Crisil Intelligence

SAEL Industries Ltd.

India Renewable Energy Market Assessment

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Crisil Intelligence

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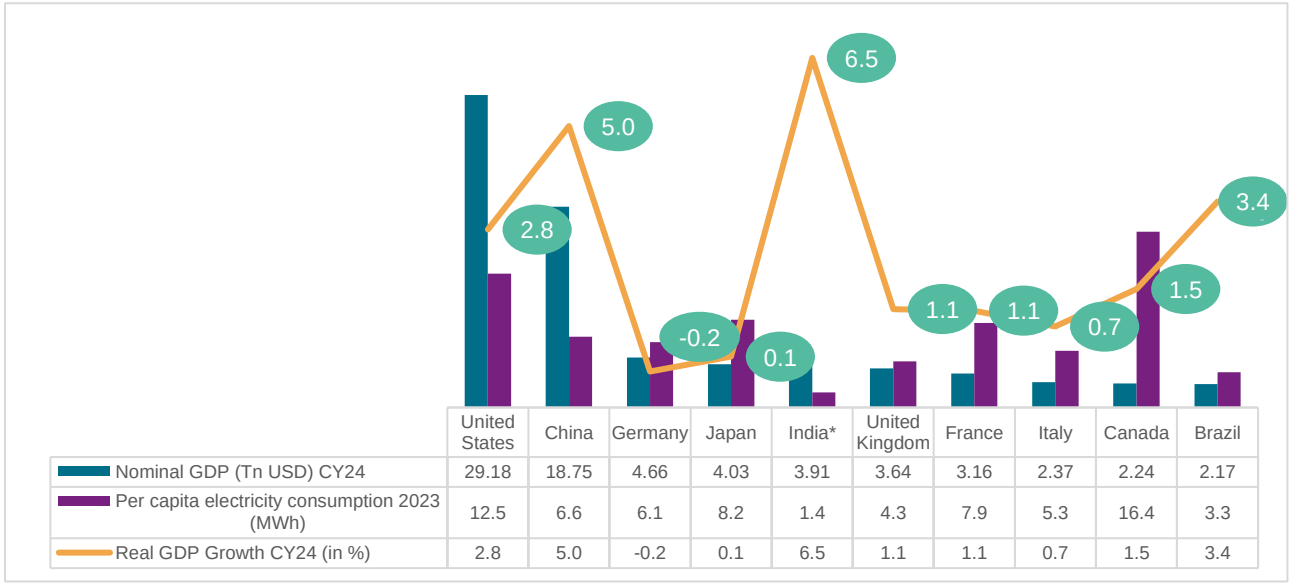
1 Overview of Indian macroeconomic landscape

1.1 Real GDP growth in India

India's gross domestic product (GDP) at constant (Fiscal 2012) prices was ₹ 187.97 trillion (provisional estimates) for Fiscal 2025 vis-à-vis ₹ 176.5 trillion (first revised estimates) for Fiscal 2024 as per data released by the National Statistical Office (NSO) in May 2025. This translates into a growth of 6.5% over Fiscal 2024.

India is projected to become the fourth largest economy in the world in Fiscal 2026, according to the International Monetary Fund (IMF) World Economic Outlook (WEO) April 2025. As per IMF WEO July 2025, India's real GDP growth is estimated at 6.4% in Fiscal 2026 and 2027, the highest amongst the top 10 economies. IMF has estimated that India will be the world's third-largest economy by Fiscal 2028 surpassing both Japan and Germany. Additionally, World Bank has estimated India's GDP to grow at 6.3% in Fiscal 2026. In the last 5 years, Indian GDP has been growing consistently. Except for years affected by COVID-19 pandemic, India's growth has been highest amongst the top 10 economies.

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



	United States	China	Germany	Japan	India*	United Kingdom	France	Italy	Canada	Brazil
Nominal GDP (Tn USD) CY24	29.18	18.75	4.66	4.03	3.91	3.64	3.16	2.37	2.24	2.17
Per capita electricity consumption 2023 (MWh)	12.5	6.6	6.1	8.2	1.4	4.3	7.9	5.3	16.4	3.3
Real GDP Growth CY24 (in %)	2.8	5.0	-0.2	0.1	6.5	1.1	1.1	0.7	1.5	3.4

** India GDP data as per NSO for Financial Year 2025,*

Source: WEO Database (Apr and July 25) by IMF-Institute of Economic Affairs; IEA, CEA-Central Electricity Authority, Crisil Intelligence

During Fiscal 2014 to 2025, India's GDP at constant (Fiscal 2012) prices grew at a compounded growth of approximately 6.1% (CAGR). Government policies focus on the manufacturing sector, exports, increased digitalisation, implementation of GST, strong domestic demand for consumption and investment contributed to GDP growth. After strong GDP growth in the past three years, Crisil Intelligence expects some moderation to 6.5% this Fiscal 2026 slower than 9.2% in the previous Fiscal. However, growth remains close to the pre-pandemic decadal average of 6.6% between Fiscals 2011 and 2020 (as per NSO data) and will allow India to retain its tag of fastest growing large economy.

India's trade relationships with other countries can influence Indian economic conditions. India's trade deficit has shown considerable improvement in Fiscal 2024. Overall trade deficit for Fiscal 2024 is estimated at US$78.12 billion as compared to the deficit of US$121.62 billion during Fiscal 2023 registering a decline of 35.77%. India's trade relationships with other countries and its trade deficit may significantly harm Indian economic conditions. If trade deficits increase or are no longer manageable because of an unexpected rise in global crude oil prices or otherwise, the Indian economy, foreign exchange rates and financial performance can be significantly harmed.

Crisil Intelligence expects retail inflation to average 3.5% this Fiscal 2026 compared with 4.6% in the last. Healthy agricultural production is expected to keep food inflation in check. The lower inflation gives the Reserve Bank of India's (RBI) Monetary Policy Committee (MPC) headroom for another rate cut this Fiscal 2026, apart from the 100 basis points pared so far. Crisil Intelligence expects the current account deficit (CAD) to remain in the safe zone, at 1.3% of GDP in the current Fiscal 2026 (compared with 0.6% of GDP in Fiscal 2025). The surplus in services trade, healthy remittances and soft crude oil prices are expected to cushion the CAD. Crisil Intelligence expects the rupee to remain volatile in the near term, settling at approximately 87.50/$ by March 2026. While the current account deficit is expected to remain manageable, there could be some risks, especially to capital flow, because of disruptions in global economic growth and geopolitical uncertainties. India's healthy macroeconomic parameters provide some cushion to the rupee against these shocks, but it is not entirely immune.

Table 1: Key economic indicators and Crisil's Projections

Parameters	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26P
GDP growth (%)	6.5%	3.9%	-5.8%	9.7%	7.0%	9.2%	6.5%	6.5%
CPI (%, average)	3.4%	4.8%	6.2%	5.5%	6.7%	5.4%	4.6%	3.5%
CAD/GDP (%)	-2.1%	-0.9%	0.9%	-1.2%	-2.0%	-0.7%	-0.6%	-1.3%
FAD/GDP (%)	3.4%	4.6%	9.2%	6.7%	6.4%	5.6%	4.9%	4.4%*
Exchange rate (₹/$ March-end)	69.5	74.4	72.8	76.2	82.3	83.0	86.6	87.5
10-year G-sec yield (%, March-end)	7.5%	6.2%	6.2%	6.8%	7.4%	7.1%	6.7%	6.3%

*Note: P: Projected; CPI: Consumer Price Index-linked; CAD: Current account deficit; G-sec: Government security; FAD: Fiscal account deficit *Budget estimates*

Source: CSO, Reserve Bank of India (RBI), Crisil estimates

1.2 Macro-economic factors affecting growth of industries

Since 1991, successive governments at Centre have pursued policies of economic liberalization and financial sector reforms, including significant relaxations of restrictions on the private sector. Nevertheless, the GoI continues to exercise a dominant influence over many aspects of the economy, and its economic policies have had and continue to have a significant effect on private-sector entities. India has a mixed economy with a large public sector and an extensively regulated private sector. The role of the GoI and the state governments in the Indian economy and the effect on producers, consumers, service providers and regulators have remained significant over the years.

Global businesses are driven by emerging sectors like data centers, artificial intelligence (AI), fintech, edutech, renewable energy, global capability centers along with large manufacturing as well as infrastructure development. These industries are influenced by various macroeconomic factors that can impact growth,

demand, and overall landscape. Supportive regulations boost industry, while stricter ones increase compliance costs. A growing global economy drives demand and innovation. Trade policies impact on equipment costs and availability. Shifts in population demographics drive demand for digital services, housing, and infrastructure. Initiatives promoting new technologies create a favorable environment. Easy access to capital at low interest rates fuels investment and growth. High energy costs impact operating costs, especially for energy-intensive facilities. Focus on sustainability and reducing carbon footprint influences operations and costs. Advances in technologies like cloud computing, AI, and the internet of things (IoT) drive demand for digital services. These factors interact and influence each other, shaping industrial growth and operations.

The following governmental policies and initiatives further impact growth of industries in India:

Union Budget 2024-25: The key budgetary allocations of ₹ 0.5 trillion and ₹ 0.9 trillion were made to the Ministry of New and Renewable Energy (MNRE) and Ministry of Power (MoP), respectively. The allocation in key schemes under MNRE increased 25% from that announced in the interim budget owing to 16% higher allocation to the IREDA and PM- *Surya Ghar Muft Bijli Yojana* of ₹ 6.3 billion for Fiscal 2025. Following the announcement of viability gap funding (VGF) support for Battery Energy Storage Systems (BESS) in February's interim budget, the government further announced removal of basic customs duty (BCD) on critical minerals, such as lithium and cobalt from the existing rate of 5.0% Continued exemption for capital goods used in manufacturing photovoltaic (PV) cells and panels also announced, and the exemption of BCD for solar glass removed.

Monetary policy. In its monetary policy statement dated June 6, 2025, the Monetary Policy Committee (MPC) reduced the policy repo rate by 50 basis points (bps) to 5.50%. Consequently, the standing deposit facility (SDF) rate under the liquidity adjustment facility (LAF) shall stand adjusted to 5.25% and the marginal standing facility (MSF) rate and the Bank Rate to 5.75%. This decision is in consonance with the objective of achieving the medium-term target for CPI inflation of 4% within a band of +/- 2%, while supporting growth. Easing interest rates and improving banking liquidity is expected to reduce cost of capital for capital-intensive renewable energy (RE) projects.

Boost infrastructure: The capital expenditure and effective capital expenditure, which are budgeted at ₹ 11.2 trillion and ₹ 15.5 trillion are projected to account for 3.1% and 4.3% of GDP, respectively. The Budget 2025 also enumerated measures to be undertaken by the GoI to support the states and the private sector in boosting investments in infrastructure. This is expected to boost the overall power demand.

Thrust on manufacturing: The government has made some progress in improving labour market efficiency through various programmes such as Skilling India, Make in India, incentives through PLI Schemes, green energy corridor.

Digitalisation: The Indian government's Digital India program aims to boost financial inclusion and deliver services electronically through increased internet connectivity. Key initiatives include digital public Infrastructure for agriculture; national digital library for children and adolescents; fintech services; skill India digital platform; data embassy; Fiscal support for digital public infrastructure; unified payments interface (UPI) for real-time payments; These initiatives are expected to drive efficiency-led growth and digitization.

2 Overview of the Indian power sector

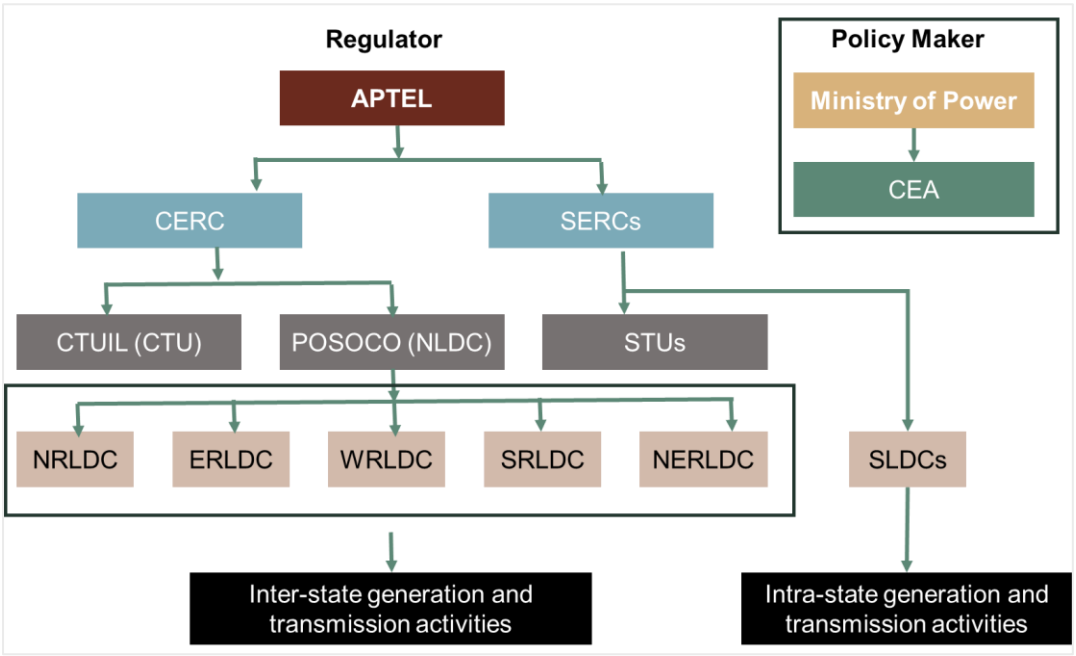
2.1 Overview of Indian power sector

2.1.1 Regulatory structure

India has a widespread power network with interconnected regional grids. The power generation profile is dominated by conventional (coal, lignite, natural gas, oil, hydro and nuclear power) sources, although, non-conventional sources (such as wind, solar, and biomass and municipal waste) are rapidly gaining traction. Transmission and Distribution infrastructure has expanded over the years for evacuation of power from generating stations to load centres through the Inter-State Transmission System (ISTS).

The sector is highly regulated, with various functions being distributed between multiple implementing agencies. There are three chief architects of the sector namely the Central Electricity Regulatory Commission (CERC), the CEA, and the SERCs.

Figure 1: Institutional and structural framework



Note:
APTEL - The Appellate Tribunal for Electricity; CERC; CEA; WRLDC- Western Regional Load Despatch Centre; ERLDC- Eastern Regional Load Despatch Centre; SRLDC- Southern Regional Load Despatch Centre; NLDC: National Load Despatch Centre (Now called as GRID-INDIA); NRLDC- Northern Regional Load Despatch Centre; NERLDC- North-Eastern Regional Load Despatch Centre.
SLDC- State Load Despatch Centre; CTU- Central Transmission Utility; STU- State Transmission Utility.

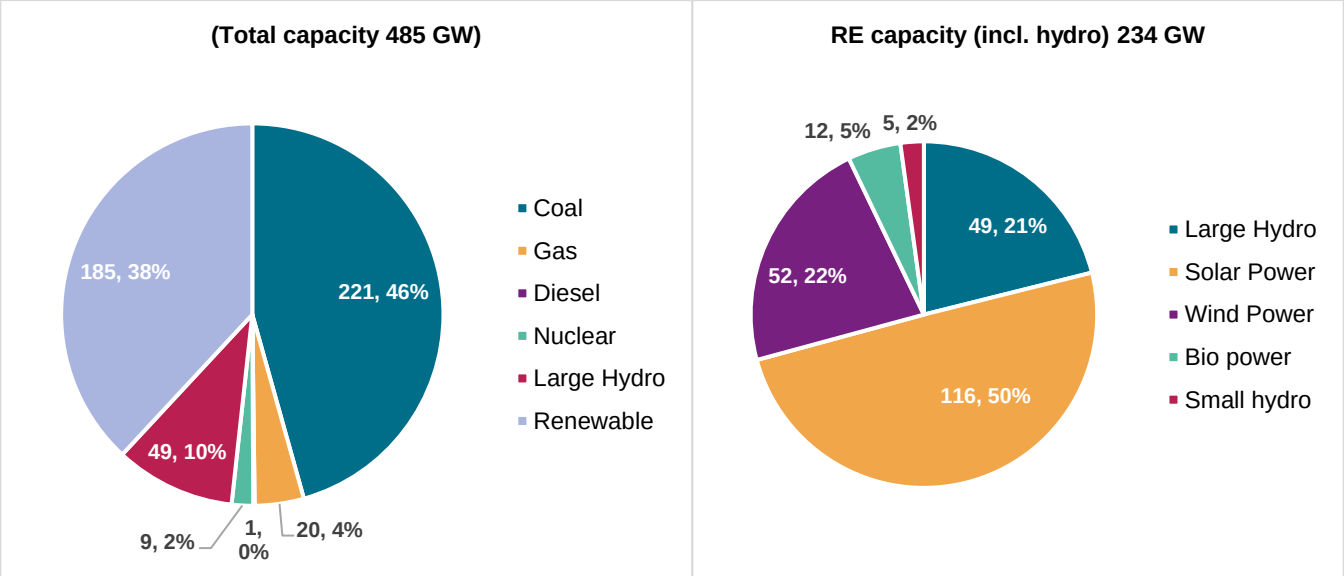
Source: Crisil Intelligence

2.2 Review of power demand-supply in India

2.2.1 Installed capacity and fuel mix

To meet India's growing energy demand led by rapid urbanization, large scale manufacturing push through PLI scheme, data center, and decarbonization efforts India's total installed capacity has increased from 302 GW from Fiscal 2016 to 475 GW in Fiscal 2025. The total installed generation capacity as of June 2025 was 485 GW. Coal and Lignite-based installed power generation capacity has maintained its dominant position over the years and accounts for approximately 46% of total Installed generation capacity as of June 2025. However, RE installations (including large hydroelectric projects) have reached 234 GW capacity as of June 2025, constituting approximately 48% of total installed generation capacity. This growth has been led by solar power, which rapidly rose to 103 GW in a decade.

