore, the other key monitorables are deterioration in the financial profile of distribution utilities resulting in offtake issues and payment defaults, declining power deficit, and aggressive bidding.

2.4.6 Project capex and O&M cost movements

Figure 22: EPC cost, Rs million/ MWp



Source: Industry, CRISIL MI&A Consulting
Note: EPC cost for utility scale projects is estimated using imported mono-crystalline modules in a fixed tilt layout and central inverters. EPC cost for rooftop solar systems is estimated for a typical industrial installation on a metal roof.

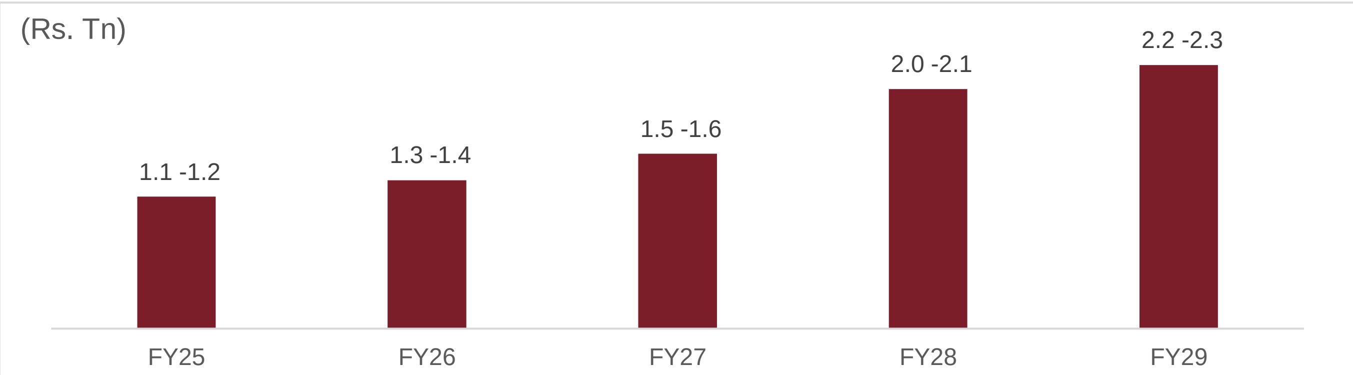
Solar project CAPEX trend has largely followed global module price trends. On the O&M front, costs have decreased by around 30% in the last 3-4 years to around Rs 0.18-0.25 Mn/MW/annum due to experience gained by service providers coupled with technology adoption including robotic cleaning.

2.4.7 Expected investment in solar segment

CRISIL MI&A Consulting foresees a surge in solar power capacity, reaching 125-130 GW from fiscal years 2025 to 2029, significantly surpassing the 50-55 GW added between fiscal years 2019 and 2024. This growth is primarily spurred by robust government backing, demonstrated through an aggressive tendering strategy. Key catalysts include technological advancements (e.g., floating solar and module efficiency), affordable financing, and supportive policies. Nevertheless, escalating component prices and added taxes may elevate capital expenditures, affecting the willingness of state discoms to procure solar power.

CRISIL MI&A Consulting expects consolidation to continue with the ongoing quest for a larger portfolio among big players and several smaller firms exiting the sector due to increased competition. CRISIL MI&A Consulting estimates investment requirements to the tune of Rs. 8-8.5 trillion over fiscals 2025 to 2029 as compared to Rs 3.5-3.6 trillion over fiscals 2019 to 2024.

Figure 23: Expected investments in the solar energy generation sector in India



Source: Industry, CRISIL MI&A Consulting

2.5 Overview of Wind sector in India

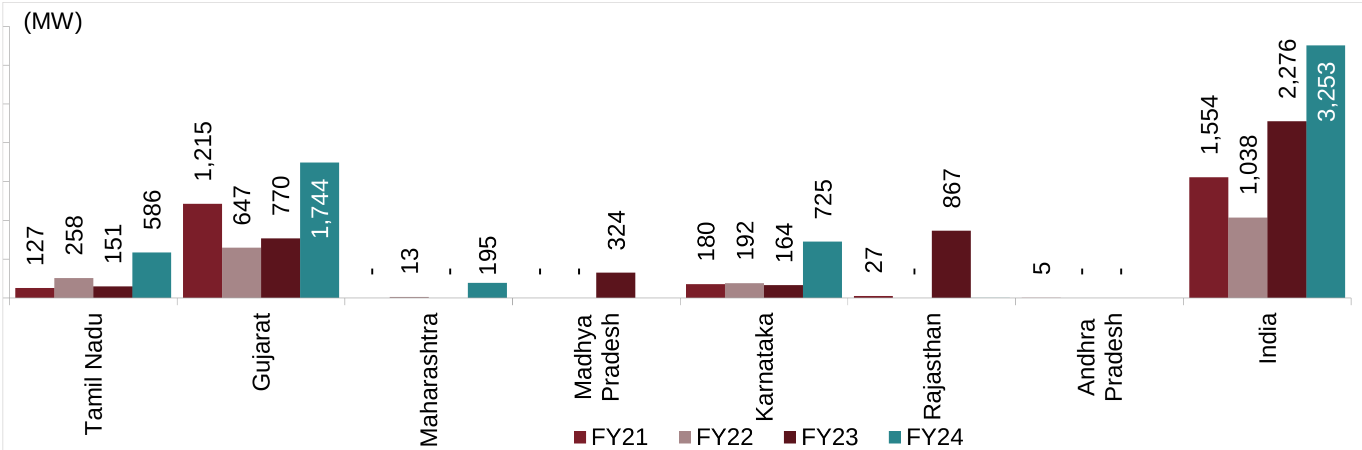
2.5.1 Evolution of Wind Power in India

India has a vast wind energy potential, estimated at 695.5 GW at 120 meters above ground level (AGL) as per estimates by the National Institute of Wind Energy.

India has the fourth largest installed wind power capacity in the world, with ~47 GW as of 30th September 2024. Wind power accounted for nearly 10.5% of India's total installed utility power generation capacity. India's wind power installed capacity increased at a CAGR of approximately 7% from 26.8 GW in Fiscal 2016 to 47.4 GW in Fiscal 2025 (As of September 2024). Wind power capacity is mainly spread across the southern, western, and northwestern states of India. Leading states in wind power installations include Tamil Nadu, Gujarat, Maharashtra, Rajasthan, and Karnataka. Wind capacity additions

Wind power has witnessed a healthy capacity addition of ~1.48 GW in six months of fiscal 2025 vis-a-vie ~3.25 GW in Fiscal 2024. In fiscal 2023, ~2.28 GW wind power capacity was installed on the back of commissioning under several schemes that have been pending - SECI Tranche IV, V and VI. The rising trend of hybrid power (solar plus wind) projects coupled with moderation and stabilisation in key commodity prices has also supported growth.

Figure 24: State-wise wind capacity additions (MW)



Source: MNRE, CEA, CRISIL MI&A-Consulting

The top five states (Gujarat, Tamil Nadu, Karnataka, Rajasthan, Maharashtra) make up ~84% of the installed wind capacity (as of 31 March 2024), with some regions within these states accounting for most wind power projects. Since April 2021, ~80% the new capacity additions have happened in 3 states – Gujarat, Tamil Nadu, and Karnataka.

The weighted average discovered tariffs for allocated capacity of competitively bid projects for FY24 is Rs 3.4/kWh as against Rs. 3.1-3.3/kWh tariff required for earning 10-13% equity IRRs. The weighted average tariff of allocations in FY 2023, have averaged at Rs 3.0/kWh, providing an indication that developers are factoring in increased commodity costs and other execution related risks. The latest auctions held in Feb 2024 recorded a weighted average tariff of Rs 3.63/kWh.

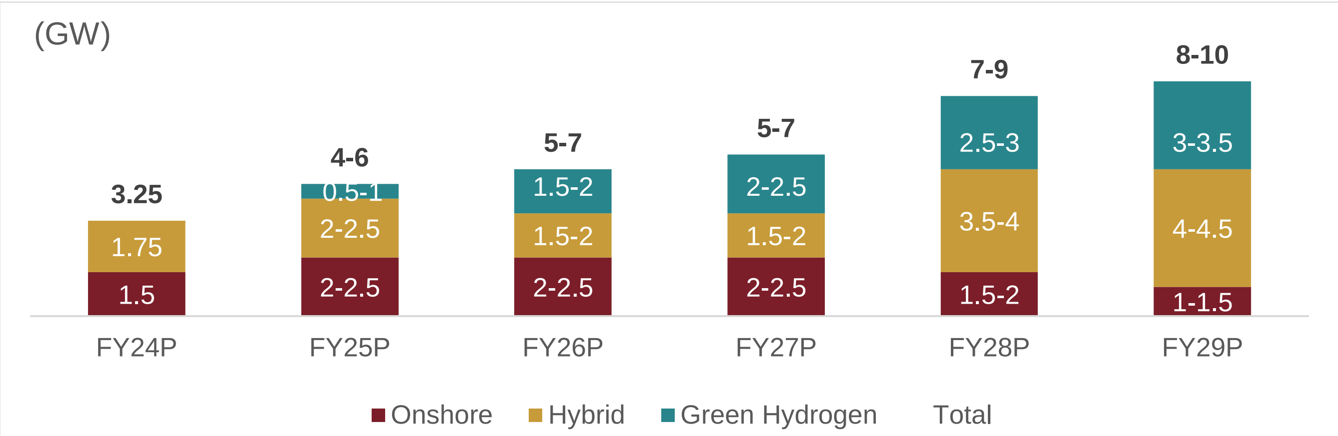
2.5.2 Outlook for capacity additions

CRISIL MI&A-Consulting expects capacity additions to grow over the next five years led by pipeline build-up under existing schemes and new tendering schemes, improvement in technology, thrust on green hydrogen, renewable generation obligation and mixed resource models (RTC, hybrid, FDRE etc.). Round the Clock renewable energy (RTC-RE) project is a form of supply that combines storage system such as battery energy storage system or PSP with Solar, Wind or Hydro to meet a demand at a desired availability and cost. However, incremental challenges pertaining to wind-site/land availability, grid connectivity, and viability at low tariffs due to elevated capital cost pose challenges for the sector.

Led by India's ambitious clean energy targets declared under NDC, focus on clean segments such as wind is expected to continue coupled with a healthy pipeline existing in the segment. The government policy to tender 10 GW wind capacity annually till fiscal 2028 will further boost the capacity additions. The Central Government is also contemplating for renewable generation obligation (RGO) mandating thermal power generators to generate certain % of their additional capacity from renewable energy. Capacity additions over the long term will also be driven by increased hybrid tenders, storage and new business model-based tenders. Central government allocations under relatively strong off-takers such as SECI and PTC, reduces risk and would support developer interest. State allocation, on the other hand, has slowed as several states have instead signed power sale agreements (PSAs) with PTC and SECI for procurement of wind power to help fulfil their non-renewable purchase obligation targets.

Considering above, CRISIL MI&A-Consulting expects wind power capacity additions to remain at ~34-36 GW over fiscals 2025-2029, higher than the ~10 GW seen over fiscals 2018-2023.

Figure 25: Expected annual wind power capacity additions



Source: CRISIL MI&A Consulting

Key factors to drive wind energy capacity additions

New tender opportunities

New opportunities have emerged in the wind sector in India with SECI tendering projects including hybrid, round-the-clock, peak power supply and FDRE projects, all of which require a mix of resources, including wind.

Improved technology

Newer wind turbines are being launched that have higher rated capacity and higher hub height (120 -140 m), which can be set up at low-quality wind sites. Technological advancements have allowed players to set up windmills in states/sites with lower wind density. Based on our estimates, for every 100-bps change in PLFs, equity IRRs improve by 100-150 bps. Innovations in blade technology with lower weight which allows for building longer blades with lower mass. These improvements in technology will enable lower levelised cost and capacity additions outside the windy region, thereby driving capacity additions.

Large-scale central allocations

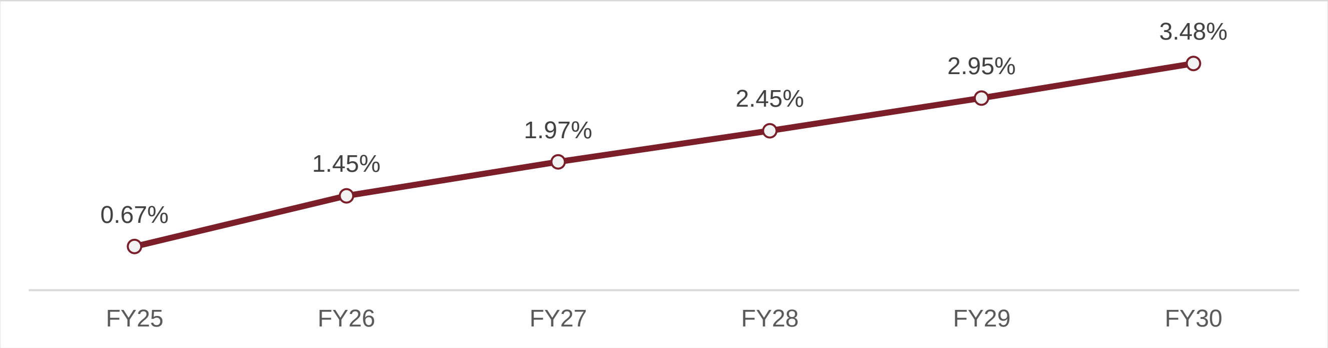
Post competitive bidding of 1 GW by SECI in February 2017, SECI further allocated ~15 GW (excluding cancelled contracts) of capacities over March 2017-Feb 2024 through wind only schemes. MNRE has outlined further plans to tender 10 GW of capacity each year by RE Implementing Agencies (like SECI, NTPC, NHPC, SJVN). This bodes well as central sector PPAs have lower counterparty risk compared with PPAs directly with discoms. The latter are known to delay payments to developers and have poor financial ratings, while SECI and PTC are better rated and provide various payment security mechanisms (LCs, payment security fund and SECI, NTPC, NHPC, SJVN being party to the tripartite agreement).

Major payment security mechanisms to de-risk investment in renewable energy inter- alia include Letter of Credit (LC); Payment Security Funds and Tripartite Agreement (TPA) between Ministry of Power, RBI and State Government (if applicable). These instruments are invoked in case of delays/default in payment to Renewable Energy Generating Companies and have been further strengthened by the notification of the Late Payment Surcharge Rules, 2022.

Upward revision in RPO targets

The MoP provided a new RPO long-term trajectory for wind energy till fiscal 2030 which proposes target of 0.67% for wind in fiscal 2025, increasing consecutively to 3.48% in fiscal 2030 for wind.

Figure 26: Revised Wind RPO trajectory



Source: MoP; CRISIL MI&A-Consulting

Most states in India have set lower RPO targets (pan-India avg. non-solar RPO target in fiscal 2023 is 8.9% vs 10.50% required as per MoP), resulting in higher compliance vis-à-vis the set targets. To meet the increased targets, states would have to procure more RE either via the REC route (which still leads to capacity additions) or via competitive bid out capacities. Waiver of ISTS charges by CERC for all projects set up until fiscal 2025 also enables states with low RE potential to procure from more able states. However, RPO compliance is dependent on strict enforcement by regulatory authorities. Amendment to the Electricity Act, 2003 has been proposed to include stricter provisions on penalty for non-compliance; however, this is yet to be passed.

Accelerated depreciation

Historically, particularly in fiscals 2015 and 2016, accelerated depreciation (AD) had been a key driver for capacity additions. However, going forward, CRISIL expects capacity additions under this mode to be restricted only to large conglomerates in other unrelated businesses but seeking tax breaks. While AD was halved to 40% from April 2017 onwards, it will continue to support additions in open-access segment.

High industrial tariffs in select states

In states such as Maharashtra, Karnataka, Tamil Nadu, and West Bengal, where industrial tariffs are high (Rs 6-6.5/unit), wind power is an attractive option since generation cost is about Rs 3.0-4.0/kWh. Capacity can be set up via the open-access mode, i.e., bilateral agreements directly with consumers such as commercial/industrial entities.

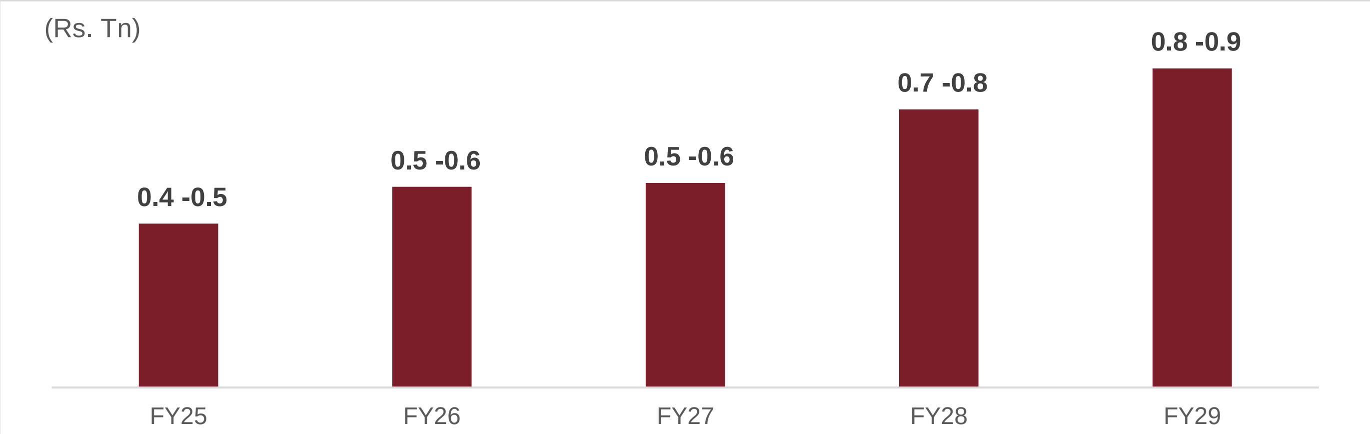
2.5.3 Movement of the project capital costs and O&M costs

Increase in prices for key commodities (4% and 26% y-o-y rise in cement and steel prices, respectively, in fiscal 2022 and further increase of ~3% and 4% in fiscal 2023), along with supply chain disruptions due to Russia-Ukraine crisis, contributed to cost escalations and higher capital cost for wind projects. Further, the shift in trend of larger size turbines of over 3 MW has further increased cost pressures. In fact, the commodity price surge has been one of the principal reasons for stagnation of growth in the industry as it has translated into lower project returns, which has impacted project commissioning since the second half of fiscal 2022. CRISIL MI&A-Consulting expects key commodity prices to reduce by 5-7% during fiscal 2025. This is expected to reduce the capital costs by 2-3%.

2.5.4 Expected investment in wind segment

CRISIL MI&A Consulting expects wind power capacity additions to grow over the next few years, mostly driven by green hydrogen, central and state allocations, and a pent-up pipeline. The previous change in the bidding mechanism has caused a slowdown in the industry due to a significant fall in tariffs, where both bid response and profitability for OEMs have dropped, however, new bidding guidelines along and increased tendering till FY28 to boost prospects in the sector. CRISIL MI&A Consulting expects wind capacity additions of 34-36 GW over fiscals 2025-29, entailing investments of ~Rs 2.75-3.0 trillion over the period.

Figure 27: Expected investments in the wind energy generation sector in India



Source: CRISIL MI&A Consulting

2.6 Overview of Wind Solar Hybrid sector

2.6.1 Overview of Indian wind solar hybrid market

WSH is fast becoming the preferred RE option in India. Although the MNRE has not yet set a generation target, the nascent sector has received strong support from SECI and several state governments. There are two types of WSH projects — pure-play ones and those with storage. There are also projects that may come up under the government's RTC power scheme, which has a mandatory 51:49 blend of RE and thermal.

India has introduced RTC generation tenders, including hybrid tenders to strengthen clean generation combining solar, wind and storage technologies. The MNRE introduced the National Wind-Solar Hybrid Policy on May 14, 2018. The main objective of the policy is to provide a framework for the promotion of large grid-connected wind-solar PV hybrid systems and efficient utilisation of transmission infrastructure and land. It also aims to reduce the variability in renewable power generation and achieve better grid stability. As on April 30, 2024, hybrid projects of aggregate capacity 15022.82 MW are under construction in the country. It is expected that India will witness 15-17 GW of WSH capacity addition in the next five years (fiscal 2025 to fiscal 2029), of which around 6-7 GW will be from wind.

2.6.2 Key growth drivers

Wind Solar Hybrid segment in India is experiencing rapid growth, driven by several key factors:

- **Potential:** India has around 696 GW (120 m hub height) wind potential and around 750 GW of solar potential. Currently only around 10% of the potential is developed and balance 90% of the potential yet to be exploited. This provides huge opportunities for wind and solar development.

- **Geographical advantages:** India's coastline provides high wind speed as well as excellent solar potential. State such as Gujarat, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh have excellent wind as well solar potential. Such an advantage provides a great opportunity for hybridisation. Depending on the project requirements, the hybrid projects can be co-located or located in different locations also making it more flexible even if natural resources are located in different places.
- **Complementary resources:** Wind and solar sources complement each other. Due to their inherent characteristics, they generate power during different times of the day as well as seasons. Wind power is at its maximum during nighttime whereas solar power is available only during the day. Therefore, for 24X7 supply, they complement each other and hence WSH projects provide more reliable power and can be used for round-the-clock (RTC) supply.
- **Resource optimisation:** Co-located WSH plants can help in resource optimisation. With optimum land utilisation and infrastructure sharing, the wind and solar resources can be optimally utilised leading to better CUF as well as cost optimisation. With energy storage facilities, the WSH plants help in better grid management and higher penetration of renewable energy into existing power systems.
- **Policy push:** Government of India's policy push has also helped the WSH segment. With increased ROP targets, VGF funding, PLI schemes, solar park schemes, simplified land allocation has helped both the resources (wind and solar) to thrive.