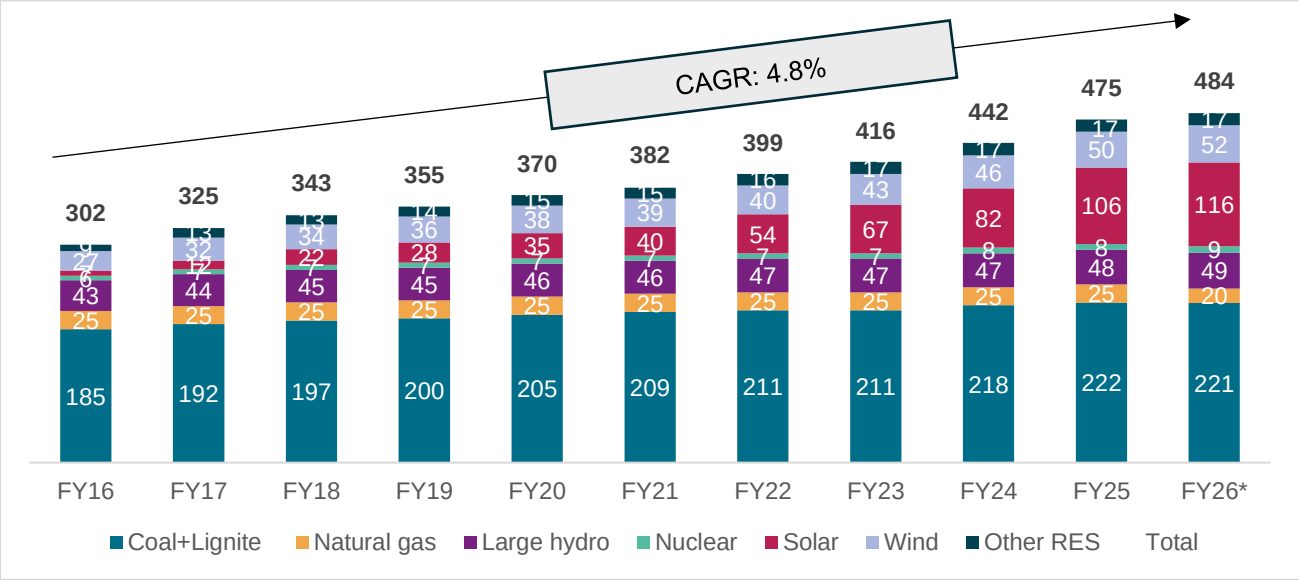
Figure 2: Installed capacity as of June 2025 (GW, %)



Source: CEA, Crisil Intelligence

Over the past five years, the installed capacity has exhibited a CAGR of 5.1% between Fiscal years 2020 and 2025. Notably, the capacity addition of RE sources (incl. large hydro) has demonstrated a more pronounced growth trajectory, achieving a CAGR of 10.6% during the same period. The primary driver of this growth has been the significant expansion of solar capacity, which has increased at a CAGR of 25%. Additionally, wind energy has also contributed to this growth, albeit at a relatively more modest pace, with a CAGR of 5.8%.

Figure 3: Growth in India's electricity installed capacity (GW)



Note:

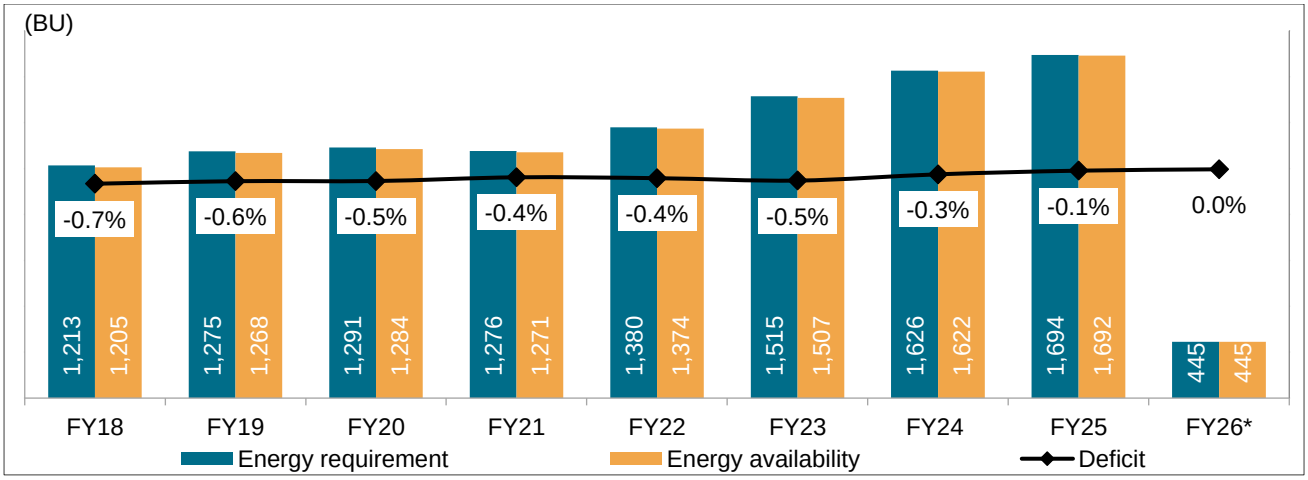
**As of June 2025, Other RES include small hydro, biomass/bagasse, waste to energy,*

Source: CEA, Crisil Intelligence

2.2.2 Energy requirement

India is the world's third-largest consumer of primary energy, behind China and the United States, and is a rapidly growing energy market. India's electricity requirement and availability have risen at a CAGR of 4.9% between Fiscals 2019 and 2025. The energy deficit reduced from 0.5% in Fiscal 2019 to just 0.1% in Fiscal 2025 due to an increase in capacity addition growth of 4.5% over the same period. Strengthening of inter-regional power transmission capacity over the past five years has supported the rapid fall in deficit levels as it reduced supply constraints on account of congestion and lower transmission corridor availability.

Figure 4: Aggregate power demand supply



Note:

**As of June 2025,*

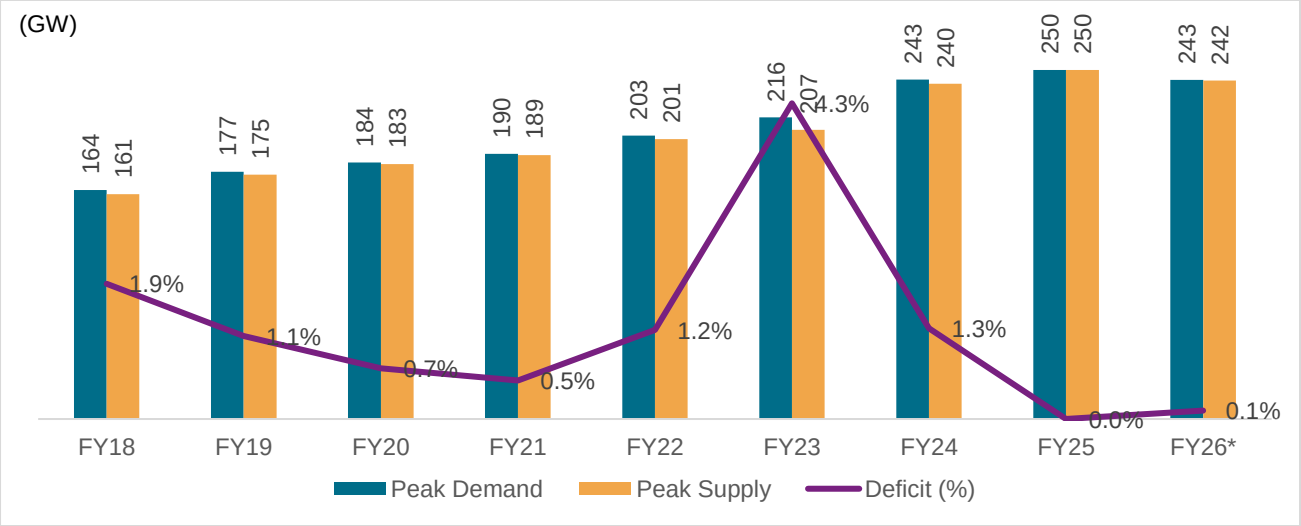
Source: CEA, Crisil Intelligence

2.2.3 Peak demand

Peak electricity demand in India has grown from 153GW in Fiscal 2016 to 250 GW in Fiscal 2025 clocking an average growth rate of 5.6% and projected to reach 335 GW by Fiscal 2030.

The constant rise in peak demand can be attributed to economic growth, seasonal vagaries, and an increasing daily average temperature that India has experienced over the last decade. In Q1 Fiscal 2025, power demand surged by 13% on year led by heatwaves and a 6.7% on year growth in GDP. Prolonged and severe heatwaves were especially prominent in the northern part of the country which was also impacted by deficient rainfall in July 2024.

Figure 5: Peak power demand and supply



Note:

**As of June 2025,*

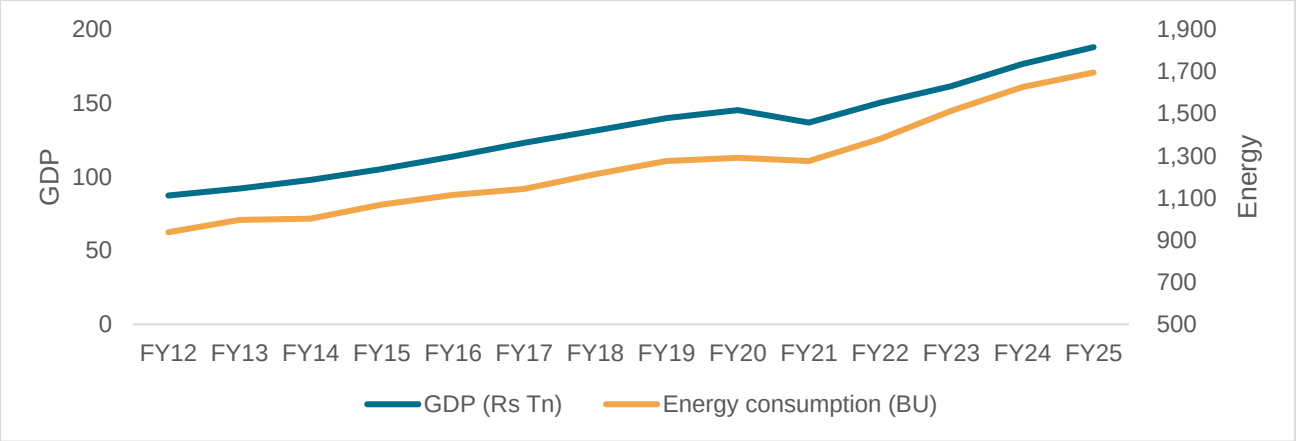
Source: CEA, Crisil Intelligence

2.2.4 Correlation between GDP and energy consumption

Historically, India's power demand has exhibited a strong positive correlation with its Gross Domestic Product (GDP), driven by key factors such as rapid industrialization, urbanization, and economic expansion. This correlation is evident in the country's energy landscape, where the energy deficit across states and union territories has been steadily declining, reaching a low of 0.1% in Fiscal 2025. A closer analysis of the correlation between national power demand and GDP, from Fiscal 2012 onwards, reveals a strong relationship, with a correlation coefficient (Multiple R) of 98.7%. This suggests that nearly 99% of the variation in power demand can be explained by changes in GDP, underscoring the critical link between economic growth and energy consumption in India.

The graph below illustrates a historical pattern of synchronized growth between GDP and energy consumption, depicting a strong correlation between the two indicators.

Figure 6: Correlation between GDP and energy consumption



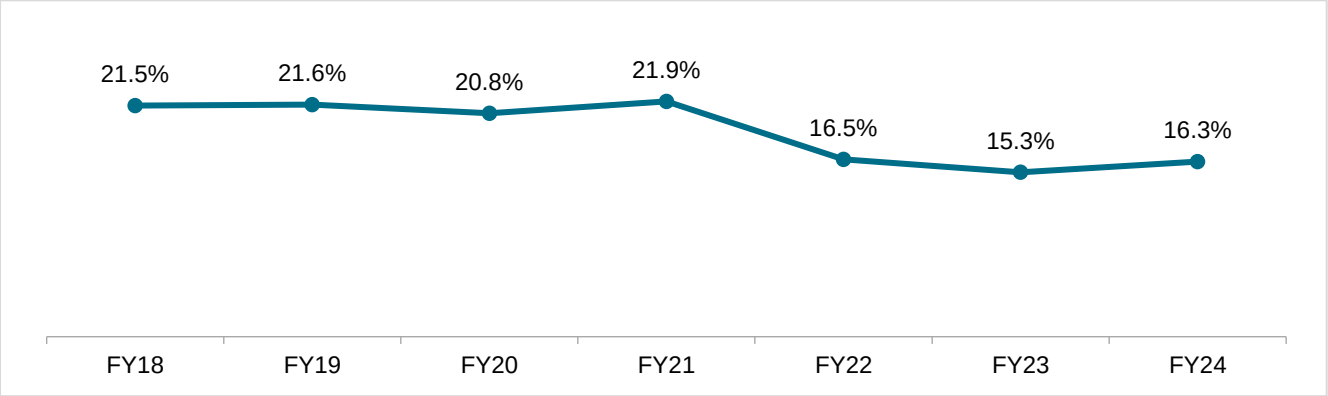
Source: MoSPI, CEA, Crisil Intelligence

2.3 Discom's financial health

2.3.1 Review of AT&C loss and ACS-ARR gap of state discoms

The AT&C losses for distribution utilities improved significantly from 21.9% in Fiscal 2021 to 16.5% in Fiscal 2022 due to an increase in collection efficiency from 92.5% to 97.2%. Collection efficiency increased due to improvement in subsidy disbursal by the state governments. The aggregate subsidy receipts of 109% were received in Fiscal 2022. The AT&C loss further improved to 15.3% in Fiscal 2023. However, the collection efficiency decreased by 1.2% from 97.6% in Fiscal 2023 to 96.4% in Fiscal 2024 which has led to an increase in AT&C loss in Fiscal 2024 to 16.3%.

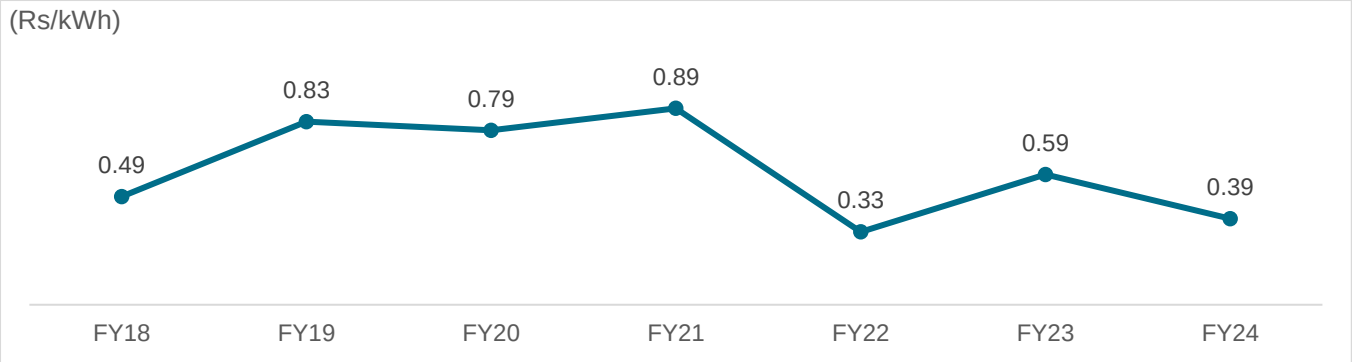
Figure 7: AT&C loss trajectory (%)



Source: PFC, Crisil Intelligence

The cash adjusted ACS and ARR gap narrowed to ₹ 0.33/kWh as of March 2022 driven by higher subsidies disbursement by state governments and better cash collections. In Fiscal 2023, the gap again increased to ₹ 0.59/kWh due to an increase in power purchase cost. However, during Fiscal 2024, the gap decreased by ₹ 0.20/kWh to ₹ 0.39/kWh.

Figure 8: ACS-ARR gap



Source: PFC, Crisil Intelligence

2.4 Assessment of key offtakers

Assessing the creditworthiness and financial stability of key off-takers is vital for the financial viability and success of power generation projects, especially those that rely on Power Purchase Agreements (PPAs). A thorough evaluation of the off-taker's risk profile is essential for securing financing and ensuring stable, long-term revenue streams. By conducting a comprehensive assessment of key off-takers, utilities and power generators can make informed decisions, optimize their operations, and ultimately enhance their overall performance.

Off taker	Credit Rating	Credit rating agency	Date	Avg day of payment to IPPs
GUVNL	AA (Stable)	ICRA	June 10, 2025	29
SECI	AAA Stable	ICRA	July 10, 2025	13
PSPCL	BBB- Stable	ACUITE	January 07, 2025	40
SJVN	AA+; Stable	Crisil	August 11, 2025	66
NTPC	AAA Stable	CareEdge	June 27, 2025	67
NHPC	AAA Stable	ICRA	July 03, 2025	NA
RUVNL	IVR C/ Stable	Infomerics Ratings	April 28, 2025	NA
JVVNL	BBB+ Stable	ACUITE	June 26, 2024	30
AVVNL	B/Stable	Brickwork	June 30, 2025	12
JdVVNL	BB+	ACUITE	July 18, 2025	33
UPPCL	A+ (CE) /Stable	Crisil	May 21, 2025	198
MSEDCL	A (Stable)	ACUITE	June 18, 2025	109
PED, Government of Mizoram	NA	NA	NA	170

Off taker	Credit Rating	Credit rating agency	Date	Avg day of payment to IPPs
HPPC	NA	NA	NA	NA
CESCOM	IND A; Stable	India Ratings	June 17, 2025	156
KPTCL	A; Stable	CareEdge	February 11, 2025	NA

Note:

NA: not available; N/A: Not applicable.

Source: Company, Rating Agencies, Annual Reports, 13th Integrated Rating Booklet by PFC, Crisil Intelligence

The following table summarises India's sovereign debt rating from various rating agencies.