2.6.3 Constraints in setting up hybrid power plants

Lack of good sites

WSH projects require wind and solar plants to be co-located to inject power into the same pooling station. This means the ideal location should have good irradiation and experience high wind speeds. But such locations are hard to find, especially as all major windy areas with strong grid evacuation facilities have been saturated. Hence, the industry has demanded that wind and solar plants of a WSH project be allowed to operate from different locations. This will also help bring down tariffs owing to better plant optimization levels. The only advantage of co-location is better optimization of transmission infrastructure. However, CRISIL MI&A Consulting believes the advantage from reduced tariff (when wind and solar units are located separately) is much higher than the benefit of improved transmission capacity optimization (with co-location).

Grid balancing requirement poses implementation risks

Developers are required to balance the grid before injecting electricity generated from a co-located WSH plant. This means they need to simulate the ideal wind and solar generation mix from the plant, in order to optimize the hybrid curve. This may lead to additional implementation risks for a developer.

Optimal sizing

The size of the WSH plant differs from state to state depending on the resource availability. Optimal sizing of storage is also a pertinent question. Overloading or oversizing may lead to underutilisation during the peak generation period (daytime in summers or night-time in monsoons) resulting in storage capacity remaining unutilised or idle.

Higher tariff

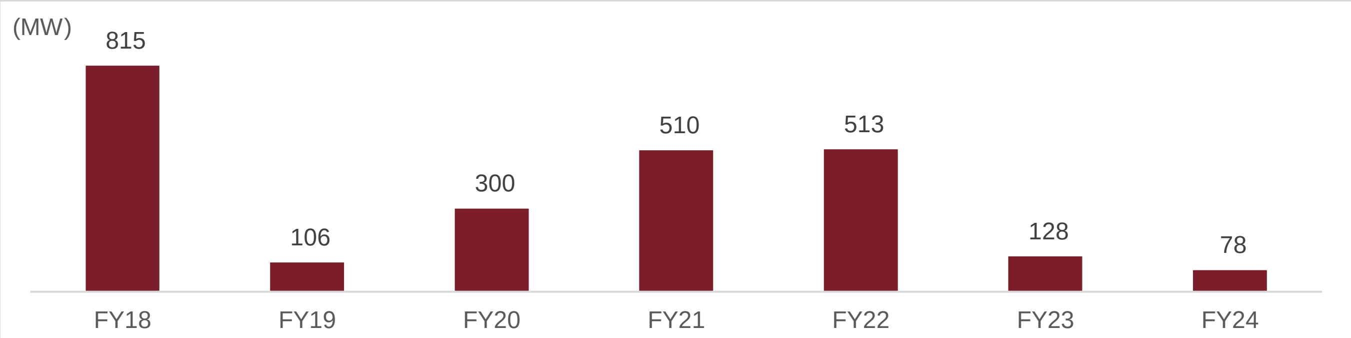
The average tariff for WSH projects is Rs 3.15-3.20 per kWh today — higher than solar tariff, which has dropped to Rs 2.55-2.56 per kWh in recent bids, and comparable to wind tariff, which has remained sticky at Rs 3.40-3.75 per kWh. And although cross-subsidising costly wind power with low-cost solar will provide some price cushion at the lower end, the pricing needs to be attractive to make WSH competitive.

2.7 Review of Large hydro Power generation in India

2.7.1 Overview of historical hydro capacity additions

In the last 6 years (fiscal 2018 to fiscal 2024) India has added only ~2,450 MW large hydro capacity. Central sector has led the capacity additions with commissioning of 600 MW of Kameng HEP, 330 MW Kishanganga followed by Private sector with 99 MW of Singoli Bhatwari HEP, 100 MW Sorang HEP, 180 MW Bajoli Holi HEP, 113 MW of Rongnichu HEP. No capacity has been added as of September 2024 in fiscal 2025.

Figure 28: Annual hydro capacity addition



Source: MoP, CEA, CRISIL MI&A Consulting

The reassessment study (regarding basin-wise reassessment of hydroelectric potential in the country) was carried out by CEA during the period 2017-23. As per the study, the assessed hydropower potential from major / medium schemes (i.e., schemes having capacity above 25 MW) is about 133.4 GW. As of March 2024, 46.93 GW (35%) has been developed and 18.08 GW (13.6%) is under construction out of 133.4 GW of potential.

Presently 38 no. of hydroelectric project (above 25 MW) totalling to 15,273.50 MW are under implementation. Out of these, 29 no. HEPs totalling to 14,037.5 MW are under active construction and 9 no. HEPs totalling to 1236 MW are presently stalled.

2.7.2 Assessment of current support policies and issues in hydro power sector

- **Declaring Large Hydro Power (LHPs) (> 25 MW projects) as renewable energy source:** To accelerate the growth of hydropower in the country, the MoP has set a target of 30 GW hydro capacity addition by 2030. In March 2019, MoP has declared Large Hydro Power Plants (LHPs) with the installed capacity > 25 MW as a renewable energy source.

  - **Putting in place a Hydro Purchase Obligation (HPO):** The MoP has set separate HPO targets. As per the MoP Notification dated 20th October 2023, the HPO targets range from 0.38% in fiscal 2025 to 1.33% in fiscal 2030.

  - **Tariff rationalization measures for bringing down hydro power tariff:** Tariff rationalization measures including providing flexibility to the developers to determine tariff by back loading of tariff after increasing project life to 40 years, increasing debt repayment period to 18 years, and introducing escalating tariff of 2%.

  - **Budgetary support towards cost of enabling infrastructure, i.e., roads/bridges:** The budgetary support for Enabling Infrastructure i.e., roads/ bridges for Hydropower projects would be provided by the MoP. The limit of this budgetary support would be Rs. 15 million per MW for projects up to 200 MW and Rs. 10 million per MW for projects above 200 MW with construction starting after March 2019.

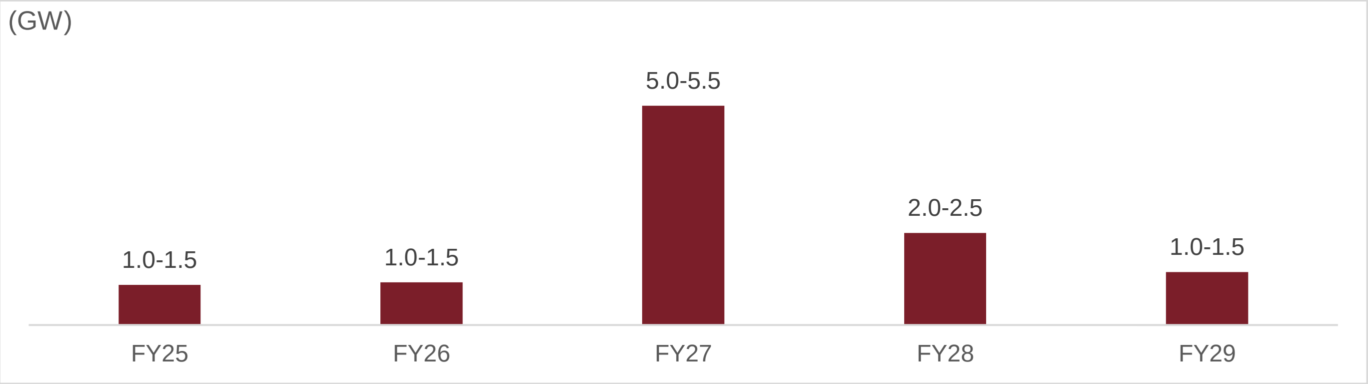
- **Waiver of ISTS charges:** 100% ISTS charges waiver for new hydro power projects in which construction work is awarded and PPA is signed on or before 30 June 2025. Subsequently, part waiver of ISTS charges, in steps of 25% from 01.07.2025 to 01.07.2028, has been extended for HEPs for which construction work is awarded and PPA is signed up to 30.06.2028.

2.7.3 Outlook on hydro capacity additions in India

CRISIL MI&A Consulting expects 11-12 GW of hydro power capacities to be commissioned (out of 14 GW presently under construction) over fiscals 2025-29 as against ~2.5 GW added during fiscals 2018-24. CRISIL MI&A Consulting further believes the central sector (NHPC and NTPC) will lead capacity additions in hydro power with 4-5 GW additions, followed by the state sector (Andhra Pradesh, Tamil Nadu, Himachal Pradesh, Uttarakhand) amounting to 2-3 GW and about 3 GW would be installed by other JV utilities such as SJVN, THDC, etc. Several private projects with aggregate capacity of 390 MW are also in the advance stages of construction and are expected to get commissioned by fiscal 2026.

Investments by hydro power giant NHPC rose by a staggering 52% to Rs 108.57 billion in fiscal 2024 from the revised estimates of Rs 71.29 billion for fiscal 2023. This is expected to provide the much-needed push to hasten the completion of hydro projects.

Figure 29: Expected annual hydro capacity additions



Source: CEA; CRISIL MI&A Consulting

2.7.4 Key issues/ challenges in hydro power projects in India

The development of hydro power projects faces difficulties in land acquisition, lack of infrastructural facilities like road and communication, environment and forest issues, resettlement and rehabilitation problems, paucity of funds, longer gestation period, geological surprises, inter-state aspects, non-availability of hydrological data, security restrictions in border areas, lack of adequate skilled manpower and contractual problems.

Hydropower projects involve submergence causing the displacement of project area people. The rehabilitation of project affected people is also a major issue. Further, getting forest and environment clearances also delays the project. Many hydropower projects with common river systems between adjoining states are held up due to a lack of inter-state agreements and disputes on water-sharing.

Hydro projects require higher upfront costs to address greater complexities in design, engineering, environmental and social impact mitigation, etc. Most hydro projects take at least 5-6 years to construct which increases the interest during construction. Although the operating cost of hydro projects are minimal, and the project life is longer but there are other multiple factors that make hydropower difficult to finance. The technical challenges in hydropower development often result in time and cost overrun, posing additional risks for financiers. Delay in cash inflows increase uncertainty and risks, resulting in higher risk premium on financing charges.

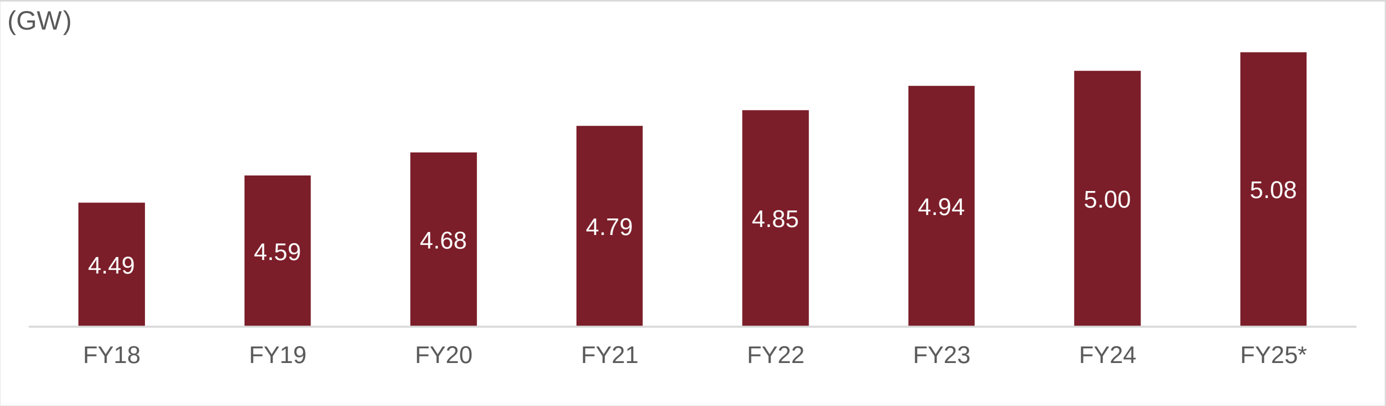
Hydropower projects are mostly located in remote areas which do not have adequate demand for electricity. This creates the requirement for developing enabling infrastructure for power evacuation. It also requires the development of associated infrastructure such as roads and bridges in the area.

2.8 Overview of Small Hydro sector

Hydro Power projects are classified as large and small hydro projects based on their sizes. In India, Hydro Power plants with capacity of 25 MW or below are classified as Small Hydro. As per MNRE, the estimated potential of small / mini hydel projects is 21,133 MW from 7,133 sites for power generation. Of the total 21.1 GW of potential, over 60% lies in these five states namely, Karnataka, Himachal, Arunachal Pradesh, Jammu & Kashmir and Uttarakhand which includes over 45% of the total 7,133 sites.

As of September 2024, the installed capacity of SHP is 5075.75 MW. In the last 5-6 years only ~483 MW of capacity was added at a CAGR of ~1.9%. Of the total potential, only 26% has been tapped so far.

Figure 30: Installed capacity of SHP



**As pf September 2024, Source: CEA; CRISIL MI&A Consulting*

2.8.1 Challenges in the small hydro power sector

SHPs are environmentally friendly as they do not encounter the problems of large-scale land acquisition/deforestation and displacement of human settlements. Being located in remote locations and at the tail end of the transmission network, they help in improving voltage levels and can also feed into the local grid in case of a major grid failure, thereby avoiding complete black out. They improve the socio-economic condition of the adjoining areas as well as a large chunk of the investment made in the project feeds into the local economy. Moreover, Micro Hydel Projects (MHP) and Watermills also have the potential to meet the power requirements of remote areas, helping the local people in developing small scale industries.

Despite various benefits, SHP projects in general faces various implementation challenges. Developing an SHP involves complex procedures and requires diligent steps to decide the site, unit size and generating equipment. Many SHPs are scrapped due to low consumption of electricity and sometimes very small size SHP adversely affect the plant's viability. Usually, the life span of SHP is 35–50 years but some SHPs are closed down even before the end of the expected life due to faults in design and construction, obsolete equipment or non-availability of grid extension.

The river flow changes with season thus, measurement of flow rate should be carried out throughout the year in order to obtain proper discharge data. However, the absence of genuine data causes improper estimate of the power potential. Sedimentation is another issue that is often faced in developing hydropower projects. Absence of geological and sedimentation data has resulted in wrong design and caused closure of many hydropower projects. Problems are faced in acquiring land due to delays in obtaining permission from community or from government department like forest and environment.

3 Energy storage

3.1 Overview of energy storage technologies

Energy storage technologies can be broadly divided into four segments – mechanical, electromechanical, chemical, and thermal storage. However, only a few technologies are available on a commercial scale worldwide. Technologies such as pumped hydro storage (PHS), lithium, and sodium batteries are available commercially and are being used for different applications. Other technologies such as compressed air, flywheel, thermal and hydrogen storage, have yet to demonstrate their commercial viability at scale.

Pumped Hydro Storage Project (PHSP) is the most widely used and commercially available means of energy storage technology in India. However, the total installed capacity of PHSP is minuscule (~4% of the exploitable potential) in the country.

3.2 Pumped hydro storage projects in India

3.2.1 Potential of PHS in India

The identified potential of PHS in the country is about 124 GW (comprising 114 PHSP). However, the operational capacity of PHSP is merely 4.7 GW, which indicates the large potential growth in this segment.

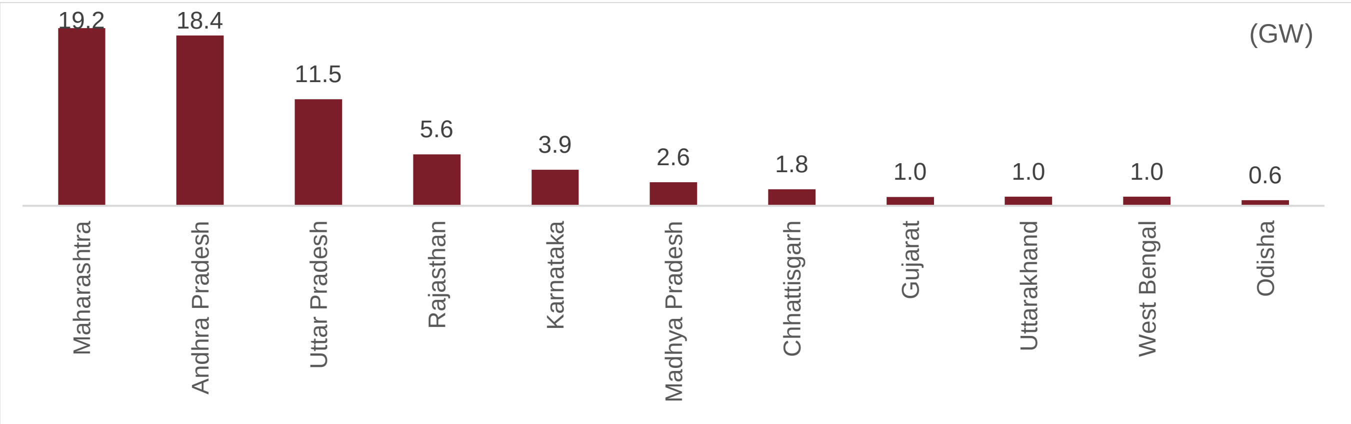
3.2.2 Overview of PHS projects in India

As on August 2024, India has an installed capacity of 4.75 GW of on-river pumped storage projects in operation. Currently, out of the 8 pumped storage schemes with aggregate installed capacity of 4.75 GW, only 6 schemes with aggregate installed capacity of 3.31 GW are being operated in pumping mode.

There has been limited traction for PHS projects which is evident in tendering activities. As compared to RE sources, the tendering for PHS projects is very low. PHS projects have their own challenges which is also reflected in negligible capacity addition in last 5-6 years, largely on account of limitations in identification of suitable sites, relatively complex implementation, long gestation period and high capital cost that make viability a major issue. The guidelines released by the MoP in April 2023 will address many of these issues. However, traction in PHS projects will depend on steps to make tariffs attractive to discoms and mitigate implementation risk to fuel private sector participation.

PHS projects with aggregate capacity of 66,000 MW, are at different stages of development and are distributed among 12 States as shown in the below figure. Of these, over 60% of capacity is expected to be installed in two states, namely, Andhra Pradesh and Maharashtra.

Figure 31: State wise total PHS capacity at different stages of development as of August -2024



Source: CEA, CRISIL MI&A-Consulting

3.3 Battery energy storage

Battery Energy Storage Systems (BESS) is another form of storage technology which has gained traction in the last few years. It has a very high energy density, making it appropriate to offer ancillary services. More importantly, BESS can be installed easily, requires less time for setup, and can be used for a wide range of grid support activities, such as energy time shift, distribution deferral, and energy arbitrage etc. The technology is yet to achieve its full potential to provide grid support services, and comes with high investment cost and changing technology, and therefore has associated risks. Further, batteries would require replacement or disposal after 10 - 12 years, depending upon usage and type of technology.

3.3.1 Comparison of PHS vs BESS

A comparative analysis of PHS and BESS technology is mentioned below:

Table 5: Comparison of PHS and BESS

Parameters	PHS	BESS
Capital cost	Total capital cost for a closed loop PHS ranges around ~Rs. 50-60 Mn/ MW*	Lithium-ion battery storage can range from USD 550-700/kW (for a four-hour storage solution)
Efficiency	75-80%	80-85%
Land requirement	~2,000 m^2/MW	~100 m^2/MW
Ideal storage duration	6 – 12 hours	Upto 4 hours
Response time	30-90 seconds	In milliseconds
Project life	40 – 50 years (life of dam/reservoir is over 80 years)	10-12 years
Construction period	4 – 5 years, it also depends upon other external and socio-political factors	1 year
Operating cost	Lower	Higher since batteries need to be replaced after certain period
Estimated levelised tariff	Rs 4 – 6 per kWh	Rs 5 – 7 per kWh
Environmental impact	Need substantial reservoirs which may cause environmental consequences, such as habitat destruction and changes in water flow downstream	Disposal of batteries is a major concern. If not taken care properly, may end up in landfills, posing risks of corrosion, flammability, and environmental contamination
Execution and operational risk	• Long approval process for land, environmental and forest clearances • Rehabilitation and resettlement issues • Limited naturally suitable sites • Long gestation period with high construction risk • Managing water requirement, especially in case of any adverse events	• Shortage of rare minerals and metals • Limited manufacturing capacity • Cost volatility • Performance deterioration and fire risk in extreme ambient conditions • Constant degradation and self-discharge

**Capex may vary based on no. of reservoirs to be built, topography/ region, etc.*
Source: Industry, CRISIL MI&A-Consulting

3.4 Policies and key driving factors for storage projects

Over the last 2-3 years, the government has taken several initiatives to promote energy storage through standardisation of the policy and regulatory framework by issuing guidelines, regulations, changes in bidding mechanisms, etc. The summary of key policy measures is listed below.

Figure 32: Key policy measures for storage projects

2021	2022	2022	2023	2023
• In June 2021, ISTS charge waiver for ESS projects commissioned on or before June 30, 2025 • In Jun 2021, PLI scheme for manufacturing of ACC batteries was launched	• In Jan 2022, CERC issued Ancillary Services Regulations. Storage projects allowed to participate in secondary and tertiary ancillary markets • In Mar 2022, govt formulated Guidelines for Procurement and Utilization of BESS as part of GTD assets	• In Dec 2022, CEA issued National transmission system plan 2030 in which district-wise BESS capacity that needs to be set up by 2030 is specified • In Apr 2023, MoP issued guideline for PHS which provides framework for bidding and allotment of PHS sites to developer	• In Jun 2023, Electricity (amendment) Rules, 2023, MoP allowed the energy stored in BESS to be considered for captive status • In Jun 2023, MoP issued bidding guidelines for FDRE based tenders which require mandatory ESS deployment	• In Aug 2023, MoP issued National Framework for Promoting ESS • In Sept 2023, the govt approved VGF scheme to develop 4 GWh BESS capacity by 2030

Source: MoP, MNRE, CRISIL MI&A-Consulting

The GoI has taken several measures such as providing legal status to storage, energy storage obligation, waiver in ISTS charges, captive status for energy stored in BESS. These measures are expected to expedite the deployment of storage systems and thereby accelerating the growth of India's RE capacity. MNRE in its RE bidding guidelines provided the option to the RE developer to tie up with energy storage system developers to meet the project parameters to provide firm and dispatchable RE power.