Table 2: India's sovereign debt rating

Name of Agency	Rating	Outlook	Date
Fitch	BBB-	Stable	29 August 2024
Moody's	Baa3	Stable	2 June 2025
DBRS	BBB	Stable	8 May 2025
S&P	BBB	Stable	14 August 2025

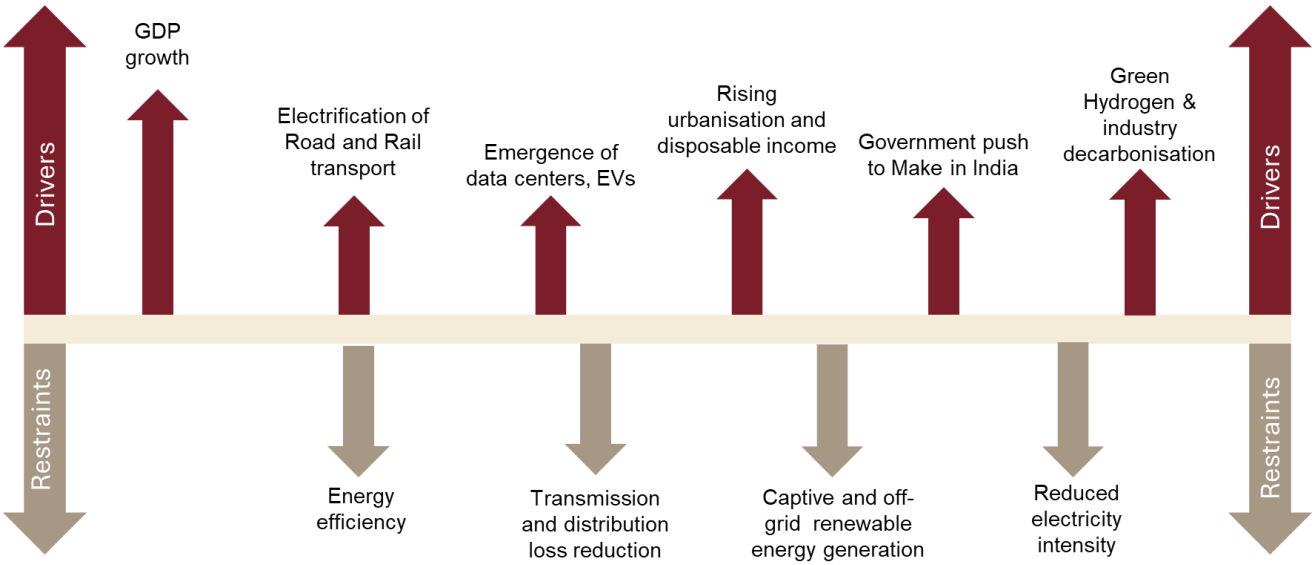
Source: Credit Rating Agencies, Crisil Intelligence

2.5 Outlook on power demand – supply scenario

2.5.1 Long term drivers and constraints for demand growth

Power demand is closely associated with a country's GDP. A booming economy automatically leads to a surge in power demand. India is already the fastest-growing economy in the world, with average GDP growth of 5.5% over the past decade. The trickle-down effect of *Aatmanirbhar Bharat* relief package, government spending on infrastructure through the National Infrastructure Pipeline, commissioning of the dedicated freight corridors, expansion of the services industry, rapid urbanisation, and increased farm income from agriculture-related reforms are key macroeconomic factors fostering 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, Production-Linked Incentive (PLI) scheme and low corporate tax rates among others have aided large scale manufacturing in India, further boosting power demand in the country.

Figure 9: Factors influencing power demand



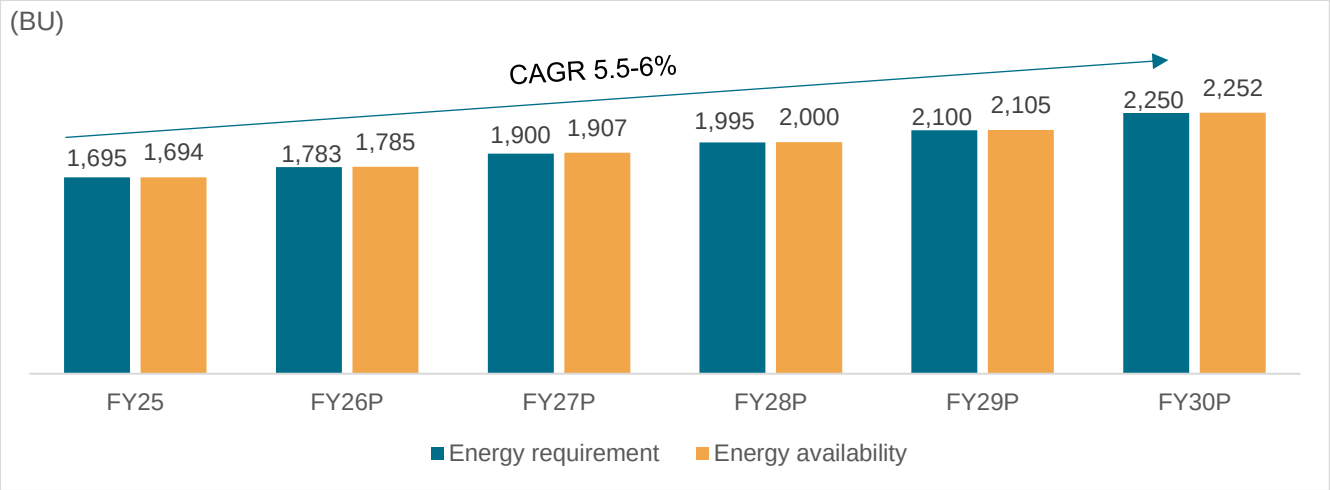
Source: Crisil Intelligence

Apart from macroeconomic factors, power demand would be further fueled by railway electrification where the government aims to achieve 100% electrification by Fiscal 2026 and under-construction metro rail projects of over 1018 km is expected to add about 120-125 BU of demand by Fiscal 2030. Further, growing demand for charging infrastructure due to increased adoption of electric vehicles would add 40-50 BU. Electrification of industrial processes and establishment of data centres would require 2-3 GW of power by Fiscal 2027 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 are expected to offset about 1% of overall electricity demand. Nonetheless, India's physical infrastructure, including its electricity grid, is less developed than that of many countries. As a result of grid constraints, such as grid congestion and restrictions on transmission capacity of the grid, the transmission and dispatch of the full output of projects may be curtailed.

2.5.2 Outlook on energy requirements

Despite the high base of the preceding three years, Crisil Intelligence expects power demand to grow by 5.5-6.0% in the next five years which is expected to 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, which are expected to improve the quality of power supply, thereby propelling power demand.

Figure 10: Energy demand outlook (Fiscals 2026-30)



Note:

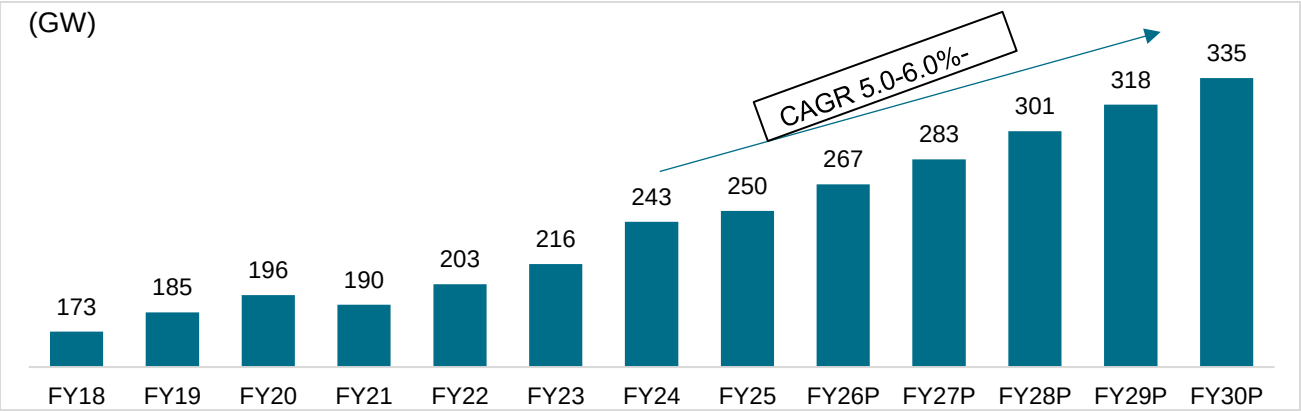
P: Projected,

Source: CEA, Crisil Intelligence

2.5.3 Outlook on peak demand growth

Peak demand is projected to grow at an annual average of 5-6% over Fiscal 2024-30 to reach nearly 335 GW by Fiscal 2030 with an expected persistent high temperature, rising urbanization, economic growth and infrastructure push leading to higher power consumption.

Figure 11: Peak demand projected to increase by 85 GW between Fiscals 2025 and 2030 to cross 300 GW



Note:

P: Projected,

Source: CEA, Crisil Intelligence

2.6 Outlook on capacity addition

2.6.1 Capacity addition outlook (FY2026-2030)

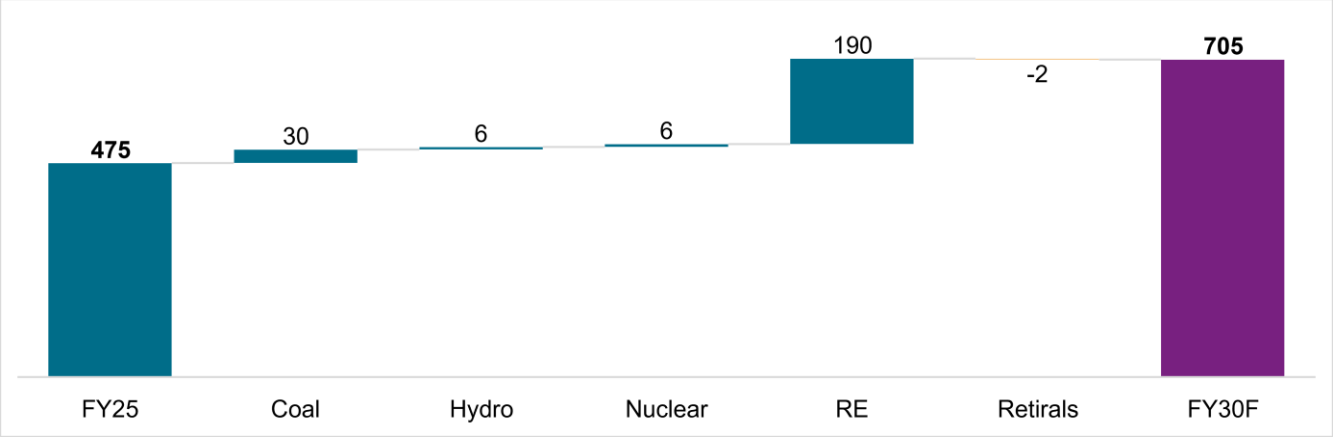
As per Crisil Intelligence estimates, the capacity additions in the conventional power generation segment are projected to be around 32-35 GW cumulatively between Fiscals 2026 to 2030, driven by higher than decadal average power demand.

Crisil expects 6-7 GW of hydro power installations and 30-40 GW of energy storage solutions including 10-12 GW pumped hydro storage projects (PSP) capacity additions and 23-24 GW of Battery Energy storage system (BESS) over Fiscals 2026-2030.

By Fiscal 2030, RE capacity (excl. large hydro) of over 180-190 GW is expected to be driven by various government initiatives, favourable policies, competitive tariffs, innovative tenders, development of solar parks and green energy corridors, among others. RE capacity is projected to account for about 50% of the installed capacity of 700-710 GW by Fiscal 2030. RE is expected to account for over 80% of the additional capacity between Fiscal 2026 and 2030.

The renewable energy sector has played a key role in capacity addition, with the renewable energy contribution to overall capacity having increased significantly from approximately 29% in Fiscal 2016 and approximately 46% in Fiscal 2025 and expected to reach approximately 66% by Fiscal 2032 as per CEA.

Figure 12: All India installed estimated capacity addition by Fiscal 2030 (in GW)



Note:

RE includes solar, wind, small hydro, and other renewable sources

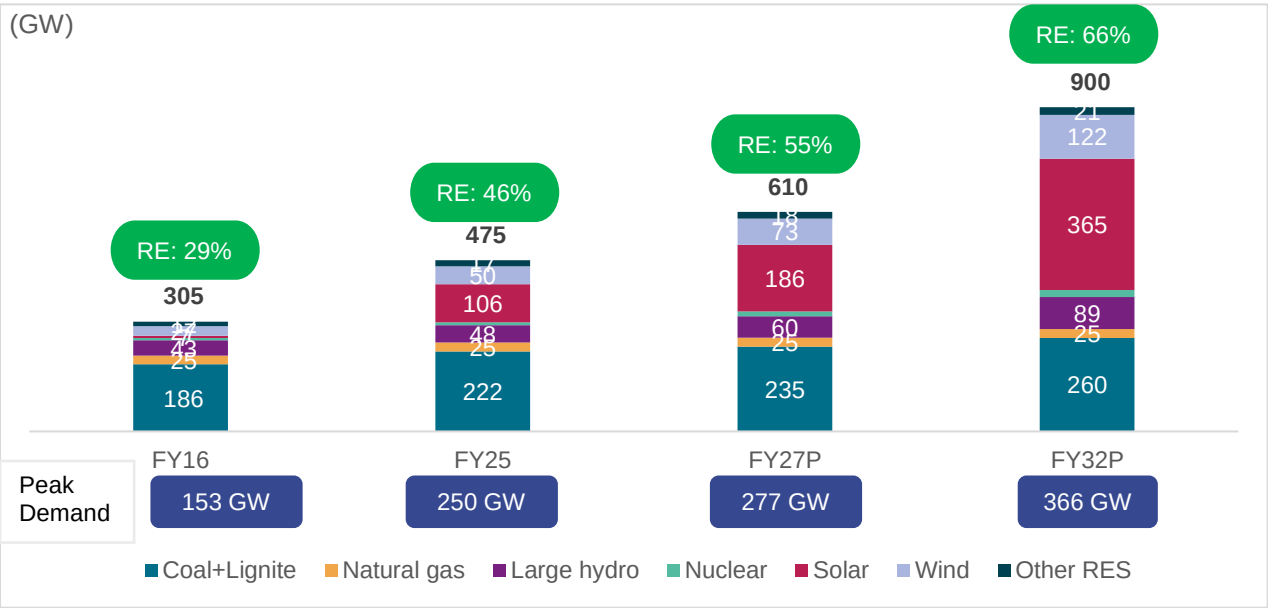
Source: CEA, Crisil Intelligence

To meet the growing energy demand led by rapid urbanization, large scale manufacturing push through PLI scheme, data center, decarbonization efforts India's total installed capacity has increased from 302 GW from Fiscal 2016 to 475 GW in Fiscal 2025 and is expected to reach 705-710 GW by Fiscal 2030.

RE is best suited for India and is therefore growing disproportionately compared to thermal energy, as evidenced by the fact that while the country plans to add 30 GW of thermal capacity over the next five years (excluding retirements), it has already added approximately 29 GW of RE capacity in Fiscal 2025 alone.

The total installed generation capacity as of June 2025 was 485 GW with RE installations (including large hydroelectric projects) being 234 GW capacity i.e., 48% of total installation. As per CEA, India's RE sector is set for significant expansion as the renewable energy mix expected go up to 66% by Fiscal 2032, supported by favourable policies and innovative projects. The total installed capacity has exhibited a CAGR of 5.0% between Fiscal years 2016 and 2025. Notably, the capacity addition of RE sources (incl. large hydro) has demonstrated a more pronounced growth trajectory, achieving a CAGR of approximately 11% during the same period. The primary driver of this growth has been the significant expansion of solar capacity, which has increased at a CAGR of approximately 36%.

Figure 13: India: Expected share of RE capacity



Source: CEA, National Electricity Plan 2022-32, Crisil Intelligence

The anticipated growth in RE capacity is expected to be driven by higher than decadal average power demand and various government initiatives, favourable policies, competitive tariffs, innovative tenders, development of solar parks and green energy corridors, among others.

This addition in RE is led by government push with significant policy initiatives such as Renewable Purchase Obligation (RPO) increase from 24.61% in Fiscal 2023 to 43.33% by Fiscal 2030, 24x7 power for all, green energy corridor to facilitate evacuation of RE power, green city scheme to promote the development of sustainable and eco-friendly cities, Production-Linked Incentive ("PLI") scheme and reduction in the GST, low corporate tax rates among others would further boost power demand in the country.

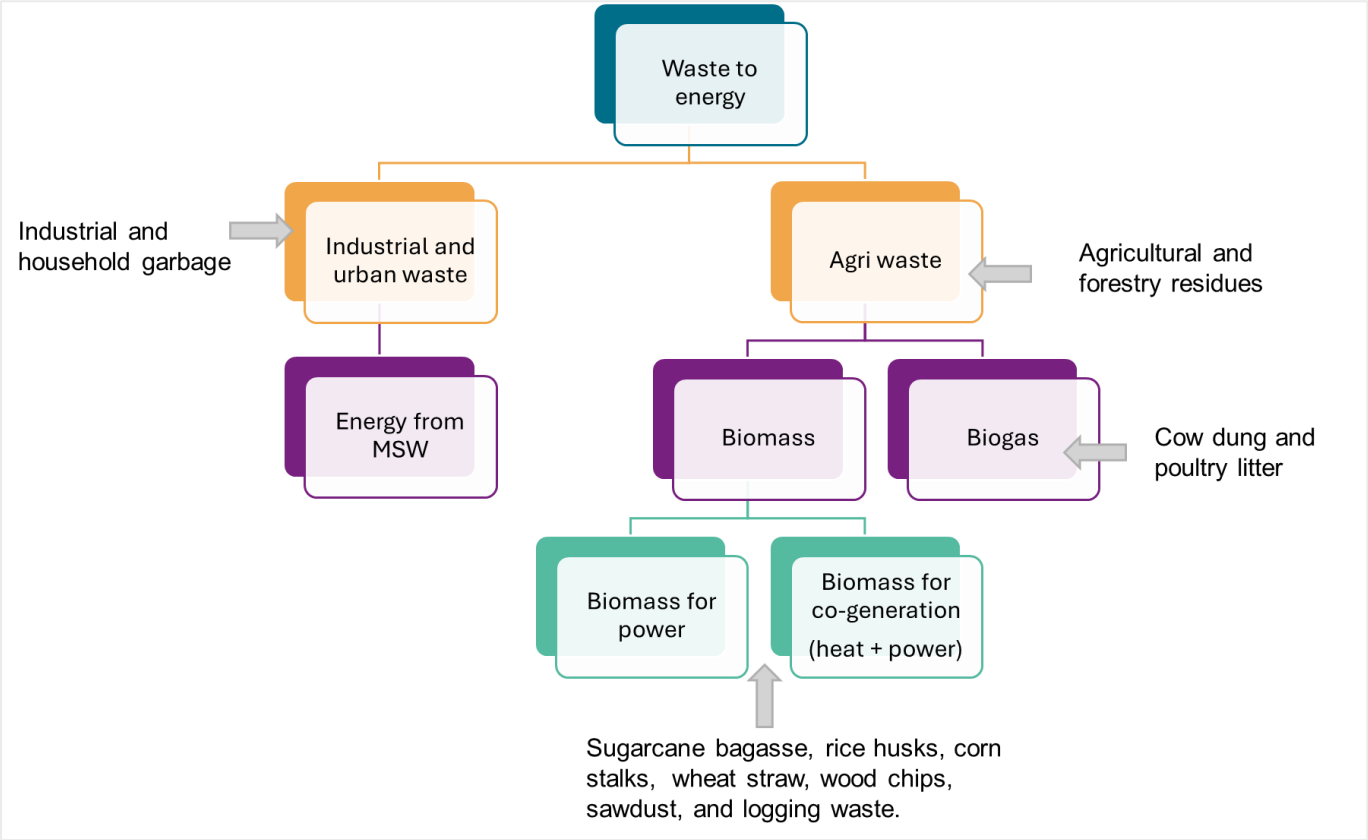
3 Overview and outlook of waste to energy sector in India

3.1 Introduction

The concept of "Waste to Energy" involves harnessing energy from renewable waste sources, including agricultural, industrial, and urban waste, to produce biogas, bioCNG, or electricity. This process utilizes various types of waste, such as municipal solid waste, vegetable and market waste, slaughterhouse waste, agricultural residues, and industrial or sewage treatment plant waste and effluents. Recent advancements in technology have enabled the decentralized generation of significant amounts of energy while also reducing waste quantities for safer disposal.