Pumped hydro projects

Pumped storage is a proven technology and has been in use for decades to support/balance grids. Unlike other storage technologies, performance of PHS is quite reliable on long term basis. PHS offers energy storage of 6 to 12 hours which is well suited for energy-shifting applications, wherein excess RE generation can be shifted to peak demand periods of late evenings. The long project life of PHS has the potential to provide a stable and consistent cash inflow for about 40 years. This healthy cash-flow profile enables favourable project financing arrangements for PHS, such as lower loan rates and a higher debt-equity ratio.

For PHS projects, several provisions are proposed to facilitate the allocation and development of PHS under the guidelines such as no upfront premium for project allocation, monetization of ancillary services, and participation in all market segments. Financial institutions are expected to provide long-term loans with competitive rates, and tax and duty incentives are provided to encourage development. States may reimburse State Goods and Services Tax (SGST) on hydropower project components, provide exemptions in stamp duty and registration fees for land, and offer land on an annual lease rent basis. The guidelines also mandated using green finance like sovereign bonds or concessional climate finance for funding such projects.

To speed up the clearance process, CEA has also established a Single Window Clearance Cell for approval of PHSPs. Additionally, MoP has provided budgetary support of Rs. 10 Mn/MW (for projects above 200 MW) and Rs. 15 Mn/MW (for projects below 200 MW and up to 25 MW) for the construction of roads and bridges for hydropower projects (including PHS projects) whose construction started after March 2019.

Battery energy storage projects

BESS can be used for multiple applications such as voltage and frequency regulation, spinning reserves, peak shaving. With rising R&D and subsequent improvement in technology as well as increasing scale, the cost competitiveness of such solutions to improve. For batteries, a special consideration is degradation. Batteries degrade as they age, decreases the amount of capacity they can store. The expected life of the batteries is about 10 to 12 years (depending on the technology and how the batteries are operated). By the end of that time, the batteries' capacity is expected to be reduced to less than 70% of their original capacity.

In September 2023, the government approved the VGF scheme for development of 4000 MWh of BESS capacity by fiscal 2031. An initial outlay of Rs.94 billion including budgetary support of Rs.37.60 billion has been provided under the scheme. The VGF would be provided from fiscal 2024-26 and will be capped at 40% of the capital cost. Prior to VGF scheme, the Ministry of Heavy Industries in June 2021 launched a PLI scheme for Advance Chemistry Cell battery storage of 50 GWh capacity with an outlay of Rs. 181 billion, which includes more than 10 GWh grid-scale battery storage. The Scheme expects direct investment of around Rs. 450 billion in ACC Battery storage manufacturing projects. As of December 2023, out of 50 GWh capacity, 30 GWh capacity has already been allotted through competitive bidding process.

Usage of battery storage is expected to be strong across the generation, transmission, and distribution segments as well as at the consumer end. The National Renewable Energy Laboratory has also forecasted a fall in the price of storage solutions, especially lithium-ion technology. With the greater adoption of lithium-ion battery storage, improvement in battery efficiency, and large-scale manufacturing, CRISIL MI&A Consulting expects the four-hour utility-scale lithium-ion battery costs to decrease to $90-100 per kWh in 2030 from the costs of $130-140 per kWh in 2023.

With the announcement of several large-scale PHS projects across the country, the PHS segment is also expected to witness significant adoption. According to the CEA's report on optimum power generation mix study in April 2023, India will require at least 41.7 GW/208 GWh of BESS and 18.9 GW of PHS by fiscal 2030.

3.5 Large scale ESS tenders

As RE penetration scales up, ESS is expected to play a critical role.

SECI issued its first 1200 MW RE+storage tender with guaranteed peak power supply of 6 hours per day which concluded in 2020. The two bidders, Greenko (900 MW at peak tariff of ~ Rs 6.12/kWh) with pumped hydro storage and ReNew Power (300 MW at peak tariff of Rs 6.85/kWh) with BESS were awarded the project. The first FDRE tender of 1500 MW conducted by SJVN in November 2023 witnessed the lowest tariff of Rs 4.38/kWh.

Also, a few large-scale standalone ESS tenders were also issued by SECI, NTPC, GUVNL, MSEDCL in the last two years. In terms of ESS technology, SECI's tender was for BESS. However, NTPC's tender was technology agnostic with the requirement of six hours of energy supply. JSW Energy won 500 MW in SECI's tender and 300 MW in PCKL's tender, whereas Greenko won the NTPC tender and 700 MW in PCKL tender. MSEDCL has also awarded 2 GW of PHS project each to Torrent Power and JSW in September 2024 which would supply power for 8 hours per day with a maximum of 5 continuous hours.

As of September 2024, ~12 GW of grid-scale ESS capacity has been tendered of which ~8 GW has been awarded.

A confluence of these initiatives indicates the large potential and keen interest from project developers in the ESS segment. Moreover, the results of these tenders also indicate the commercial competitiveness of ESS and RE+ESS as compared to electricity sources.

A list of recently concluded storage tenders are mentioned below:

Table 6: Recently concluded storage tenders

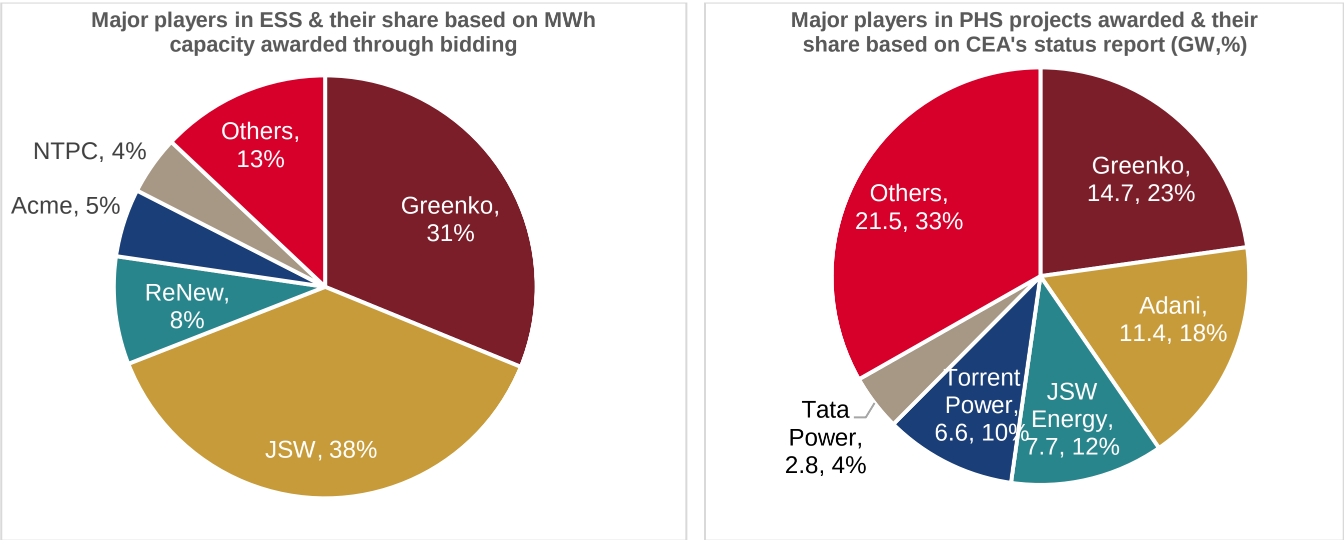
Sr. No.	Tender name	Tender type	Capacity (MW/MWh)	Result date	Lowest bid	Winners
1.	SECI Rajasthan Tranche - II	Standalone BESS	1000 MW / 2000 MWh	Sept 2024	Rs 4.57 Mn/MW/year	JSW, Reliance
2.	SECI	Solar + Storage	600 MW/1200 MWh	Jul 2024	Rs 3.42/kWh	Acme, Hero, JSW
3.	GUVNL	Standalone BESS	250 MW/500 MWh	Mar 2024	Rs 0.448 Mn/MW/month	Gensol, Indigrid
4.	SJVN, Firm Power	FDRE	1500 MW	Nov 2023	Rs 4.38/kWh	Acme, Juniper, Tata, ReNew, Bluepine, Hero, O2 Power
5.	NTPC Storage	Standalone ESS	500MW/ 3000 MWh	Dec 2022	Rs 2.79 Mn/MWh/year	Greenko
6.	SECI Rajasthan	Standalone ESS	500MW/ 1000 MWh	Aug 2022	Rs 1.08 Mn/MWh/month	JSW

Source: SECI, Bidding agencies, CRISIL MI&A-Consulting

3.6 Major players in pumped storage and BESS technology

Major RE developers such as ReNew, Greenko, Tata Power, JSW are aggressively adopting ESS. ReNew won two ESS tenders (Peak Power Supply, RTC-1). Greenko is developing ESS through PHS. It is developing Integrated Renewable Energy Storage Projects (IRESP) in Andhra Pradesh combining GW scale wind, solar and PHS power.

Figure 33: Major players and their share in ESS/PHS based projects as of September 2024



Source: CEA, SECI, Bidding agencies, CRISIL MI&A-Consulting

Greenko has the highest share in terms of capacity awarded under energy storage projects. It has won 2.1 GW under tariff based competitive bidding conducted by SECI, PCKL and NTPC. According to CEA's status report on PHS development as of September 2024, a cumulative capacity of ~14.7 GW has been allotted to Greenko in the states of Karnataka, Madhya Pradesh, Rajasthan, and Uttar Pradesh. Other players such as Adani Green Energy, JSW, Tata Power, Torrent Power are cumulatively developing ~28.5 GW of PHSPs.

Further, the developers who won RTC, peak power, FDRE tenders under competitive bidding route such as ReNew, Acme, Tata Power, Bluepine, O2 Power, NTPC are deploying BESS to meet the power requirements of their respective offtakers as indicated in the RFPs.