Various types of waste are generated from daily and industrial activities, including organic waste, electronic waste, hazardous waste, and inert waste. Notably, organic waste constitutes a substantial portion of overall waste generation in the industrial, urban, and agricultural sectors, making it a viable source for energy production.

Figure 14:Waste to energy classification



Source: MNRE, Crisil Intelligence

Energy generation potential in India from urban and industrial organic waste is roughly around 5.6 GW India has a large and readily available supply of agricultural residues, forestry waste and other organic waste that can be used for energy production. The availability of biomass in India is estimated at approximately 750 MT per annum with surplus availability of approximately 230 MT per annum. The estimated biomass power potential for India is approximately 28 GW, and this potential is derived from the availability of surplus biomass resources in the country.

Like India, China possesses substantial biomass resources, particularly agricultural and forestry residues, which are being increasingly utilized for energy production. China has been actively promoting the development of biomass

energy in recent years, with a focus on reducing greenhouse gas emissions, improving energy security, and promoting sustainable development. China has been actively promoting biomass energy development through various policies and initiatives, including Renewable Energy Law, Biomass Energy Development Plan, Subsidies and incentives, Research, and development etc. Biomass energy is being used in various applications in China, including power generation, heat supply, transportation (bio-fuels), industrial applications etc. China has made significant development in biomass energy and achieved an overall capacity of approximately 33 GW in 2024 from approximately 8 GW in 2015 (at a CAGR of 16.8%). Similarly, the USA, European countries like Germany, Denmark have been advocating from biomass energy development. India can draw lessons from China's biomass development experience to accelerate its own biomass energy growth. By learning from China's biomass development experience and leveraging its own strengths, India should be able to accelerate its biomass energy growth and achieve its renewable energy targets.

In 2022, at CoP 26 in Glasgow, India made a commitment to increase its non-fossil fuel based installed energy capacity to 500 GW by 2030. CEA, in its National Electricity Plan 2022-32, has estimated that by Fiscal 2032, India's installed capacity of biomass energy would be around 15.5 GW. The current capacity of Bio-Energy and Waste to Energy in the country is given in the table below:

Table 3: India-Bio-Energy and Waste to Energy capacity as on 30th June 2025

Sr. No.	Source	Installed Capacity (MW)
1	Biomass Power	864.66*
2	Bagasse Cogeneration	8,956.66
3	Biomass (non-bagasse) Cogeneration	921.79
4	Waste to Power	309.34
5	Waste to Energy (off-grid)	543.86
	Total	**11,596.31**

Note:

**Based on Crisil estimates considering tariff filings, tariff orders, State RE Development Agencies websites etc.*

Source: MNRE, Crisil Intelligence

National Bioenergy Program, Phase II as well as allowing power generated from co-firing of biomass for meeting non-solar RPO targets is expected to boost the development of bio-energy in India. National Bioenergy Program allows for the co-firing of biomass to meet non-solar RPO targets, budget outlay of ₹ 9.98 billion for central financial assistance (CFA) amongst others.

Various steps taken by the Government to promote and encourage the establishment of new waste to energy plants across the country, inter-alia, include:

- MNRE is implementing Waste to Energy (WtE) Programme under the umbrella of National Bioenergy Programme. The WtE Programme has a budget outlay of Rs 600 crore for the period Fiscal 2022 to Fiscal 2026. This Programme, inter-alia, supports setting up of plants for generation of Bio-CNG from urban, industrial, and agricultural waste by providing CFA.
- The Ministry of Petroleum and Natural Gas (MoPNG), under the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative envisages setting up of 5000 Bio-CNG plants with production target of 15 MMT of Bio-CNG. SATAT initiative encourages entrepreneurs to set up Bio-CNG plants, produce & supply Bio-CNG to Oil Marketing Companies (OMCs) for sale as automotive fuels.
- Department of Drinking Water and Sanitation (DDWS) launched Galvanizing Organic Bio-Agro Resources Dhan (GOBAR-DHAN) scheme in 2018. It is an integral part of Swachh Bharat Mission Phase II under Solid Waste

Management. The operational guidelines of Phase-II of SBM(G) provide for financial assistance up to ₹50.00 lakh per district for the period of 2020-21 to 2024-25 for setting up cluster/community level biogas plants.

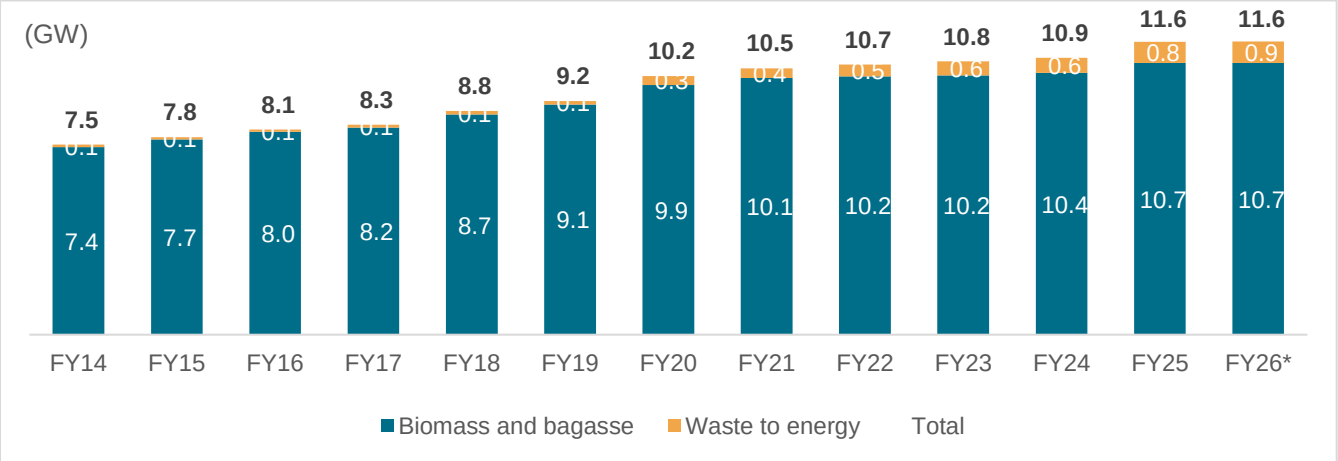
- MoPNG has introduced "Scheme for providing financial assistance to Compressed Biogas (CBG) producers for procurement of biomass aggregation machinery.
- The Government has approved "Scheme for development of Pipeline Infrastructure (DPI) for injection of Compressed Biogas (CBG) in City Gas Distribution (CGD) network".
- The Government has introduced phase wise mandatory blending of Compressed Bio-Gas (CBG) in Compressed Natural Gas (Transport) {CNG (T)} and Piped Natural Gas (Domestic) {PNG (D)} segments of City Gas Distribution (CGD) networks reaching up to 5% by Fiscal 2029.
- Concession is available on custom duty for import of machinery and components required for initial setting up of projects for generation of Power from non-conventional materials.
- Bio-CNG/Compressed Bio-Gas has been included under Priority Sector Lending.
- As per Solid Waste Management Rules 2016, non-recyclable waste having calorific value of 1500 Kcal/kg or more shall not be disposed of on landfills and shall only be utilised for generating energy either or through refuse derived fuel or by giving away as feed stock for preparing refuse derived fuel.

Favorable government policies, huge potential due to ample availability of feedstocks, government focus on waste management, and socioeconomic upliftment of farmers along with environmental benefit to boost biomass production is expected to drive the capacity additions.

3.2 Installed capacity of Bioenergy

India's bioenergy capacity is substantial and growing, with a total installed capacity of 11.58 GW (As of March 2025) in bioenergy, including off-grid and waste-to-energy projects. The bioenergy capacity has witnessed a growth of 4% over the last 10 years. (CAGR from Fiscal 2014-Fiscal 2025). This capacity is a key component of India's renewable energy mix, contributing to the country's efforts to diversify its energy sources and meet its climate commitments.

Figure 15: Installed capacity of bioenergy in India



Note:

**As of June 2025.*

Source: MNRE, Crisil Intelligence

Annual capacity additions in bio-energy have been in the range of 120-312 MW from Fiscal 2020 to Fiscal 2024. However, Fiscal 2025 saw the highest capacity addition of 642 MW. Fiscal 2025 witnessed 388 MW of biomass (bagasse), 195 MW waste to energy (off-grid) and 60 MW of waste to power capacity additions.

3.3 Comparison of various technologies for power generation

Parameter	Solar	Wind	Hydro (with storage)	Thermal (Coal)	Waste-to-Energy
Fuel	Not required (Sunlight)	Not required (Wind)	Not required (Water)	Coal	Agri wastes
Capital cost (₹ Cr/MW)	4.5-5.0	7.5-8.5	10-12	8-10	14.0-16.0
Tariffs (₹/kWh)	2.50-2.75	3.00-3.25	2.50-3.50	3.50-4.50	9.0-10.0
PLFs	20-25%	25-30%	40-50%	75-85%	75-85%
Payback Period (Years)	6-8	7-9	12-15	10-12	4-5
IRR	14-16%	12-14%	12-14%	10-12%	14-16%
Carbon emissions	No	No	No	High	Medium
Land requirement/MW	High	High	Low	Low	Low
Water requirement	Medium	Low	Low	High	Medium
Socio-economic impact	Low Minimal job creation, local economic benefits, and environmental concerns.	Low Minimal job creation, local economic benefits, and environmental concerns.	Medium with significant job creation, local economic benefits, but also concerns about displacement, ecosystem impact, and water usage.	High with high job creation, local economic benefits, but also significant environmental concerns and health risks.	Moderate with some job creation, local economic benefits, but also concerns about pollution, health impacts, and community acceptance.

Renewable energy sources such as solar and wind energy are becoming increasingly competitive with thermal (coal) power in terms of cost, with solar being the cheapest option. Hydro energy is still a viable option, but its high capital cost and long gestation period make it less attractive. Waste-to-energy is a niche technology with high capital costs, but it offers a unique solution for waste management and energy generation. Additionally, Agri Waste to Energy (AgWtE) provides higher PLF compared to solar and wind making it a good alternative to thermal (coal) power with lower emissions as well as other socio-economic benefits. Thermal (coal) power is still a dominant source of energy, but its high fuel costs and emissions make it less attractive in the long run. AgWtE is also reliable as it is free from fluctuations in supply and does not require energy storage for continuous and reliable power supply, unlike other renewable sources such as wind and solar.

3.4 Environmental benefits for WtE

The increasing global population, urbanization, and economic growth have led to a significant rise in waste generation, posing significant environmental and health concerns. The traditional methods of waste disposal, such as landfilling, have become unsustainable due to the scarcity of land, greenhouse gas emissions, and potential contamination of soil and groundwater. WtE technology has emerged as a viable alternative, offering a sustainable

solution to manage waste while generating clean energy. This report highlights the environmental benefits of WtE, a crucial aspect of a circular economy.

Reduced Greenhouse Gas Emissions

WtE technology helps mitigate climate change by reducing greenhouse gas (GHG) emissions in several ways:

1. **Avoidance of methane emissions**: Landfills are a significant source of methane, a potent GHG with a global warming potential 28 times higher than carbon dioxide over a 100-year timeframe. By diverting waste from landfills to WtE facilities, methane emissions are significantly reduced.

2. **Displacement of fossil fuels**: WtE plants generate electricity and heat, reducing the need for fossil fuels and the associated GHG emissions.

3. **Carbon sequestration**: Some WtE technologies, such as gasification and pyrolysis, can produce biochar, a stable form of carbon that can be stored in soils, reducing atmospheric CO2 levels.

Conservation of Natural Resources

WtE helps conserve natural resources in the following ways:

1. **Reduced landfilling**: By diverting waste from landfills, WtE technology helps preserve land for other uses, such as agriculture, conservation, and urban development.

2. **Water conservation**: WtE plants can be designed to recover water from waste, reducing the demand on freshwater resources.

3. **Material recovery**: WtE facilities can be integrated with recycling and materials recovery operations, increasing the recovery of valuable materials and reducing the need for primary raw materials.

Improved Air Quality

WtE technology can improve air quality by:

1. **Reducing particulate matter**: WtE plants are equipped with advanced air pollution control systems, minimizing particulate matter emissions and improving local air quality.

2. **Decreasing dioxin and furan emissions**: Modern WtE facilities employ technologies that minimize the formation of dioxins and furans, toxic pollutants that can have severe health impacts.

3. **Lowering volatile organic compound (VOC) emissions**: WtE plants can be designed to capture and utilize VOCs, reducing their release into the atmosphere.

Protection of Soil and Groundwater

WtE technology helps protect soil and groundwater by:

1. **Preventing leachate generation**: WtE facilities eliminate the need for landfills, which can generate leachate, a toxic liquid that can contaminate soil and groundwater.

2. **Reducing heavy metal emissions**: WtE plants are designed to capture heavy metals, preventing their release into the environment and potential contamination of soil and water.

3. **Minimizing waste disposal in sensitive ecosystems**: By providing a reliable and efficient waste management solution, WtE technology can reduce the likelihood of waste disposal in sensitive ecosystems, such as wetlands, forests, and coastal areas.

Waste to Energy technology offers a range of environmental benefits, including reduced greenhouse gas emissions, conservation of natural resources, improved air quality, and protection of soil and groundwater. As the economies shift towards a circular economy, WtE can play a vital role in managing waste sustainably, reducing the environmental impacts of human activity, and promoting economic growth.

Figure 16: Socio-economic impact of AgWTE

Employment

The seasonal nature of agriculture results in fluctuating job availability, with high demand during planting and harvesting periods, but prolonged unemployment during off-seasons. In many areas, particularly those with challenging terrain or small farms, mechanization is limited, and tasks like tilling, sowing, irrigation, and spraying are often performed manually. Tractor usage in most regions is relatively low, averaging 500-600 hours per year, which is significantly below the optimal utilization rate of 800-1,000 hours. However, AgWtE projects can help address these issues by creating new job opportunities in waste collection, processing, and plant operation, while also providing year-round employment and improving the utilization of farm equipment that would otherwise remain idle during off-seasons.

Emission

The practice of stubble-burning in northern India is a significant contributor to air pollution, releasing large amounts of particulate matter and trace gases into the atmosphere, which has severe consequences for both local and regional climate, as well as human health. In recent years, the surge in PM2.5 concentrations in the Delhi-NCR region and surrounding areas during the post-monsoon period has been linked to the burning of crop residue in northwestern India, exacerbating the problem of air pollution. Limited options with the farmers to manage stubble and short intervals between harvesting and sowing for the next cycle often lead to burning crop residue in open fields. The practice of stubble-burning in northern India is a significant contributor to air pollution during the months of October and November, releasing large amounts of particulate matter and trace gases into the atmosphere, which has severe consequences for both local and regional climate, as well as human health.

Research has shown that stubble burning is a major contributor to PM2.5 levels in Delhi during the months of October and November. However, AgWtE projects offer a solution by converting waste into energy, thereby eliminating the need for open burning or decomposition, which releases potent greenhouse gases like methane. By replacing fossil fuels with renewable energy, these projects also help reduce the overall carbon footprint, mitigating the impact of climate change.