Table 7: List of key players in ESS segment

Key players	Achievements in ESS segment
Greenko	• 900 MW project won under SECI tender for peak power supply • 500 MW/3,000 MWh ESS capacity under NTPC tender • Developing IRESP at Andhra Pradesh with 3 GW solar, 0.5 GW wind and 1.2 GW/10.8 GWh PHS
ReNew	• 300 MW peak power supply project with a storage capacity of 75 MW/150 MWh • 400 MW RTC project with storage capacity of 25 MW/100 MWh
JSW Energy	• Won 500 MW/1,000 MWh BESS under SECI tender • Plan to install 5 GW/40 GWh energy storage capacity by 2030
NHPC	• Scouting for over 20 GW of PHSPs in the States of Andhra Pradesh, Maharashtra and Odisha and have also signed MoU with the respective State departments • Signed MoU with Gujarat Power Corporation for investment in Kuppa PHSP of 750 MW
Tata Power	• 10MW/10MWh BESS commissioned in Delhi • 20MW/50MWh BESS project in Leh, Ladakh • 100 MW Solar with 40MW/120 MWh BESS at Chhattisgarh
L&T	• 20 MW solar with 8 MWh BESS at Andaman & Nicobar
Mahindra Susten	• 6MW Solar with 6MW/19MWh BESS at Gujarat
Prozeal Green Energy	• 25 MW_{AC} solar plant with 20 MW/50 MWh BESS at Taru, Leh

Source: Company websites, press releases, CRISIL MI&A-Consulting

4 Green Hydrogen

4.1 Different types of hydrogen

Hydrogen, the universe's most abundant element, is making waves as a clean energy source for a sustainable future. Hydrogen can be classified into different types based on its colour, which is often an indication of its production method, purity, or intended use and also use of fuel for production of hydrogen.

Green hydrogen is produced from renewable energy sources, such as solar, wind, or hydro power, through electrolysis of water. This process splits water molecules into hydrogen and oxygen, without generating any greenhouse gas emissions. Green hydrogen is considered a clean and sustainable energy carrier.

4.2 National Green Hydrogen Mission

4.2.1 Green hydrogen mission and policy

The National Green Hydrogen Mission was approved by the government on January 4, 2022. The mission aims to make India a leading producer and supplier of green hydrogen in the world. The mission would result in development of green hydrogen production capacity of at least 5 million metric tonne per annum with an associated renewable energy capacity addition of about 125 GW in the country. As per Central Government, the targets by 2030 are likely to bring in over Rs. 8 trillion investments.

The initial outlay for the Mission is Rs.197.44 billion, including an outlay of Rs.174.9 billion for the Strategic Interventions for Green Hydrogen Transition Programme (SIGHT) programme, Rs.14.66 billion for pilot projects, Rs.4 billion for R&D, and Rs. 3.88 billion towards other Mission components. Under the SIGHT, two distinct financial incentive mechanisms have been proposed, one is targeting domestic manufacturing of electrolysers and the other for production of Green Hydrogen. The Mission will also support pilot projects in emerging end-use sectors and production pathways.

4.2.2 Key highlights of green hydrogen policy

Some of the key highlights of Green Hydrogen Policy are as follows:

- The waiver of inter-state transmission charges shall be granted for a period of 25 years for Green Hydrogen and Green Ammonia projects commissioned before 31st December 2030.
- Developers can manufacture Green Hydrogen/Green Ammonia using Renewable Energy from co-located or remotely located plants, or from the Power Exchange. They will be granted Open Access within 15 days of a complete application. Open Access charges will be in accordance with the Rules.
- Banking permitted for a period of 30 days for renewable energy used for making Green Hydrogen /Green Ammonia.
- Under the Electricity (Transmission system planning, development, and recovery of Inter State Transmission charges) Rules 2021, renewable energy projects set up to manufacture green hydrogen/green ammonia will be granted priority for ISTS connectivity.
- Land in Renewable Energy Parks can be allotted for the manufacture of Green Hydrogen / Green Ammonia.
- Manufacturers of green hydrogen/ammonia can set up bunkers near ports to store green ammonia for export or use by shipping. Port authorities will provide land for storage at applicable charges.
- Renewable energy used to produce green hydrogen /ammonia counts towards RPO compliance for consumer and the discom in whose area the project is located.

- Distribution licensees may also procure and supply Renewable Energy to the manufacturers of Green Hydrogen / Green Ammonia in their States. In such cases, the Distribution licensee shall only charge the cost of procurement as well as the wheeling charges and a small margin as determined by the State Commission.
- MNRE to create a single portal for all Green Hydrogen/Ammonia clearances. All clearances will be provided within a period of 30 days from date of application.

4.3 Storage and transportation of hydrogen

4.3.1 Challenges in storage and transportation of hydrogen

Hydrogen is a promising energy carrier that has the potential to decarbonize various sectors. However, the storage and transportation of hydrogen pose significant challenges due to its unique properties. The challenges include low energy density, material compatibility issues, compression and liquefaction energy losses, temperature sensitivity, high storage costs, safety requirements, and purity requirements. To store hydrogen, it must be compressed or liquefied, which requires high-pressure tanks or low-temperature storage.

Globally, hydrogen is stored and transported through pipelines, trucks, ships, and storage tanks. Gaseous hydrogen can be transported through pipelines the way natural gas is transported worldwide. Hydrogen can be transported either via the existing natural gas infrastructure or by building new pipelines exclusively for hydrogen transport. Hydrogen transport via existing pipelines is a low-cost option since setting up new pipeline for hydrogen transport is capital intensive. For shorter distances, Hydrogen is transported over the road - in liquid tanker trucks or gaseous tube trailers.

Pipelines or truck transport are normally used for shorter distances. However, where pipeline transport is not possible, hydrogen transport by ship is technically possible for longer distances, especially inter country transport. Gaseous hydrogen converted into liquid can be transported via sea. However, due to the costs of liquefaction, refrigeration, and regasification, it is a high-cost operation.

Liquified or compressed hydrogen can be stored in storage tanks specially designed for hydrogen storage. Some of the popular hydrogen storage options include compression or cryogenic systems (or their combination), chemical production systems (such as ammonia), nanomaterial-based storage, and geologic storage. The tanks are typically found at production facilities, transport terminals and end use locations.

4.3.2 Infrastructure requirements for hydrogen storage and transport

The hydrogen infrastructure can be referred to hydrogen storage, transportation, storage terminals and infrastructure available for export. Hydrogen storage systems are critical components in the use of hydrogen as energy carrier. Compressed gas storage and liquid hydrogen storage are commonly used storage systems. Development of effective hydrogen storage systems is essential for various applications. Choice of storage of hydrogen largely depends on quantity, economy and end use. Different types of tanks such as gaseous hydrogen storage tanks, liquid hydrogen storage tanks (cryogenic tanks), horizontal cylindrical with hemispherical ends, vertical cylindrical with hemispherical ends and spherical storage tanks etc. are available in market. In India, several initiatives are under process for integration of hydrogen with natural gas through existing natural gas pipelines. Even though this is a low-cost option, it requires careful monitoring to ensure the correct percentage of blending. Additionally, on arrival at destination, additional technology is required to separate hydrogen from natural gas leading to more cost. NTPC Green Energy Ltd. has commissioned India's first green hydrogen blending project. The green hydrogen blending has been started in the piped natural gas (PNG) network of NTPC Kawas township, Surat. The project is a joint effort of NTPC and Gujarat Gas Limited (GGL). Adani Total Gas Ltd. (ATGL) has also announced the initiation of a ‘Green Hydrogen Blending Pilot Project’ for Ahmedabad in Gujarat. Previously, GAIL (India) Ltd. had commenced its project of blending hydrogen with natural gas in Indore, MP. A key component of the National Green Hydrogen Mission is the identification and development of regions capable of supporting large scale production and/or utilization of Hydrogen as Green Hydrogen Hubs. The Mission provides for setting up of two Green Hydrogen hubs in the initial phase. The Ministry of Ports, Shipping and Waterways has identified three major ports viz. Deendayal Port (Kandla), Paradip and V.O. Chidambaranar (Tuticorin) Ports to be developed as hydrogen hubs. Alternatively, hydrogen can be transported in the form of ammonia, methanol and liquid organic hydrogen. At present, around 13 port in India handle ammonia imports in bulk volumes.

4.4 PLI Scheme for green hydrogen production and electrolysers manufacturing

4.4.1 PLI Scheme under SIGHT Scheme

In July 2023, SECI has issued a Tender for selection of green hydrogen producers for setting up 450,000 MT per annum production facilities for green hydrogen in India under the SIGHT Scheme (Mode-1-Tranche-I). The green hydrogen auction, which offered a per-kilogram maximum of 50 rupees in the first year, 40 rupees in the second, and 30 rupees in the third, awarded subsidies to eight companies out of thirteen bidders. Total Capacity available for bidding under Technology Agnostic Pathways (Bucket I) was 410,000 MT/annum and Biomass Based Pathways (Bucket II) 40,000 MT/annum.

Under its first green hydrogen tender, India has awarded incentives to various bidders for a total production of more than 400kt per annum.

The scheme guidelines for SIGHT Mode 2A (aggregation model for Green Ammonia) and Mode 2B (aggregation model for Green Hydrogen) have been notified on 16th January 2024. Further, in July 2024, MNRE has notified guidelines under SIGHT for green hydrogen production (under Mode-1) Tranche-II for setting up 450,000 TPA green hydrogen. The total government outlay for both the Tranches is Rs. 131 billion.

4.4.2 Pilot Schemes for use of green hydrogen

Shipping Sector: The Central Government has issued guidelines for undertaking pilot projects for using green hydrogen in the shipping sector. Two areas have been identified as thrust areas under the pilot projects. These are retrofitting of existing ships to enable them to run on Green Hydrogen or its derivatives; and development of bunkering and refueling facilities in ports on international shipping lanes for fuels based on Green Hydrogen. The Scheme will be implemented with a total budgetary outlay of Rs. 1.15 billion till the fiscal 2026.

Steel Sector: The Central Government has come up with guidelines for undertaking pilot projects for using green hydrogen in the steel sector. Three areas have been identified as thrust areas for the pilot projects in the steel sector. These are use of Hydrogen in Direct Reduced Ironmaking process; use of Hydrogen in Blast Furnace; and substitution of fossil fuels with Green Hydrogen in a gradual manner. The scheme will also support pilot projects involving any other innovative use of hydrogen for reducing carbon emissions in iron and steel production. The Scheme will be implemented with a total budgetary outlay of Rs. 4.55 billion till fiscal 2030.

Transport sector: The Central Government has issued guidelines for undertaking pilot projects for using green hydrogen in the transport sector. The scheme will support development of technologies for use of Green Hydrogen as a fuel in Buses, Trucks, and 4-wheelers, based on fuel cell-based propulsion technology / internal combustion engine-based propulsion technology. The other thrust area for the scheme is to support development of infrastructure such as hydrogen refueling stations. The Scheme will be implemented with a total budgetary outlay of Rs. 4.96 billion till the fiscal 2026.

4.5 Electrolysers

Electrolyser technologies vary with respect to cell design, variation within components, and degree of technology maturity. Alkaline and PEM electrolysers are the most advanced technologies with higher adoption rates compared to other technologies. On the other hand, Solid oxide and AEM (anion exchange membrane) electrolysers have high potential but are much less mature technologies.