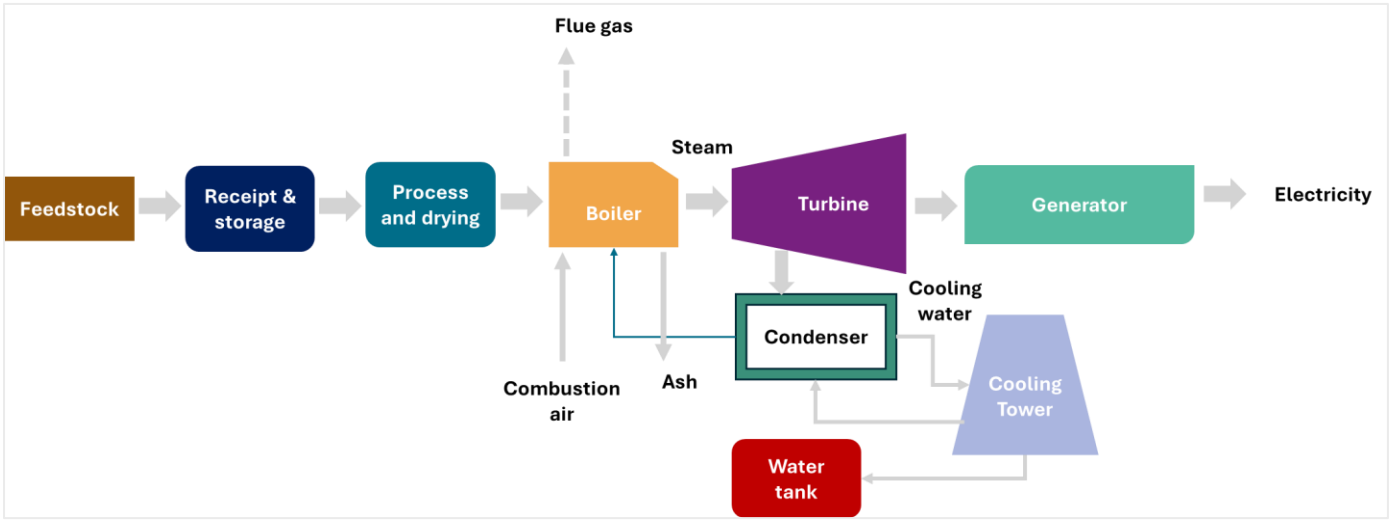
Economy

AgWtE projects have a profound impact on the economy, generating substantial benefits through the creation of revenue streams from waste, reduction of fuel costs, and decreased landfill expenses. Additionally, these projects stimulate local economic growth by creating employment opportunities in waste collection, processing, and plant operation, while also diversifying the income sources of farmers. Beyond their economic advantages, AgWtE projects also yield significant socio-economic benefits, including the promotion of a circular economy, enhancement of energy security, reduction of waste pollution, and improvement of the livelihoods of rural communities, ultimately contributing to a more sustainable and equitable development.

3.5 Overview of Biomass power generation equipment

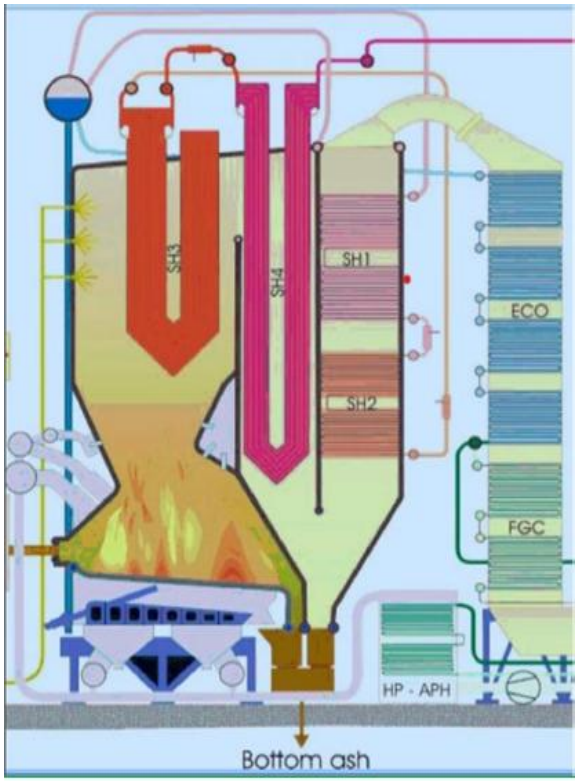
Biomass power plants essentially operate on regenerative Rankine cycle either with water cooled or air-cooled condenser. The condensing turbine uses 540^{0}C steam temperature at 92 ATA pressure and feed temperature of 235^{0}C for best cycle efficiency. Electricity generated from fuel is produced by direct combustion.

Figure 17: Pictorial representation of power generation from biomass



Source: Crisil Intelligence

A) Boiler



Biomass fired boiler is the heart of the bio-mass power plant and most critical equipment for availability of the plant. Fuel is manually loaded in the conveyor and distributed uniformly to achieve smooth feeding into the boiler. Conveyor feeds the fuel into the screw feeder which delivers the fuel into the boiler furnace. The load is controlled by controlling the speed of the conveyor using a variable frequency drive. The water-cooled stoker uses state of art technology. The stoker panel is part of the water wall circuit and remains cooled during its operation preventing damage by overheating. The grate panel vibrated from time to time to discharge the ash into the submerged chain conveyor. The vibration mechanism uses eccentric ram with heavy duty motors and gear boxes. The great panel is mounted with 'Flex tube' arrangement to allow movement of the water-cooled grate panel. Balanced draft Furnace is designed with sufficient precautions to retain heat and allow high moisture fuel to burn with maximum possible combustion efficiency. Superheaters are disposed according to the requirement of steam temperature and superheat temperature is controlled by multi-stage attemperators. High temperature superheaters are designed with austenitic steel to minimize corrosion due to aggressive fuel properties. Economisers are designed to extract maximum heat from the flue gas. Air heater uses feed water as heating medium wherein part of the incoming feed water is diverted for the purpose of heating air. Flue gas cooler is

the last heat trap in the entire boiler and designed to extract maximum heat for best boiler efficiency. The boiler is multi pass and bottom supported and mounted with soot blowers and water cannons to clean the heating surfaces of superheaters and furnace walls, respectively.

B) Turbo generator

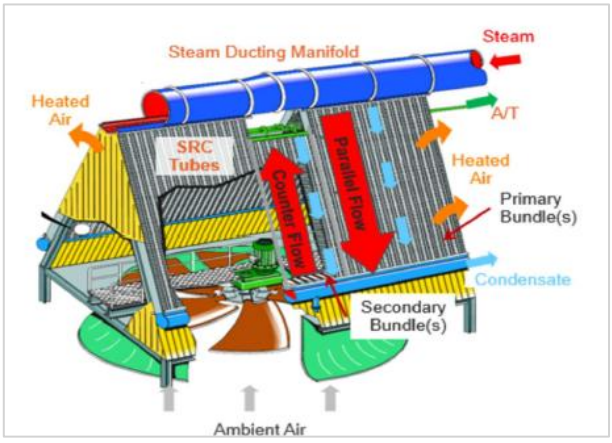
Single cylinder turbine with regenerative extraction is used for these projects. One or two numbers of low pressure heaters (depending on the size of the turbine), two high pressure heaters and one deaerator is configured in the steam and water cycle to derive the best efficiency of the regenerative cycle. A generator is coupled with the turbine through a gear box. Associated turbine and generator auxiliaries like lube oil system, barring gear and generator cooling system etc. are employed to complete the power generation cycle.



C) Condenser

Depending on the availability of water, air cooled or water-cooled condenser is installed.

- Water cooled condensers are designed with stainless steel tubes and surfaces are designed to achieve required vacuum in the condenser.
- Air cooled condenser (ACC) - The ACC unit is designed in multiple of modules. Each module consists of a number of finned tube bundles. The bundles are arranged in A-Frame shape. Each module is served by one axial flow fan driven by an electrical motor via a gearbox. The mechanical equipment is located underneath the tube bundles, delivering cooling air in forced draft mode.
  - The steam from the turbine exhaust flows through the duct, riser/s to the manifold at top of the tube bundles.
  - The steam enters the primary modules first. The uncondensed steam enters the secondary modules from the bottom header, operating in reflux mode.
  - The non-condensable are removed at the top of the secondary modules.
  - The condensate is drained from the bottom headers through condensate drain lines to the condensate storage tank (CST).
  - The condensate is pumped back to the deaerator by condensate extraction pumps.



D) Pollution abatement equipment:

While some of the projects uses electrostatic precipitator (ESP) to control particulate emission, some are designed with bag filters. The equipment are designed generously to achieve particulate emission of 50 mg/ Nm^3.

E) Stack

Stack height is maintained at 60m to disperse the residual pollutants as per the industrial norm. Concrete stack is used to safeguard the same from corrosive flue gas. Internal refractory brick lining is employed to prevent flue gas come in contact with the outer layer of concrete. Stack is mounted with staircase, ports for flue gas monitoring, aviation lamps and lightning arrestors as per the statutory norms.

F) Pre-treatment and DM plant

The power cycle requires high quality clarified and demineralized (DM) water. Some plants are using surface water while some are using borewell water. Surface water is treated in pretreatment process using clarifier and DM chain (Dual Media Filter (DMF), Activated Carbon Filter (ACF), Strong Base Anion (SBA), and Strong Acid Cation (SAC) etc.). For Borewell water, two stage reverse osmosis (RO) is used, service, make up and fire water is being taken after first stage RO while the second stage RO is used for preparing water for DM quality. microfiltration (MF) and ultrafiltration (UF) is also used to get finer quality water for high pressure boilers.

G) Environmental compliances

- **Abatement of Air Pollution:** Particulates are arrested in the ESP/ bag filter and can meet as low as 50 mg/Nm^3. The boilers are designed to control nitrogen oxides (NOx) emission below 400 mg/NM^3 at 6% O_2 level. Sulphur is very low in biomass compared to coal and as such the emission of SO_2 is also much lower than pulverized coal fired Boilers (without installation of FGD).
- **Zero Liquid Discharge:** Water cycle is designed in such a way that the wastewater from Cooling tower blowdown, DM plant back wash and regeneration is recycled and used in the Ash disposal process wherein it gets evaporated in the boiler furnace. Remaining water is used for floor wash and green belt development. Typically, for 15 -25 MWe plant water consumption per Mwe would be around 3.5 m3/hr with water cooled condenser and 1.0 m3/hr with air cooled condenser.
- **Sewage Treatment Plant:** STP is installed in the plant to treat the Sewage. The treated water is used for green belt development.

H) Electrical System

Suitable electrical system comprising of generator transformer, auxiliary transformer, motor control centre (MCC) and switchyard compatible to 33/66/132 kV is installed for operation and evacuation of power.

I) Land requirement

For a typical 15-25 MWe plant, one acre per MWe would be required with 4-5 days of fuel storage. This area includes internal roads, offices and provision for labour and staff quarters. Fuel storage facilities also help to buffer fluctuations in fuel feedstock prices and ensure a stable supply of fuel for AgWTE plants. The scale of storage is determined by the feedstock collection, processing, and transportation chain as well as the plant's capacity.

J) Imported Components

Except some critical components in boilers, other components and equipment are generally sourced from India from reputed suppliers. Indian supplies constitute 80 – 85% of total cost.

Biomass-based power projects in India offer a viable alternative to fossil fuels, with a relatively stable cost structure and returns. Unlike other RE PPAs, AgWtE PPAs have provision for annual escalation, allowing better ROI/better financing, and a more stable EBITDA margin profile over the life of the PPA. However, the cost of generation for AgWtE is higher compared to other renewable energy sources, and the sector faces challenges like fuel availability and quality. State-wise benchmarking highlights the variations in costs and returns across different regions, with returns in higher teens. To improve the competitiveness of biomass-based power projects, it is essential to focus on reducing costs, improving efficiency, and enhancing fuel availability and quality. The high cost to install and operate waste-to-energy plants is a reason for the comparatively lower penetration of waste-to-energy power generation in India. This is counter-balanced by the typically higher tariff structure that an AgWTE power plant is able to benefit from, as compared to alternative renewable technologies.

3.6 Overview on Value chain and stakeholder ecosystem

3.6.1 Value chain in agriculture waste to energy

The agriculture waste to energy value chain involves the conversion of agricultural waste into energy, which can be in the form of heat, electricity, or biofuels. The value chain includes various stakeholders, technologies, and processes that work together to generate energy from agricultural waste as summarise in following figure.

An agricultural fuel supply system involves several steps, including harvesting, collection, transport, and delivery of fuel to the plant. The value chain starts with harvesting. Then agricultural residues such as crop stubble, straw, or other biomass materials are collected from the fields after harvesting. Reaping involves cutting the agricultural residues into smaller pieces to facilitate easier handling and processing. Raking is the process of gathering the cut residues into windrows or piles, making it easier to collect and transport them. Baling involves compressing the gathered residues into large bundles or bales, which can be easily transported and stored. Baling can be done using machines such as balers or compactors. These are mechanized systems for cutting paddy straws and packing them into bales. Collection and loading involve gathering baled agricultural waste from the field or storage areas and loading it onto transportation vehicles. Transportation involves moving baled agricultural waste from the collection point to the energy generation facility. Storage involves storing baled agricultural waste at the energy generation facility or an intermediate storage location. Energy generation involves converting baled agricultural waste into energy, such as heat, electricity, or biofuels.

Figure 18: Agri Waste-to-Energy value chain

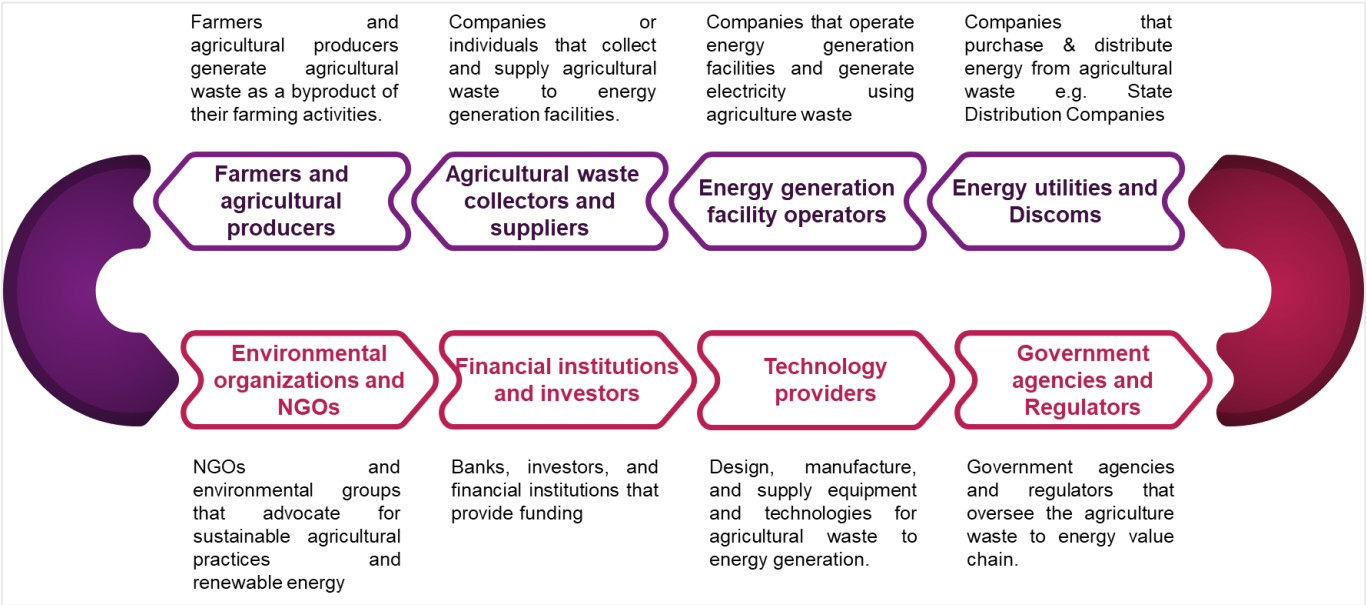


Source: Crisil Intelligence

3.6.2 Stakeholders in agriculture waste to energy value chain

Various stakeholders are involved in agriculture waste to energy value chain. These stakeholders play important roles in agriculture waste to energy value chain, and their interests and motivations can impact the development and operation of agricultural waste to energy projects.

Figure 19: Stakeholders involved in agriculture waste to energy value chain



Source: Crisil Intelligence

3.6.3 Supply chain challenges

- **Feedstock quality and quantity:** Ensuring a consistent and sufficient quantity of feedstock, as well as quality, is crucial for efficient energy generation. Managing logistics and labor for harvesting and baling as well as minimizing losses is also critical. Pre-treating agricultural waste to improve its quality and consistency can be challenging.
- **Collection and transportation:** Collecting and transporting agricultural waste safely and efficiently can be challenging and expensive due to logistics and labor for collection and loading.
- **Energy conversion technologies:** Energy conversion technologies, such as anaerobic digestion, gasification, or pyrolysis, can be complex and require significant investment. Energy efficiency and conversion rates can vary greatly depending on the technology and feedstock used.
- **Regulations and policies:** Regulations and policies governing agricultural waste management and energy generation can be unclear or inconsistent. Developing and implementing supportive policy and regulatory frameworks can be challenging due to competing interests and priorities.
- **Public perception:** Public perception of agricultural waste to energy projects can be negative, due to concerns about environmental impact or health risks. Gaining public acceptance and support for agricultural waste to energy projects can be challenging due to concerns about environmental impact or health risks.
- **Economic viability:** Agricultural waste to energy projects can be capital-intensive and may require significant investment to be economically viable. Securing financing and funding for agricultural waste to energy projects can be difficult due to high upfront costs and perceived risks.
- **Scalability:** Scaling up agricultural waste to energy projects can be challenging due to limitations in feedstock availability, technology, and financing. Also, scaling up energy conversion technologies to accommodate large quantities of feedstock can be complex, expensive, and unviable.
- **Environmental impact:** Agricultural waste to energy projects can have environmental impacts, such as air and water pollution, which need to be mitigated.
- **Crop Cycle and Handling:** The short crop cycle of 2-3 months can be a challenge for the plant operators along with the ability to procure and store the paddy straw and such raw materials in satisfactory condition to be able to be utilized effectively after the harvesting period.

3.7 Key Government Initiatives & Policies

India is on a path to tap into its bioenergy potential, prioritizing biogas, biomass power, and cogeneration as key drivers to achieve this goal. A range of programs and initiatives have been launched to foster the growth and adoption of bioenergy technologies nationwide, driving progress in this field. MNRE is leading the charge, introducing initiatives such as the National Bioenergy Programme, which aims to leverage the country's abundant surplus biomass, cattle dung, industrial waste, and urban biowaste to unlock its bioenergy potential.

Policy/Scheme	Key objective
National Biofuels Policy (NBP)	To promote the production and use of biofuels, aiming to reduce reliance on fossil fuels and enhance energy security
National Bio-Energy Programme (2022–2026)	To promote the generation of energy from various biomass sources like urban, industrial, and agricultural waste, as well as municipal solid waste.
SATAT (Sustainable Alternative Towards Affordable Transportation)	To promote the production and use of Compressed Bio-Gas (CBG) as a sustainable and affordable alternative to fossil fuels for transportation
SAMARTH (Sustainable Agrarian Mission on Use of Agro Residue in Thermal Power Plants)	To reduce air pollution from stubble burning and lower carbon footprint in thermal power generation.