As per NITI Aayog, India may witness a 20 GW electrolyser demand by 2030. There have been a number of announcements by key industry players towards boosting the electrolyser production capacity in India. Adani New Industries Limited (ANIL) is currently setting up a 5 GW integrated electrolyser plant and has signed an agreement with Cavendish Renewable Technology (CRT) to manufacture electrolysers based on AE, PEM and SOEC technologies. Ohmium, which has a PEM electrolyser capacity of 500 MW/year set up in Karnataka has plans to take its capacity to 2 GW in the near future. Greenko and John Cockerill partnered in March 2022 to set up a 2 GW electrolyser manufacturing plant in Andhra Pradesh. H2E Power Systems is building a 1 GW electrolyser plant in a phased manner while exploring all four electrolyser technologies. Lastly, Reliance has partnered with Stiesdal and L&T with HydrogenPro to set up AE-based electrolyser plants in Gujarat and Maharashtra, respectively.

In the global scenario, China presently dominates electrolyser manufacture with players like LONGi, PERIC and Sungrow Power. However, American and European players have announced significant capacity plans that will make them competitive over the next few years.

Table 8: Existing major electrolyser manufacturers globally

Manufacturer	Country	Technology	Existing Capacity	Expansion Plans
LONGi	China	Alkaline	1.5 GW	5 GW by 2025
PERIC	China	Alkaline/PEM	1.5 GW	-
Sungrow	China	Alkaline/PEM	1.1 GW	1.1 GW by 2024
John Cockerill	Belgium	Alkaline	1.0 GW	8 GW by 2025
Thyssenkrupp	Germany	Alkaline	1.0 GW	5 GW by 2025
Plug Power	US	PEM	1.0 GW	10-12 GW by 2025
ITM Power	UK	PEM	1.0 GW	5 GW by 2024
Nel	US	Alkaline/PEM	0.5 GW	4 GW by 2025
Bloom Energy	US	SOEC	2.0 GW	-

Source: Company websites, CRISIL MI&A Consulting

Incentive scheme for Electrolyser manufacturing under SIGHT program

The MNRE has issued guidelines for the implementation of the SIGHT programme in June 2023. This programme consists of two components: the incentive scheme for electrolyser manufacturing (component-I) and the incentive scheme for hydrogen production (component-II). The national green hydrogen mission has allocated a total of Rs. 174.90 billion for the SIGHT programme, with Rs 44.40 billion allocated for electrolyser manufacturing and Rs. 130.50 billion for green hydrogen production.

Component-I focuses on the electrolyser scheme with an allocation of Rs. 44.40 billion, aiming to maximize domestic electrolyser manufacturing capacity. The first phase of the SIGHT programme would assist in developing 1500 MW of manufacturing capacity. The incentives for electrolyser manufacturing would be provided based on manufacturing capacity, calculated in rupees per kilowatt, for a period of 5 years from the start of electrolyser manufacturing.

The introduction of these schemes is expected to have a transformative effect on the Green Hydrogen ecosystem in India, propelling it forward and laying the groundwork for a cleaner and more sustainable energy future for the country.

SECI issued its first electrolyser manufacturing tender awarded under SIGHT program for total manufacturing capacity of 1.5 GW.

Subsequently, in August 2024, SECI announced the snapshot of opening of enevlope-2 under SIGHT (Tranche II) for a total capacity of 1.5 GW.

4.6 Overview of current market size and outlook

After China and USA as of March 2024, India is the third largest consumer & producer of hydrogen in the world. In 2020, India's hydrogen demand stood at 6 million tonnes (MT) per year. ~48% hydrogen is used in fertilizers to produce ammonia/urea and ~46% in refineries for hydrodesulfurization. India's grey hydrogen market is estimated to be ~ USD 9-10 billion considering production costs of ~USD 1.5-1.8 per kg. Additionally, India's annual Ammonia consumption for fertilizer production is about 15 MTPA, roughly 15% of this demand (over 2 MTPA) is currently met from imports. Driven by captive consumption by refineries, fertilisers and ammonia, the hydrogen demand in expected to reach ~11-12 MTPA by 2030 making it ~USD 22-25 billion market. Out of this ~4-4.5 MTPA is expected from refineries and ~6-6.5 MTPA from Fertilisers. Very small quantum (~0.5 to 0.75 MTPA) will be from Petrochem and other industries. Considering ~8-10% of hydrogen demand from fertilisers and 22-24% of hydrogen demand from refineries can be met through green hydrogen in 2030, ~1.4-1.8 MTPA will be from green hydrogen. Considering a production cost of ~USD 2 to 2.5 per kg, the green hydrogen market is expected to be ~USD 3-4 billion in 2030.

5 Landscape of leading project developers

Competitive mapping covers the details of companies, their products and services within a given market to understand competitive intensity. Some of the key players in the renewable energy sector include NTPC Green Energy (~3.5 GW operational solar and wind), Adani Green Energy (~11.2 GW operational wind, solar and hybrid), Renew Power (~8.3 GW operational wind & solar), ACME Solar (1.34 GW operational solar), TATA Power RE (~4.7 GW operational solar and wind), Greenko (5.4 GW operational wind and solar) and JSW Neo (operational ~0.7 GW Solar and 2 GW wind) as of 30th September 2024. These players also have sizeable quantum of capacity under consideration/development.

Table 9: Key leading project developers

Parameter	NTPC GEL	Adani Green Energy	Renew	Greenko	ACME Solar Holding	JSW Neo	TATA Power REL
Promoter/Group	NTPC	Adani Group	Renew Group	Greenko group	ACME Group	JSW	TATA Power
Years in Business (As on 30/09/2024)	~3 Yrs	~10 Yrs	~14 Yrs	~22 yrs	~16 Yrs	~3 Yrs	~17 Yrs
Operational capacity (GW) as on 30/09/2024	Solar:3.34 Wind:0.21 (Incl. NTPC and NTPC REL)	Solar:7.4 Wind:1.7 WSH:2.1	Solar:4.0 Wind:4.3	Solar: 2.175 Wind: 3.192	Solar: 1.34	Solar:0.7 Wind:2.0	Solar:3.7 Wind:1.0
Under construction/ Development capacity (GW) as on 30/09/2024	under-construction :8.13 Pipeline: 10.57	Solar:16.8 Wind:2.4 WSH:2.7	Solar:3.3 Wind:1.8	Solar:1.0 Wind:0.4	Solar 1.8 Wind 0.15 Hybrid 0.83 FDRE 1.25	Wind:1.7 Wind: 1.0 (pipeline) Solar: 3.2 (pipeline) Hybrid/FDRE:2.3 (pipeline)	Solar:1.0 Hybrid: 4.5
Solutions offered	IPP Hybrid Corporates RTC/ Storage	IPP Corporates RTC/ Storage Solar Park development	IPP Corporates Green credits Energy management RTC/Storage Solar PV manufacturing	IPP RTC/ Storage	Renewable IPP, RTC Storage Hybrid, FDRE	IPP Corporates RTC/ Storage	IPP Corporates RTC/Storage Rooftop solar Solar PV manufacturing

Parameter	NTPC GEL	Adani Green Energy	Renew	Greenko	ACME Solar Holding	JSW Neo	TATA Power REL
Key Offtakers for operational capacity	SECI, GUVNL, RUMSL, IREDA, NVVNL, REC/NTPC MPPMCL Raj. Discoms AP Discoms UPPCL Telangana Discoms etc.	SECI, NTPC, PTC, TANGEDCO, Karnataka ESCOMS, UPPCL, PSPCL, MSEDCL, GUVNL, TSSPDCL, MPPMCL, Merchant etc.	SECI, MSEDCL, APSPDCL, GUVNL, MPPMCL, TSNPDCL, NTPC, PTC, Corporates etc.	SECI, Delhi Discoms, AP Discoms, Karnataka Discoms, Telangana Discoms, Tangedco etc.	SECI, NTPC, GUVNL, CSPDCL, MSEDCL, UPPCL, MPPMCL, PSPCL, GRIDCO, TSNPDCL, TSSPDCL, APSPDCL, NBPDCL & SBPDCL etc.	SECI, AP, HP, Maharashtra, Rajasthan, Telangana, PTC, Open Capacity, Others etc.	SECI, SJVN TANGEDCO APDISCOMs GUVNL BESCOM UPPCL NPCL MSEDCL TPCD KSEB MPPCL JVVNL, JdVVNL , Others etc.
Green Hydrogen ambitions	Planning for the development of an Integrated Green Hydrogen Hub in Andhra Pradesh; Hydrogen-PNG Blending at Kawas, Gujarat; Mobility at Leh and Delhi (Hydrogen Fuel Cell (FC) based electric vehicles)	Adani New Industries Ltd has planned a Green Hydrogen Project in Mundra, Gujarat.	Proposed to set up green hydrogen project in Kerala as well as plans to set up a Green Hydrogen Project in Egypt	Planned a Green Ammonia plant in Himachal Pradesh.	ACME Group has set up pilot project for green hydrogen and ammonia, in Rajasthan. Planned green hydrogen capacities in Tamil Nadu, Odisha and Duqm, Oman.	Received LOA for setting up of 6.5 KTPA green hydrogen production facility from SECI	NA

NA: Not available; Source: Company websites, Annual Reports, Press Releases, CRISIL MI&A-Consulting

The following table summarises the competitive analysis of NTPC GEL with some of the leading players.