A. National Biofuels Policy (NBP)

The “National Policy on Biofuels - 2018” was notified by MoPNG on June 4, 2018 in replacement of National Policy on Biofuels, promulgated through the MNRE, in 2009. The NBP aims to promote biofuels and increase their usage in the energy and transportation sectors. It envisions a central role for biofuels in India's energy security and climate change mitigation, while also creating new employment opportunities. The policy expands the scope of raw materials for biofuel production, including sugarcane juice, sugar-containing materials, and even surplus food grains under specific conditions. It also encourages the development of advanced biofuels and promotes the establishment of biofuel production facilities in Special Economic Zones (SEZs) and Export-Oriented Units (EoUs). NBP-2018 was amended in May 2022.

B. National Bio-Energy Programme (2022–2026)

MNRE has notified the National Bioenergy Programme in November 2022. MNRE has continued the National Bioenergy Programme for the period from Fiscal 2022 to 2026. The Programme has been recommended for implementation in two Phases. The Phase-I of the Programme has been approved with a budget outlay of ₹ 858 crores.

The National Bioenergy Programme comprises the following sub-schemes:

a) **Waste to Energy Programme:** Programme on Energy from Urban, Industrial and Agricultural Wastes /Residues to support setting up of large Biogas, Bio-CNG and Power plants (excluding MSW to Power projects).
b) **Biomass Programme:** Scheme to Support Manufacturing of Briquettes & Pellets and Promotion of Biomass (non-bagasse) based cogeneration in Industries to support setting up of pellets and briquettes for use in power generation and non-bagasse based power generation projects.

c) **Biogas Programme:** to support setting up of family and medium size Biogas in rural areas.

Budget outlay for sub-schemes of National Bioenergy Programme is as per table given below.

Sub-scheme	Budget outlay of Phase-I (₹ Crore)
Waste to Energy Programme	600
Biomass Programme	158
Biogas Programme	100
Total	**858**

To utilize huge surplus biomass, cattle dung, industrial and urban biowaste available in the country for recovery of energy, the MNRE has been promoting bioenergy in India since 1980s. One major support extended by MNRE has been CFA provided for setting up of Bioenergy projects such as Biogas, Bio-CNG, Power from urban, Industrial and Agricultural Waste / Residues for reducing their capital cost/ interest on loan therefore increase project viability.

a) Waste To Energy Programme (WtE)

MNRE has been implementing a Programme on Energy from Urban, Industrial, Agricultural Wastes/ Residues and Municipal Solid Waste since 2018 for recovery of energy in the form of Biogas/Bio-CNG/Power from urban, industrial, agricultural wastes and municipal solid waste. Under new guidelines of the programme for the period of 2021-22 to 2025-26, CFA shall be made available to projects for setting up large Biogas, Bio-CNG and Power plants (excluding MSW to Power projects).

The programme provides CFA to project developers and service charges to implementing/inspection agencies in respect of successful commissioning of Waste to Energy plants for generation of Biogas, Bio-CNG/enriched Biogas/Compressed Biogas, Power/ generation of producer or syngas.

Program	Central Finance Assistance
i. Biogas	₹0.25 Cr per 12000cum/day (maximum CFA of ₹ 5.0 Cr/project)
ii. Bio-CNG/Enriched Biogas/ Compressed Biogas	a) ₹4.0 Cr per 4800 kg/day (for Bio-CNG generation from new biogas plant) b) ₹3.0 Cr per 4800 kg/day (for Bio-CNG generation from existing Biogas plant*) (Maximum CFA of ₹ 10.0 Cr/project for both cases.)
iii. Power (based on Biogas)	a) ₹0.75 Cr/MW (for power generation from new biogas plant) b) ₹0.5 Cr /MW (for power generation from existing Biogas plant) (Maximum CFA of ₹ 5.0 Cr/project for both cases)
iv. Power based on bio & agro-industrial waste (other than MSW through incineration process)	₹0.4 Cr/MW (maximum CFA of ₹ 5.0 Cr/project)
v. Biomass Gasifier for electricity/thermal applications	i. ₹ 2,500 per kWe with dual fuel engines for electrical application ii. ₹ 15,000 per kWe with 100% gas engines for electrical application iii. ₹ 2 lakh per 300 kWh for thermal applications.

The eligible CFA would be 20% higher for plants set up in Special Category States/UTs (NE Region, Sikkim, Himachal Pradesh, Uttarakhand, Jammu & Kashmir, Ladakh, Lakshadweep and Andaman & Nicobar Islands), and Biomethanation plants set up in registered Gaushala/Shelter.

The amount of CFA to be disbursed for the WtE projects will be calculated based on the performance the projects (for at least three consecutive months).

Average PLF achieved during minimum 3 consecutive months	% of eligible CFA
≥80%	100%
≥ 60% and < 80%	80%
≥ 50% and < 60%	60%
<50%	0%

b) Biomass Programme

MNRE has been implementing the programme to promote Biomass Power and Bagasse Cogeneration in the country since the 1990s. The Biomass-based Cogeneration Programme (launched in May 2018) was under implementation with the main objective of promoting cogeneration for optimum use of the country's biomass resources through cogeneration technology in sugar mills and other industries (rice, paper mills, etc). The Programme which earlier focused on cogeneration is expected to support the manufacturing of pellets and briquettes for use in power generation. The scheme is likely to support the implementation of the National Mission on Co-firing of Biomass in Thermal Power Plants. This is expected to enable a reduction in the practice of stubble burning particularly in the northern states of the country. Burning of paddy stubble in North India is a major cause of air pollution and is also leading to the degradation of soil quality. Under new guidelines of the programme for the period of 2021-22 to 2025-26, CFA shall be made available to projects for setting up of pellets and briquettes for use in power generation and non-bagasse based power generation projects.

Revision in Guidelines for the Biomass Programme under the Umbrella scheme of National Bioenergy Programme for duration for FY 2021-22 to 2025-26 (Phase-I)

MNRE has issued revised guidelines for the Biomass Programme under Phase-I of the National Bioenergy Programme, applicable for the period FY 2021–22 to 2025–26. These amendments aim to promote cleaner energy solutions, ease of doing business, and accelerate the adoption of biomass technologies across India. One of the major highlights of the revision is technological integration by enabling the use of IoT-based monitoring solutions or quarterly data submissions instead of expensive and high-tech systems like SCADA. This cost-effective step promotes digital monitoring and accountability, especially for smaller business operators. The guidelines also encourage significant simplification of documentation requirements. Developers of briquette and pellet manufacturing plants will no longer be required to submit number of documents related to clearance matters. This change is expected to save time and promote ease of doing business. In a move to enhance operational flexibility, the earlier requirement for a two-year briquette or pellet sale contract has been replaced with a general sale agreement. Furthermore, the subsidy disbursement mechanism under the CFA component has been made performance-based and transparent. Projects that run efficiently, above 80%, will receive full financial assistance, while those below 80% will receive it on pro-rata basis.

c) Biogas Programme

MNRE has been promoting the installation of small biogas plants since 1981-82 under National Biogas Programme to provide clean gaseous fuel mainly for cooking and lighting purposes in rural areas. Similarly, for medium size biogas plants in the capacity range of 25 - 2500 cubic meter per day biogas generation for decentralized power generation and thermal energy applications in the range of 3-250 kW has been supported by MNRE since the year 2005-06. Under the new scheme for the period of 2021-22 to 2025-26, the scope of the scheme has been revised with enhanced financial assistance for the setting up of biogas plants from 1 to 2500 cubic meter biogas per day.

C. SATAT (Sustainable Alternative Towards Affordable Transportation)

The SATAT (Sustainable Alternative Towards Affordable Transportation) scheme, launched in 2018, with the aim of establishing an ecosystem for production of Compressed Biogas (CBG) from various waste/ biomass sources and for promoting its use along with Natural Gas by the MoPNG. It aims to promote the production and utilization of CBG as an alternative to traditional fossil fuels. CBG is a biofuel produced using feedstock such as paddy straw, municipal solid waste, press mud from the sugar industry and cattle dung or poultry litter. It is chemically similar to natural gas and can be used for automotive and industrial applications. A maximum financial assistance of 50% of the procurement cost of biomass aggregation machinery or ₹ 9 million per set (whichever is less) will be admissible as grant to a CBG producer. The financial assistance of ₹ 18 million for 4 TPD CBG capacity project would be provided with a capping of ₹ 90 million per project on pro rata basis. The MNRE has notified CFA of ₹ 40 million per 4,800 kg of CBG per day generated from 12,000 cubic meters of biogas per day, with a maximum of ₹100 million per project.

D. SAMARTH (Sustainable Agrarian Mission on Use of Agro Residue in Thermal Power Plants)

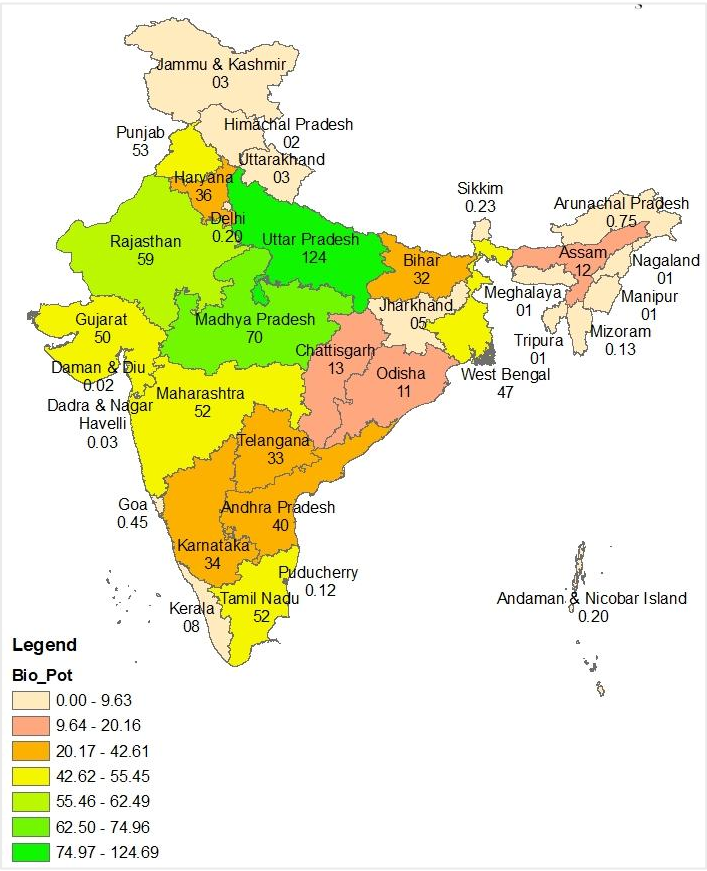
The MoP is implementing a National Mission on use of Biomass in coal based thermal power plants known as SAMARTH (Sustainable Agrarian Mission on use of Agri Residue in Thermal Power Plant) Mission. The mission aims at conversion of Biomass to Power in an eco-friendly and cost-effective manner with suitable market mechanism thereby mitigating air quality deterioration. As a result, the mission is expected to address the issue of air pollution due to farm stubble burning as well as reduce carbon footprints of thermal power generation. The revised policy of the MoP issued on 08.10.2021 on Biomass utilization for power generation through co-firing in coal based power plants states mandatory use of 5% blend of biomass pellets made, primarily, of agro residue along with coal with effect from one year of the date of issue of the policy. This obligation shall increase to 7% with effect from two years after the date of issue of above policy and thereafter. As per MNRE, the power generated from co-firing of biomass in TPPs is renewable energy and such power is eligible for meeting other RPO. As per July 2024, notification financial support of ₹ 9 Lakh per TPH of capacity with a capping of ₹ 45 Lakh per project by MNRE is provided under SAMARTH for Briquette/ Pellet Manufacturing plants.

3.8 Overview of Feed Stock

3.8.1 Crop-wise Biomass availability in India

As per Land Use Statistics for 2022-23, the reported area of India is 306,650 thousand hectares, of which around 59% is agricultural land, 140,705 thousand hectares is the reported net sown area, and 219,357 thousand hectares is the gross cropped area with a cropping intensity of 155.9%. This includes the Kharif, rabi and summer seasons acreage and annual crops. The total biomass available at India level was 754.8 million tonnes (MT) average from 2015–2018 (TE 2015-18). Out of this total biomass production certain portions of biomass are used for domestic uses such as domestic fuel, cattle feed, and manure etc. After domestic use, around 228.5 MT surplus biomass residue remains available for other uses. Following figure indicates the State wise biomass availability. Thus, around 70% of total biomass produced is utilised for domestic uses and for consumption, whereas the remaining 30% has resulted in surplus biomass. The MoP revised the biomass policy in 2021 and now mandated 5% biomass co-firing in thermal power plants from FY 2024-25. This obligation is increased to 7% from FY 2025-26.

Figure 20: Total biomass available in India (Mn Tonnes)



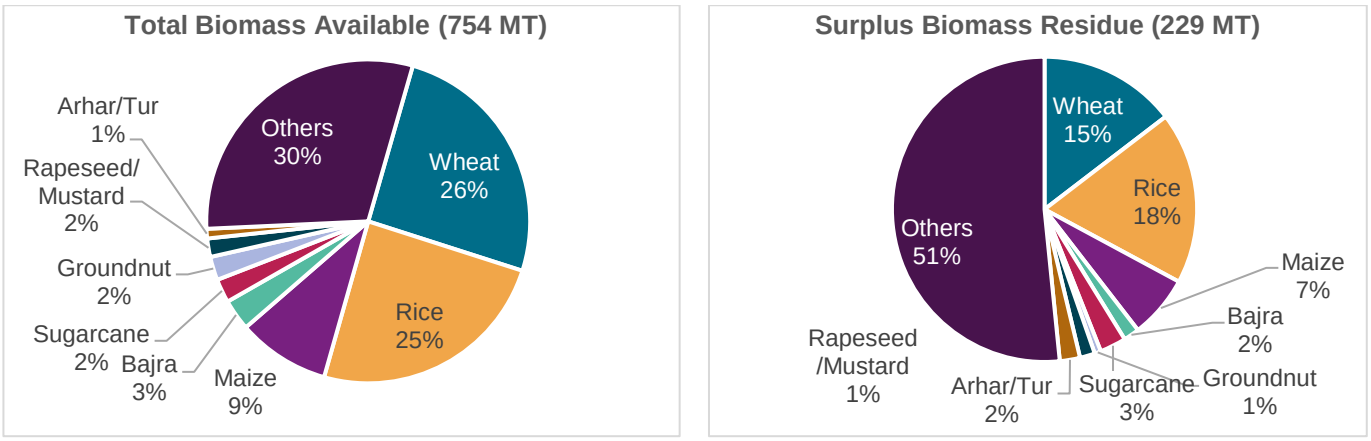
Note: Total includes–Arhar/Tur, Bajra, Banana, Barley, Coriander, Cowpea (Lobia), Dry chillies, Garlic ,Ginger, Gram, Groundnut, Guar seed, Jowar, Jute, Linseed, Maize, Masoor, Mesta, Moong (Green Gram), Moth, Onion, Other Kharif pulses, Other oil seeds, Peas & beans (Pulses), Potato, Ragi, Rapeseed & Mustard, Rice, Sesamum, Small millets, Soyabean, Sugarcane, Sunflower, Sweet potato, Tobacco, Turmeric, Urad, Wheat.

Source: National Institute of Bio-energy; Crisil Intelligence

3.8.2 Crop-wise Surplus Biomass Residue Available in India

Key crops such as wheat, rice, maize, bajra, sugarcane, groundnut, rapeseed/mustard, and arhar/tur contribute approximately 70% in total biomass production whereas approximately 48% of surplus biomass residue remains available from these crops as shown in following figure.

Figure 21: Crop wise surplus Biomass Residue Available in India



Note:

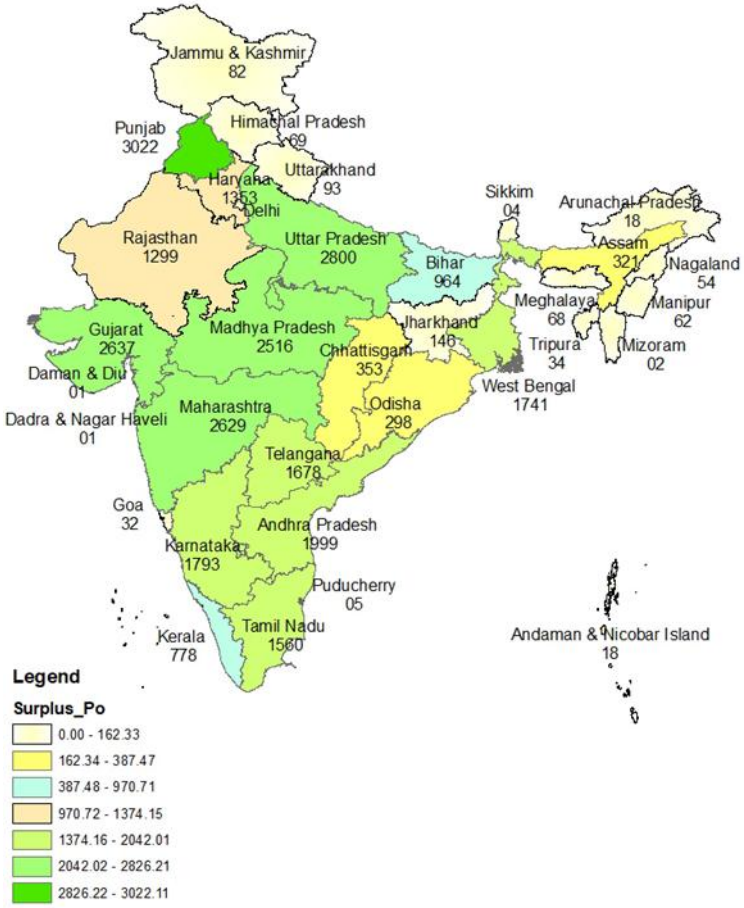
Crop wise availability and surplus may vary depending on seasonality, monsoon patterns as well as cropping pattern

Source: National Institute of Bio-energy; Crisil Intelligence

3.9 Biomass Power Generation Potential in India

The estimated biomass power potential for India is approximately 28 GW, according to a study conducted by the Administrative Staff College of India (ASCI) for the MNRE in 2021. This potential is derived from the availability of surplus biomass resources in the country. Key states such as Andhra Pradesh, Gujarat, Madhya Pradesh, Maharashtra, Punjab, and Uttar Pradesh contribute approximately 55% of the total potential of biomass power.

Figure 22: Surplus biomass power potential in India (MW)



Source: National Institute of Bio-energy; Crisil Intelligence

3.9.1 Benefits of Energy Generation from Paddy Straw

Generating energy from paddy straw offers a range of benefits, from reducing greenhouse gas emissions and improving air quality to promoting energy self-sufficiency and rural development.

- Paddy straw a byproduct of wheat/rice cultivation is a renewable energy source, as it reduces dependence on fossil fuels and helps mitigate climate change.

- Paddy straw is available in large quantities, particularly in agrarian country like India where wheat and rice are grown. This abundance makes it a reliable feedstock for energy generation.

- Converting paddy straw into energy helps manage agricultural waste as burning paddy straw in the field, a common practice, releases harmful pollutants and greenhouse gases. Converting it into energy reduces these emissions and helps minimize air pollution. resulting in improved air quality and a decrease in respiratory problems.

- The collection, processing, and conversion of paddy straw into energy can create employment opportunities in rural areas leading to additional income streams for farmers and contributing to local economic development
  .

Air pollution in Delhi and NCR due to stubble burning

Air pollution in Delhi and NCR is a collective result of multiple factors including high level of anthropogenic activities in the high-density populated areas in NCR, arising from various sectors viz. Vehicular Pollution, Industrial Pollution, Dust from Construction and Demolition activities, Road, and Open Areas Dust, Biomass Burning, Municipal Solid Waste burning, Fires in Landfills, and air pollution from dispersed sources, etc.

As only 2-3 weeks' time is available for farmers to clear crop residue post harvesting and make the fields ready for the next season, they mostly resort to crop residue burning. The practice of burning paddy stubble in the northern states, including Punjab, Haryana, and parts of Uttar Pradesh within the National Capital Region (NCR), is a significant concern. This activity notably deteriorates the air quality in the NCR, especially during the months of October and November. The burning of crop residue is a major source of fine particulate matter in Delhi and the surrounding NCR region during the winter months each year. These tiny particles pose a substantial health risk to the general public, with farmers and those living in areas where crop residue burning occurs or nearby being particularly vulnerable.

The Indian Space Research Organization (ISRO) has established standardized protocols, in collaboration with key stakeholders such as the Indian Council of Agricultural Research (ICAR), to systematically record and monitor crop residue burning incidents and estimate the area of paddy fields that have been burned. This initiative aims to ensure a unified and accurate assessment of fire events, thereby avoiding discrepancies in the reporting and counting of such incidents. Despite persistent warnings and appeals from environmental scientists to discontinue the practice, the unconventional and harmful tradition of burning crop stubble persists.

The winter harvest season, which falls in November and December, significantly contributes to air pollution due to the widespread practice of crop stubble burning. Farmers, often driven by factors such as poor crop yields, time constraints, financial pressures, and low market prices, resort to burning their fields to quickly prepare for the next crop cycle. Unfortunately, this period coincides with cold weather and low wind speeds, which lead to a meteorological condition known as temperature inversion. This phenomenon traps pollutants close to the ground, preventing them from dispersing and rising, and resulting in dense smog. The toxic emissions from these agricultural fires, when combined with the already high levels of carbon emissions in urban areas, severely exacerbate air pollution in Delhi, the national capital. This not only has detrimental effects on public health but also leads to substantial economic losses, underscoring the urgent need for alternative, sustainable practices.

Indian law, specifically the Air (Prevention and Control of Pollution) Act of 1981, clearly prohibits the burning of any material that causes pollution, with the exception of fuel. Furthermore, the Supreme Court has emphasized that the practice of stubble burning infringes upon the fundamental right of citizens to live in a clean and pollution-free environment, as enshrined in the Constitution. This underscores the legal and constitutional imperative to prevent such environmentally harmful activities.

A study conducted by The Energy and Resources Institute (TERI) on enhancing and managing air quality in the Delhi-NCR region shed light on the significant impact of stubble burning on air pollution. The findings revealed that crop residue burning (CRB) is a substantial contributor to the high levels of particulate matter (PM) in the ambient air of Delhi and the surrounding NCR region. The elevated PM concentrations in the air have severe adverse effects on public health, highlighting the urgent need to address and mitigate the issue of stubble burning to improve air quality and protect the well-being of the population.

In February 2025, the Supreme Court issued a directive to the Commission for Air Quality Management (CAQM) to organize a meeting with representatives from the states bordering Delhi, namely Punjab, Haryana, and Uttar Pradesh. The objective of this meeting was to formulate a comprehensive strategy aimed at preventing the practice of stubble burning in these states. This agricultural practice, which typically occurs post-harvest, is a major contributor to the severe air pollution crisis in Delhi, and the Supreme Court's intervention seeks to address this critical issue through a coordinated effort among the concerned states.

3.10 Key drivers for agri waste to energy capacity additions

Increased thrust on RE capacity additions and energy security: Government of India has set ambitious targets for non-fossil fuel-based capacity. The government's commitment to clean energy is evident in its ambitious national targets, such as achieving 175 GW of renewable energy capacity by 2022 and later revised to 500 GW of non-fossil fuel capacity by 2030, which has provided a clear long-term vision for the sector. Biomass energy can help reduce India's dependence on imported fossil fuels, improving energy security and reducing the trade deficit. With the increasing share of intermittent RE sources, such as solar and wind power, biomass can help support grid stability since it can be scheduled and dispatched on demand.

Huge potential: India has a large and readily available supply of agricultural residues, forestry waste and other organic waste that can be used for energy production. As per MNRE, the availability of biomass in India is estimated at approximately 750 MT per annum with surplus availability of approximately 230 MT per annum which translates into a potential of about 28 GW. Sugarcane which forms approximately 2-3% of surplus biomass residue has achieved GW scale installations. Success of bagasse-based plants can be replicated in other agricultural residues which are abundantly available like wheat, rice and, maize etc.

RPO Compliance: The MoP has set a RPO target for states to procure 43.33% of their total energy consumption from renewable sources by the Fiscal year 2029-2030. This target is a key part of India's broader strategy to increase its reliance on renewable energy and reduce its carbon footprint. RPO is a trajectory with incremental increases each year, starting from 29.91% in 2024-25 and reaching 43.33% by 2029-30. The RPO is further broken down into targets for different renewable energy sources like wind, hydro, and other RE sources (solar, biomass, MSW etc.). Considering the current installed capacity, there have been noncompliance of RPO targets by States like Maharashtra, Gujarat, Uttar Pradesh, Punjab, Haryana, Rajasthan etc. The Draft amendment to Electricity Act 2003, has proposed penalties for noncompliance of RPO. Stricter implementation is required to achieve the 2030 sustainability targets. e.g., UPERC in May 2025, directed UPNEDA to provide comprehensive compliance report from the year 2010-11 onwards. MERC in June 2025 directed all open access entities to comply with any cumulative RPO shortfall for the period from FY 2014-15 to FY 2019-20, by the end of FY 2025-26. This shortfall is expected to drive non-fossil fuel-based capacity additions.

Supportive government policies: The Indian government offers various incentives, such as subsidies, tax benefits, and feed-in tariffs, to encourage the development of biomass energy projects. The Biomass Power and Bagasse Co-generation Programme and the National Policy on Biofuels are among the programmes creating a positive legal framework. The purpose of these policies is to promote biomass usage in India’s energy mix by making financial subscriptions and the establishment of biomass power plants easy. This support is crucial for attracting investments and driving the expansion of biomass capacity.

Environmental Benefits: Open field burning of agricultural residues is a major contributor to air pollution, particularly PM2.5 emissions. Utilizing this biomass for energy generation can help reduce emissions and improve air quality. Biomass energy is a cleaner source of energy compared to fossil fuels, producing lower greenhouse gas emissions, and contributing to a reduction in air pollution.

Technological development: AgWtE technologies are rapidly advancing, focusing on efficiency, sustainability, and economic viability. Recent advancements in biomass conversion technologies have significantly improved the efficiency and environmental benefits of energy generation. Agri waste-to-energy technologies are constantly evolving, driven by the need for sustainable energy solutions and a circular economy. These advancements offer promising pathways for converting waste into valuable resources and reducing reliance on fossil fuels. Unlike solar

and wind, Agri waste-to-energy based plants have higher PLFs which can provide round the clock power and can provide a solution to intermittency of other RE sources without being dependent on the weather or time of day.

Waste management: Surplus biomass/stubble generated from agriculture is often burnt specially in northern part of India, resulting in air pollution and black carbon emissions. Biomass energy can help manage agricultural waste, which is a significant problem in India, by converting it into energy. Converting waste to energy can reduce the costs associated with waste disposal.

Socio economic upliftment of farmers: Biomass projects can create rural employment opportunities in collection, processing, and operation of facilities and thereby contribute to rural development. Farmers and millers can earn additional income by selling biomass to power plants. Even though the tariffs of agri waste to energy projects are relatively higher than the conventional thermal power plants, these plants provide commercial benefits to rural population and give impetus to rural circular economy. Considering the socio-economic developments, such plants are expected to gain prominence.

3.11 Outlook on Installed Capacity of Bioenergy

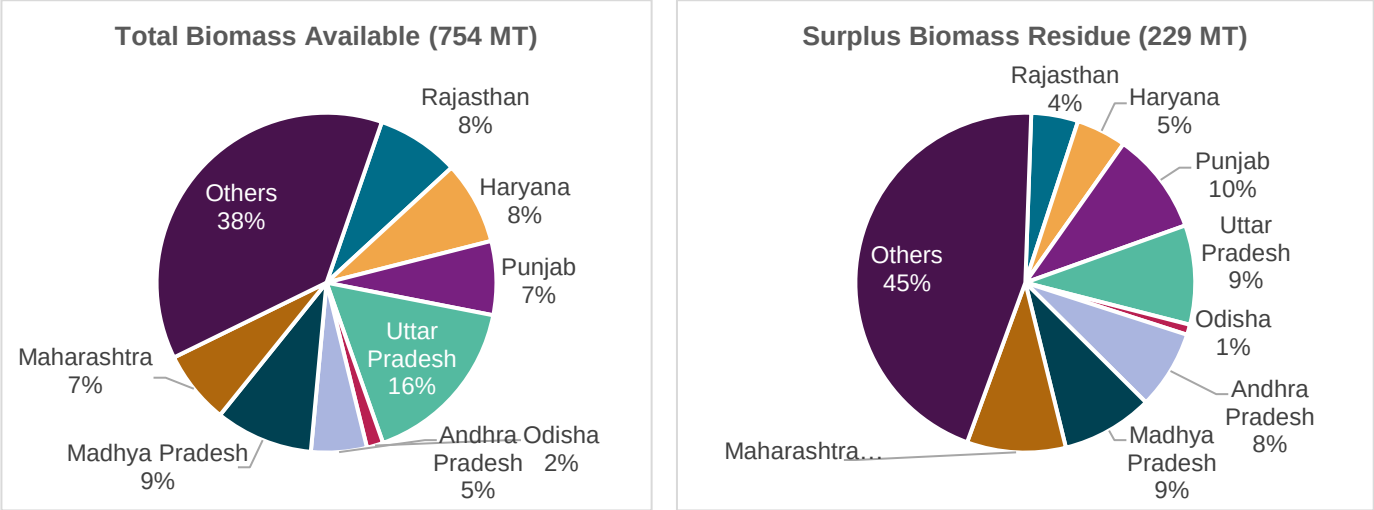
India's total installed capacity under the Biomass Programme is 11.583 GW as of March 2025. The estimated biomass power potential for India is approximately 28 GW. There is huge untapped biomass potential in India. CEA has estimated the biomass capacity to be around 15.50 GW by 2032. The AgWtE capacity is projected to grow at 3.4% with installed capacity projected to reach 2.42 GW in 2032. Favourable government policies, ample availability of feedstocks, government-led initiatives to boost biomass production, stringent mandates to increase the utilization of renewable resources to minimize GHG emissions are projected to drive capacity additions. However, availability of viable alternatives such as wind and solar may act as restraint in future growth.

3.12 State-wise dynamics of (Agri-Waste to Energy) Sector

3.12.1 State-wise Biomass Availability in India

India has a significant amount of biomass available, with variations across states due to differences in agriculture and land use. States like Punjab, Rajasthan, Haryana, Uttar Pradesh, Gujarat, Maharashtra, Madhya Pradesh, and Andhra Pradesh contribute the most to the biomass power potential. The type of biomass available also varies, with rice straw common in Punjab, Haryana, and Uttar Pradesh, and wheat straw in Punjab, Haryana, Rajasthan, and Uttar Pradesh.

Figure 23: Key states for biomass availability TE 2015-18



Average from 2015–2018

Source: National Institute of Bio-energy; Crisil Intelligence

3.12.2 Biomass power generation installed capacities and potential across states

The major share of all India's agricultural-based biomass power potential is contributed by Punjab (10.6%) and Uttar Pradesh (9.9%), followed by Gujarat (9.3%), Maharashtra (9.3%), Madhya Pradesh (8.9%), and Andhra Pradesh (7%) states. It is pertinent to note that Maharashtra and Karnataka have already crossed the potential capacity. However, the majority of states have only been able to achieve 15-20% of the potential capacity leaving a large potential to tap.

Table 4: State wise biomass power generation potential (TE 2015-18) and installed capacity

State	Power Potential (GW)	% Share	Installed Capacity (GW)*	% Share	Balance Potential
Punjab	3.02	10.6%	0.58	5%	81%
Uttar Pradesh	2.80	9.9%	2.31	20%	18%
Gujarat	2.64	9.3%	0.13	1%	95%
Maharashtra*	2.63	9.3%	3.00	26%	-
Madhya Pradesh	2.52	8.9%	0.16	1%	94%
Andhra Pradesh	2.00	7.0%	0.59	5%	70%
Karnataka*	1.79	6.3%	1.92	17%	-
West Bengal	1.74	6.1%	0.35	3%	80%
Telangana	1.68	5.9%	0.22	2%	87%
Tamil Nadu	1.56	5.5%	1.05	9%	33%
Haryana	1.35	4.8%	0.31	3%	77%
Rajasthan	1.30	4.6%	0.21	2%	84%
Others	3.39	11.9%	0.78	7%	77%
Total	**28.43**	**100%**	**11.59**	**100%**	**59%**

Note:

Considering biomass availability and cropping pattern, these states have already crossed potential capacity

*Average from 2015–2018; *As of June 2025*

Source: MNRE, Crisil Intelligence

3.12.3 State Policies for Bioenergy

Particulars	Punjab	Uttar Pradesh	Gujarat	Haryana
Policy	New and Renewable Sources of Energy (NRSE) Policy – 2012	Bio-Energy Policy-2022	Waste to Energy Policy 2022	Haryana Bio-energy Policy 2018
Target	Biomass: 600 MW MSW: 50 MW	not available	not available	150 MW by 2022
Financial Incentives	Exempted from Value Added Tax (VAT) and any cess thereupon 100% exemption from entry tax 100% exemption from payment of fee and stamp duty for registration/lease deed charges	100% exemption of stamp duty payable on rent deed/lease/sale deed/registration 100% exemption from the development charges	Exemptions from tax, cess, royalty, and levy for MSW-based power plants. Stamp duty and land allotment charge exemptions. Land provided at ₹ 1 per annum lease rent for MSW-based power projects.	100% exemption from octroi for biomass fuels. 100% entry tax exemption on project supplies No fee required for consent to establish or operate bioenergy plants. 100% exemption from payment of fee and stamp duty charges
Subsidy benefits	As per MNRE, GOI scheme (if any)	30 percent subsidy (up to a maximum limit of ₹ 20 Lakh) on Agricultural Mechanization scheme to the aggregators defined devices	Up to 60% subsidy under the National Biogas and Manure Management Program Up to 75% subsidy for SC/ST and below poverty line beneficiaries.	Reaper, raker, baler and trawlers will be provided either on rent or on upfront subsidy as per the schemes of the Agriculture & Farmer Welfare Department, Haryana
Open Access charges	exemption of transmission & wheeling charges on intra state open access for 10 yrs (COD up to 31.3.2017)	Not mentioned	Exemption of 50% of Wheeling Charges & Losses (As applicable to Normal Open	All cross subsidy charges, Transmission & distribution charges, surcharges, and reactive power charges will be

Particulars	Punjab	Uttar Pradesh	Gujarat	Haryana
			Access consumers) for Captive consumption. Exemption from Cross Subsidy Surcharge & Additional Surcharge for Captive consumption as well as third party sale.	totally waived off for any biomass projects set up in the State.
Other benefits	No parallel operation charges	100% exemption in electricity duty will be provided for 10 years from COD	Electricity duty in accordance with Electricity Duty Act 1958 and its amendments from time to time (Presently exempted) UDDs / ULBs shall provide MSW to the WtE Project Developer at Project Site without charging any cost.	Exemption from Land use approval, External Development Charges, scrutiny fee and infrastructure development charges

Source: Respective State Policies, Crisil Intelligence

3.12.4 Market growth trajectory and challenges

The global WtE and agricultural bioenergy market has experienced steady growth over the past five years, expanding across multiple regions and various feedstock categories, including bagasse, agri waste to energy, solid biomass, liquid biofuels, and biogas. This upward trend is attributed to the convergence of several key factors, including decarbonization commitments, rising waste volumes, the need for rural electrification, and advancements in clean energy technologies, all of which are driving the demand for sustainable and renewable energy solutions.

The global renewable energy market has witnessed significant growth in bioenergy installation from agricultural residues and waste streams, with a CAGR of 5.85% between CY 2010 and CY 2024.The biogas and solid biomass segments have been the primary drivers of this growth, with the European Union (EU) and China emerging as the largest contributors, driven by robust policy support for renewable heating, bioenergy in transportation, and circular economy frameworks.

India has consistently demonstrated growth in the bioenergy sector, particularly in solid biomass and bagasse-based cogeneration, driven by supportive policies such as the National Bio-Energy Programme and the SATAT initiative for compressed biogas. The country's agricultural waste management policies have also played a significant role in this growth. Meanwhile, Brazil continues to lead in bagasse utilization due to its large sugarcane industry. The United States has shown stable growth in landfill gas recovery and anaerobic digestion projects. Solid biomass has also witnessed steady expansion, particularly in Europe, China, and India, where biomass-fired cogeneration plants and pellet-based heating systems are gaining popularity.