Table 10: Competitive analysis with some of the leading players

INR Mn	NTPC GEL				NTPC RE Group*		RENEW					Adani Green				
Parameters	H1FY25 (A)	H1FY24 (A)	FY24(A)	FY23(A)	FY23(A)	FY22(A)	H1FY25 (UA)	H1FY24 (UA)	FY24(A)	FY23(A)	FY22(A)	H1FY25 (UA)	H1FY24 (UA)	FY24(A)	FY23(A)	FY22(A)
Installed Capacity (MW)	3,320	2,711	2,925	2,611	2,611	1,445	NA	8,200	9,100	7,880	7,470	11,184	8,316	10,934	8,086	5,410

INR Mn	NTPC GEL				NTPC RE Group*		RENEW					Adani Green				
Parameters	**H1FY25 (A)**	**H1FY24 (A)**	**FY24(A)**	**FY23(A)**	**FY23(A)**	**FY22(A)**	**H1FY25 (UA)**	**H1FY24 (UA)**	**FY24(A)**	**FY23(A)**	**FY22(A)**	**H1FY25 (UA)**	**H1FY24 (UA)**	**FY24(A)**	**FY23(A)**	**FY22(A)**
Solar	3,220	2,661	2,825	2,561	2,561	1,395	NA	4,000	4,500	3,970	3,690	7,393	4,975	7,393	4,975	NA
Wind	100	50	100	50	50	50	NA	4,200	4,600	3,910	3,780	1,651	1,201	1,401	971	NA
Hybrid	-	-	-	-	-	-	NA	NA	NA	NA	NA	2,140	2,140	2,140	2,140	NA
Megawatts Contracted & Awarded as on September																
Total Contracted & Awarded Capacity (MW)	**13,576**	**8,600**	**11,571**	**6,250**	**6,250**	**4,766**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Solar	10,576	7,050	9,571	5,750	5,750	4,616	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Wind	3,000	1,550	2,000	500	500	150	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Generation (MUs)																
Solar	3,118	2,907	5,591	467	3,759	1,864	NA	4,449	8,794	8,112	8,469	7,751	5,501	11,046	10,457	8,097
Wind	124	66	122	6	103	104	NA	6,565	10,243	9,002	5,677	2,348	1,996	3,117	1,820	1,329
Hybrid	-	-	-	-	-	-	NA	NA	NA	NA	NA	4,029	4,263	7,643	2,603	-
Average CUF for the assets held as on last date of the financial year/period (%)																
Solar	24.61%	25.04%	23.97%	27.17%	22.74%	19.21%	NA	23.1%	24.4%	24.8%	23.1%	23.9%	25.2%	24.5%	24.7%	23.8%
Wind	28.27%	30.14%	19.78%	16.48%	23.58%	23.66%	NA	41.3%	26.4%	25.5%	25.4%	35.7%	40.2%	29.4%	25.2%	30.8%
Hybrid	-	-	-	-	-	-	NA	NA	NA	NA	NA	42.9%	45.4%	40.7%	35.5%	NA
Financial parameters																
Revenue from Operations	10,823	10,083	19,626	1,697	14,497	9,104	NA	47,508	81,948	79,328	62,043	58,890	43,820	92,200	77,760	51,330
Total Revenue	11,327	10,211	20,377	1,706	14,575	9,182	NA	53,291	96,531	89,309	69,195	64,760	49,790	104,600	86,170	55,770
Operating EBITDA	9,316	9,146	17,465	1,514	13,096	7,949	NA	36,101	58,648	54,416	36,091	49,260	39,070	75,860	49,900	35,110
Operating EBITDA Margin (% of Revenue from Operations)	86.07%	90.71%	88.99%	89.21%	90.34%	87.31%	NA	75.99%	71.57%	68.60%	58.17%	83.65%	89.16%	82.28%	64.17%	68.40%
Profit/(Loss after Tax (PAT)	1,753	2,082	3,447	1,712	4,565	947	NA	6,754	4,147	(5,029)	(16,128)	11,440	6,940	12,600	9,730	4,890
PAT margins (% of Revenue from Operations)	16.20%	20.64%	17.56%	100.91%	31.49%	10.41%	NA	14.22%	5.06%	(6.34%)	(25.99%)	19.43%	15.84%	13.67%	11.29%	9.53%
Net Debt/Equity (x)	1.91	1.82	1.98	1.09	1.09	4.41	NA	4.69	5.19	4.08	3.07	5.65	6.67	5.52	6.96	19.36
Cash PAT	5,331	5,191	9,875	2,211	9,130	3,775	NA	15,380	21,730	10,872	(2,364)	23,550	16,190	31,630	22,730	13,380
Cash PAT margin (as % of Revenue from operations)	49.26%	51.48%	50.31%	130.32%	62.98%	41.46%	NA	32.37%	26.52%	13.71%	(3.81%)	39.99%	36.95%	34.31%	29.23%	26.07%

INR Mn	NTPC GEL				NTPC RE Group*		RENEW					Adani Green				
Parameters	H1FY25 (A)	H1FY24 (A)	FY24(A)	FY23(A)	FY23(A)	FY22(A)	H1FY25 (UA)	H1FY24 (UA)	FY24(A)	FY23(A)	FY22(A)	H1FY25 (UA)	H1FY24 (UA)	FY24(A)	FY23(A)	FY22(A)
Cash RoE (% of Average Equity)	7.39%	10.40%	17.76%	NA	26.70%	23.08%	NA	14.33%	20.49%	9.65%	(2.62%)	23.08%	21.25%	36.91%	45.84%	55.59%
Interest Coverage (x)	2.60	2.76	2.64	3.05	2.80	3.17	NA	1.75	1.54	1.26	1.04	1.86	1.71	1.71	1.98	1.51

*Note: On Consolidated basis; NTPC GEL- Based on restated consolidated financial statements for H1 of fiscal 2025, H1 of fiscal 2024, fiscal 2024 and fiscal 2023; *NTPC RE Group- Based on special purpose carved out financial statements for fiscal 2023 and fiscal 2022 which includes the carved-out business of RE Assets (part of NTPC Ltd.);*
NA: Not available; (-): Not applicable
Average CUF refers to the weighted average of CUF of Installed Capacity in the portfolio as on given date.
Source: Company, Company websites, Annual Reports, Regulatory Filings, CRISIL MI&A Consulting

Formulae used:
Operating EBITDA: Profit before tax + Finance cost + Depreciation and amortization expense - Other income - Exceptional items
Operating EBITDA margin: Operating EBITDA / Revenue from operations
PAT margin: PAT / Revenue from operations where PAT: Profit after tax
Net Debt/Equity: (Long term borrowing + Short term borrowing – Cash and cash equivalents – Other Bank balances)/ Equity
Interest coverage: EBITDA/Finance costs
Cash PAT: PAT + Depreciation
Cash PAT margin: Cash PAT / Revenue from operations

- From the above comparison, it can be observed that:
    - NTPC GEL's revenues are primarily driven from the energy sales, which account for ~99% of its total operating revenues.
    - Among its peers, the Company has earned higher EBITDA margins and PAT margins in the last 2 Fiscals.
    - The Company has debt: equity ratio of 1.98 for Fiscal 2024 which indicates a moderate leverage. Further, it is lower than its peers, indicating higher funding through equity.
    - With strong parent support and diversified portfolio with long term PPA, the Company is able to maintain a healthy interest coverage ratio.
- The Company is promoted by its parent company, NTPC Limited, India's largest power company both in terms of installed capacity as of March 31, 2024, and power generation in Fiscal 2024. NTPC Limited is a Central Public Sector Enterprise (CPSE) under the ownership of the Ministry of Power of the Government of India.
- The Company benefits from the support, vision, resources and experience of the NTPC Group which is looking to expand its non-fossil-based capacity to 45-50% of its portfolio that will include 60 GW RE capacity by 2032.
- The NTPC Group is a large-scale integrated energy business with an electric power generating capacity of over 76 GW as of 30 September 2024, across coal, hydro, gas and renewable operations with a pan-India presence.
- As of 30 September 2024, the NTPC Group contributed ~17% in India's total installed capacity and contributed ~24% in total power generated in India during the Six months ended 30 September 2024.
- The company enjoys a strong parentage of NTPC which has a legacy of around five decades, is one of India's largest power companies, and has experience in operating and maintaining power stations efficiently and in acquiring land for large power projects throughout India.

- The NTPC Group also brings to the fore financial strength of Rs.4,922,304 million of assets as of 30 September 2024. NTPC limited has highest credit rating from leading Indian rating agencies and ratings equivalent to India's sovereign ratings from foreign rating agencies. NTPC's Green arm NGEL as well as its Subsidiary NREL also enjoy highest credit rating from leading Indian rating agencies.
- NGEL is one of the top 10 leading renewable energy companies in India (in terms of total operational capacity) as of September 2024.
- NGEL is a subsidiary of NTPC Limited (a 'Maharatna' CPSE) and the largest central public sector renewable energy player (excluding hydro) in terms of operating capacity as of September 30, 2024, and power generation in Fiscal 2024.
- In Fiscal 2024, NGEL has emerged as the market leader in the winning capacities under Tariff Based Competitive Bidding in the sector with an aggregate capacity of 3.5 GW which is equivalent to AC capacity of around 5 GW.
- NGEL has been one of the front runners in development of Round the Clock RE Projects in the country. It is presently developing 2.7 GW of RE RTC capacities which also includes one of the world's largest RE RTC Projects of 1.3 GW
- The assets owned by the Company are diversified into solar and wind with presence in multiple locations in more than six states which helps mitigate the risk of location-specific generation variability.
- The Company has superior execution capabilities which is demonstrated almost 50 years of successful operations by its parent company. The Company also benefits from long-term experience in dealing with State DISCOMs by its parent company.

6 Key challenges/threats impacting RE Sector

6.1 Key challenges and threats impacting renewable energy sector

6.1.1 Threats

Any adverse shift in government policies, including reductions in incentives or changes in energy regulations, can significantly impact NTPCGEL's revenue and profitability. However, considering the COP commitment, climate change ambitions and government push for RE, the chances of drastic changes in regulatory regime are less likely. This can also be ascertained from the fact that as against capacity addition of ~70 GW of RE, only ~20 GW of conventional capacity is added over the last 5 years. There were some delays in signing PSAs having higher tariffs by Discoms due to declining tariffs in subsequent tenders. However, with the government's plan for stricter adherence to RPOs, higher penalty in case of non-compliance, and revision of tariff in manufacturing-linked tenders, PSA signing activity improved during fiscal 2022 onwards. There are only a few states which are complying with the RPO obligations fully and there has been limited enforcement on obligated entities - discoms and open access and captive power users - to meet RPO targets. Proposed amendment to Electricity Act, 2003 has stipulated a penalty on RPO non-compliance and uniform imposition of penalties and strict enforcement would be critical for significant improvement and fair distribution of RPO compliance across states. The RE sector is highly competitive, with numerous players vying for market share. Established competitors along with capable new entrants can pose challenges. Climate change and extreme weather events can affect the performance and reliability of renewable energy systems, potentially leading to disruptions or damage to infrastructure.

6.1.2 Challenges

There is counterparty credit risk due to the depleted financial position of most Discoms. Due to legacy issues, higher T&D losses, lack of adequate tariff revisions, lack of timely subsidy support, operational challenges, financial position in most of the State Discoms is weak. However, with competitive tariffs, payment security mechanism, diversification in counter parties largely mitigates the counterparty credit risk. Further, execution risk in under construction projects may impact profitability and in turn liquidity. However, experience in execution of large-scale projects should mitigate this risk. Furthermore, availability of contiguous land and acquisition challenges associated with land parcels are some of the key challenges that developers are facing. To acquire large tracts of land in a single resourceful location, many stakeholders have to be involved, which slows down the pace of project execution. The 40 GW solar park scheme, which provides land to successful bidders for setting up of the projects, is facilitative in this aspect. Availability of timely transmission connectivity is another challenge. To optimize costs, utilization levels, and losses associated with the transmission system, it is crucial to have robust transmission planning. Concerns about connectivity for renewable projects have been raised by the various stakeholders at the appropriate levels. Nodal agencies (PGCIL and SECI) have planned various schemes to reduce grid congestion and enhance connectivity, taking this into account. Green Energy Corridor Scheme and Renewable Energy Zones expected to add ~80 GW of transmission grid capacity, taking it to more than 100 GW for RE projects. This will give comfort against the planned capacity additions in renewable energy segment.

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