Challenges

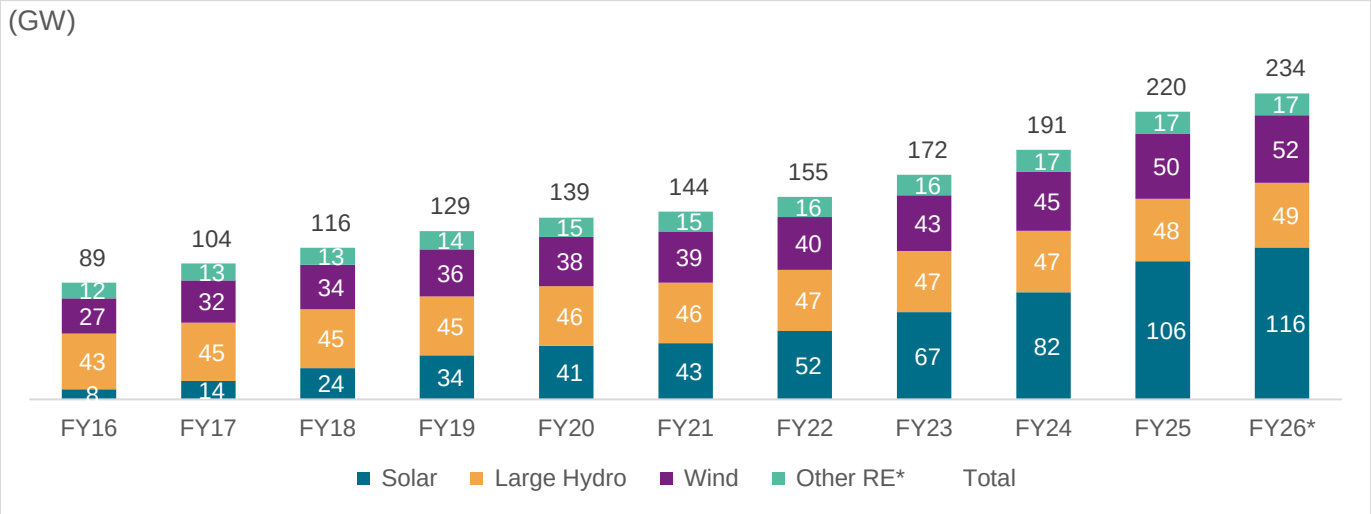
The growth of the WtE and biomass industry is hindered by several challenges. One of the major challenges is the high capital costs associated with these projects, which can be a significant deterrent to investment, particularly in lower-income markets. Additionally, the lack of organized waste collection and low waste segregation rates, as well as the seasonal variability of agricultural residues, can limit the consistent operation of WtE plants, especially in emerging markets. Furthermore, incineration-based WtE projects often face public opposition due to environmental and health concerns, emphasizing the need for greater transparency and the adoption of advanced emission control technologies. The policy uncertainty including inconsistent or changing government policies, subsidy frameworks, and RPOs, can create investment risks and delay project implementation, underscoring the need for stable and supportive policies to foster the development of the WtE and biomass sector.

4 Assessment of the Renewable IPP Business in India

4.1 Overview of RE capacity addition in India

Renewable energy installations (incl. large hydro) in India have increased to 234 GW as of June 2025, as compared with approximately 63 GW as of March 2012 (source: MNRE), led by various central and state-level incentives. As of June 2025, installed grid connected RE generation capacity (including large hydro) in India constituted approximately 46% of the total installed generation base in India. This growth has been led by solar power, which has grown to 116 GW from merely approximately 0.9 GW in March 2012.

Figure 24: India's RE (incl. Large Hydro) capacity was approximately 48% as of June 2025 (GW)



Note:
**As of June 2025; Other RE includes small hydro, biomass power, waste to energy.*
Source: MNRE; CEA, Crisil Intelligence

However, owing to lower capacity utilisation factors, the RE penetration (incl. large hydro) in terms of energy generation was at approximately 27% as of June 2025, Also the total ESS installed capacity of India is 6.65 GW out of which 0.20 GW is from BESS and the remaining 6.45 GW GWh is from PSP.

Despite such strong capacity addition, there is huge untapped potential for RE installations in India, with solar energy having the highest potential, as is evident from the table below.

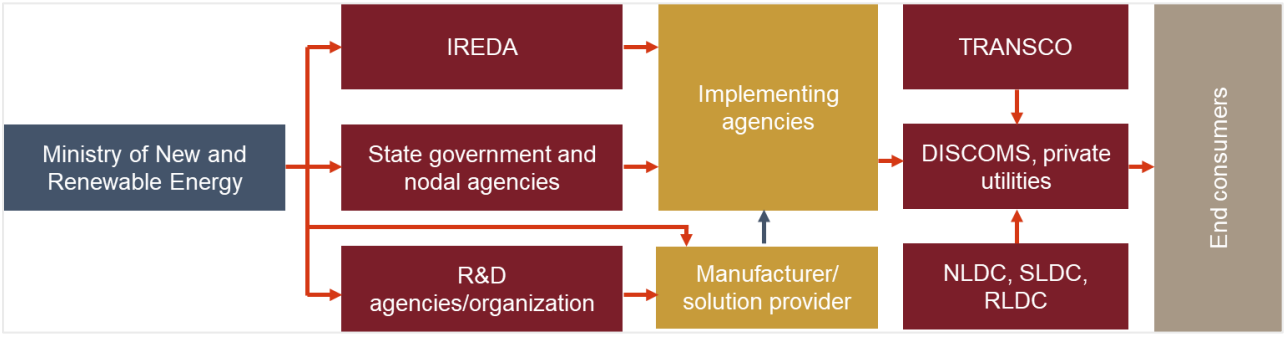
Table 5: Potential and cumulative capacity of RE (technology-wise)

Technology	Potential	Cumulative capacity (as of June -25)	Untapped potential
Wind	approximately 696 GW (120 m hub height)	51.02 GW	92.67%
Solar	750 GW	116.25 GW	84.50%
Bioenergy	25 GW	10.74 GW	57.04%
Hydro	165 GW	54.48 GW	66.98%
Waste to energy	NA	0.9 GW	NA

Note:
Hydro: Large + Small hydro
Source: MNRE; NITI Aayog; Crisil Intelligence

The key stakeholders in the RE segment are represented in the figure below:

Figure 25: Key stakeholders in the renewable sector in India



Source: Crisil Intelligence

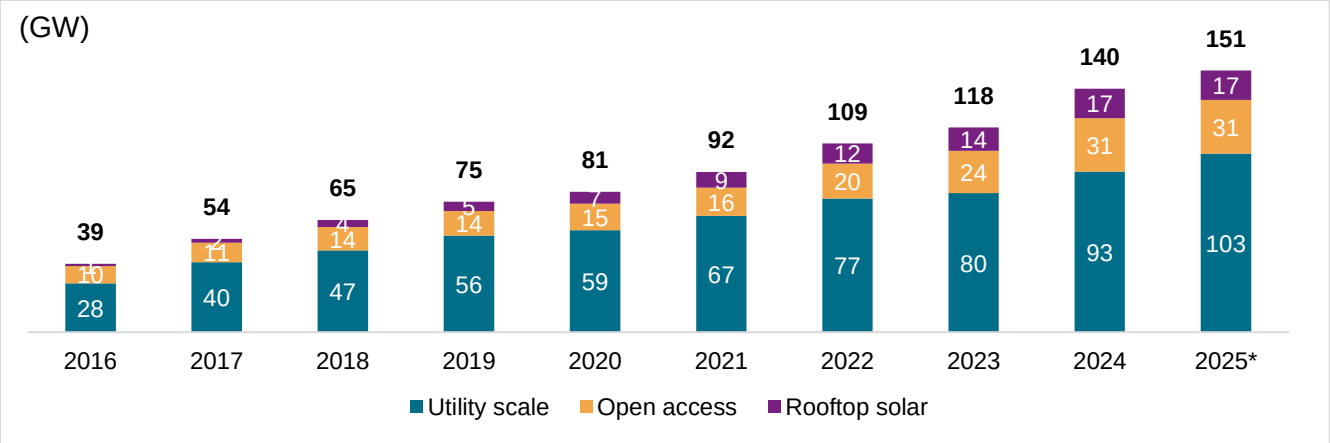
4.2 Business models adopted by Renewable IPPs

4.2.1 Overview of business models adopted by the leading RE IPPs

Leading Renewable Energy Independent Power Producers (IPPs) in India have adopted diverse business models to optimize returns and mitigate risks. The most common model is the utility-scale PPA model, where IPPs sign long-term PPAs with central agencies like SECI, NTPC, or state DISCOMs, ensuring revenue stability. Another growing model is the C&I PPA, where IPPs directly sell power to corporate consumers through open access, offering better tariffs and reducing dependency on DISCOMs. Many IPPs also operate under the merchant power model, leveraging market-based pricing through power exchanges or short-term contracts.

The total installed renewable capacity in the country is 156 GW (solar and wind) as of March 2025. The installed solar capacity was 106 GW which is split in ground mounted, rooftop, hybrid component and off-grid by 81:17:3:4. Total wind capacity was approximately 50 GW. The utility scale market has grown at a rate of 16% CAGR in the last nine years. The corporate renewable market is experiencing rapid growth, driven by an increasing focus on decarbonization and sustainability. Since 2022, the share of open access in total capacity addition has been steadily increasing, averaging around 22%. This trend is expected to continue, with open access and rooftop solar emerging as the most viable sources of renewable power for corporate consumers.

Figure 26: RE capacity addition under various business models as of March 2025



**As of June 2025*

Source: Crisil Intelligence

Note: Excludes off-grid capacity of 4,742 MW

Note: Utility scale, open access and rooftop capacity split is available till March 2025.

Note: Numbers have been rounded off

4.2.2 Key drivers that supported renewable capacity additions over the past decade

India's renewable energy sector has made tremendous progress, driven by a combination of factors including progressive policy interventions, technological advancements, and robust stakeholder participation. The government's commitment to clean energy is evident in its ambitious national targets, such as achieving 175 GW of renewable energy capacity by 2022 and 500 GW of non-fossil fuel capacity by 2030, which has provided a clear long-term vision for the sector. The introduction of transparent competitive bidding mechanisms by central agencies like SECI, along with long-tenure Power Purchase Agreements (PPAs), has instilled investor confidence and ensured revenue visibility for IPPs, thereby attracting significant investments in the sector. As a result, India's renewable energy sector has witnessed a remarkable transformation over the past decade, with solar and wind energy emerging as major contributors to the country's energy mix. Overall, the sector's growth is expected to continue, driven by favorable policies, declining technology costs, and increasing demand for clean energy, making India a leading player in the global renewable energy market.

Furthermore, the reduction in capital costs, driven by economies of scale, global supply chain efficiencies, and rapid innovation in photovoltaic and wind turbine technologies, has significantly lowered the levelized cost of energy (LCOE), making renewables increasingly cost-competitive with other technologies. Fiscal incentives viability gap funding, exemptions on inter-state transmission charges and PLI schemes have further enhanced the commercial viability of projects. The PLIs in the 14 sectors for the *Aatmanirbhar Bharat* vision received an outstanding response, with the potential to create 6 million new jobs (as per government estimates).

Table 6: Sector-wise focus of *Aatmanirbhar Bharat* Vision

Sector	Government spends	Key schemes
Renewable energy	₹1300 billion	• ₹45 billion Production Linked Incentive Scheme 'National Programme on High Efficiency Solar PV Modules'. This was further increased by ₹195 billion in the budget for Fiscal 2023, taking it to ₹240 billion; in tranche I 8.7 GW and in tranche II 39.6 GW capacity were allocated for domestic solar module manufacturing capacity under the PLI scheme. • PM Surya Ghar Muft Bijli Yojna: This scheme has a proposed outlay of ₹ 750 billion and aims to light up 10 million households (rooftop solar) by providing up to 300 units of free electricity every month. • Public procurement (preference for 'Make in India') to provide for purchase preference (linked with local content) in respect of renewable energy (RE) sector • Implementation of Pradhan Mantri Kisan Urja Suraksha Utthan Mahabhiyan (PM KUSUM) scheme; MNRE, in November 2020, scaled up and expanded the PM KUSUM scheme to add 30.8 GW by 2022 with central financial support of ₹344 billion. The scheme has been extended till March 31, 2026 • Approved Models & Manufacturers of Solar Photovoltaic Modules (Requirement for Compulsory Registration) Order, 2019 • List of manufacturers and models of solar PV modules recommended under Approved Models and Manufacturers of Solar Photovoltaic Module (ALMM) order • Scheme of grid connected wind-solar hybrid power projects • Basic customs duty (BCD) of 25% on solar cells and 40% on modules, respectively, effective April 1, 2022

Sector	Government spends	Key schemes
Power distribution companies (discoms)	₹970 billion	• ₹1.35 trillion liquidity infusion for discoms via Power Finance Corporation/ Rural Electrification Corporation (PFC/ REC) against receivables • Rebate for payment to be received by generation companies (gencos) to be passed on to industrial customers • Revamped distribution sector scheme (RDSS) to help discoms improve their operational efficiencies and financial sustainability by providing result-linked financial assistance; outlay of ₹3,037.58 billion over 5 years i.e., Fiscals 2022 to 2026. The outlay includes an estimated government budgetary support (GBS) of ₹976.31 billion.
New energy	₹ 388 billion	• ₹181 billion under production linked incentive (PLI) scheme for Advanced Chemistry Cell (ACC) Battery Storage in India launched in October to achieve 50 GWh manufacturing capacity • Green Hydrogen Policy launched in February 2022 to facilitate production of green hydrogen/green ammonia • PLI scheme on green hydrogen manufacturing with an initial outlay of ₹197.44 billion with an aim to boost domestic production of green hydrogen • BCD exemption on critical minerals (cobalt, lead, zinc, etc.), scrap of lithium-ion batteries proposed in Budget 2025-26
Nuclear energy	₹ 200 billion	• Nuclear energy mission announced in Budget 2025-26 • 100 GW of nuclear power capacity by 2047 • Budgetary allocation to support R&D for indigenous development of small modular reactors (SMR) • Private sector participation in the development of Bharat small reactors, R&D of SMR and newer technologies

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

The supportive regulatory frameworks streamlined land acquisition processes, and the active participation of international development finance institutions have created a conducive environment for private sector participation and foreign direct investment, empowering IPPs to scale up operations, diversify portfolios across solar, wind, hybrid, and storage-based models, and contribute meaningfully to India's clean energy transition.

4.3 Review of competitive bidding of RE projects

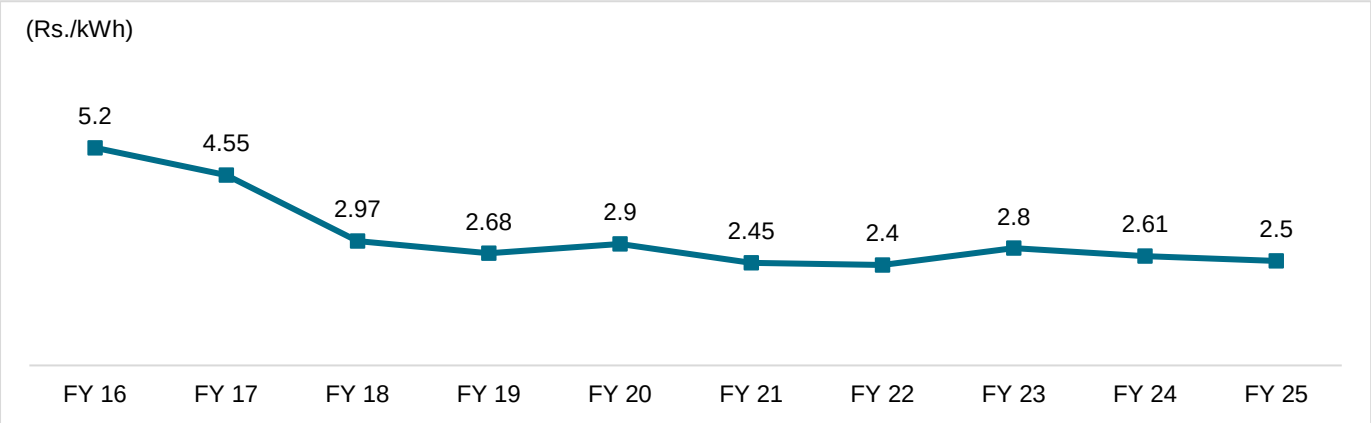
4.3.1 Recently discovered RE tariffs in major state and central tenders

To promote the renewable energy sector, the government introduced feed-in tariffs (FiTs) in the early stages of development, when production was not economically feasible. The FiT mechanism guarantees a fixed tariff to renewable energy producers for energy supplied to the grid. The tariff is fixed for a long period (15-20 years) to minimise the risk of renewable IPPs. For solar projects over 2009-2013, most states signed PPAs at FiTs determined by the state commission on a fixed regulated equity return of approximately 16%. For wind energy projects, states followed the FiT mechanism until March 2017. However, from Fiscal 2018 onwards, the sector veered towards competitive bidding.

Solar tariffs showed a rapid decline from Fiscal 2016 to Fiscal 2020, with a rapid fall in component pricing, technological improvements in efficiency, and the government's policy push. While declining module prices contributed to a reduction in tariffs over Fiscals 2017-2019, access to low-cost financing was the primary driver for the decline in tariffs over Fiscals 2020-2022. Over the said period, global investments in the Indian renewable energy segment picked up via green bond issuance and external commercial borrowings, helping the lower cost of debt for the space. The participation of global players and entities with strong credit profiles (CPSUs) has helped tariffs remain

in the ₹2.4 - 2.6 per unit range even until Fiscal 2022 when supply-side disruptions started to emerge. Weighted average tariffs recorded a 16% uptick in Fiscal 2023, when it rose to ₹2.8 per unit before declining to ₹2.61 per unit in Fiscal 2024, a drop of close to 7%. Tariff drop in Fiscal 2024 was majorly on account of price decline in upstream components, mainly solar cells, where prices fell by approximately 47% in Fiscal 2024. In H1 Fiscal 2025, the tariffs remained consistent as last year with a weighted average tariff of ₹ 2.50 per unit. The falling trend in tariffs is also partially attributable to the competitive bidding process, and relaxation of bid requirements allowing more number of bidders to participate.

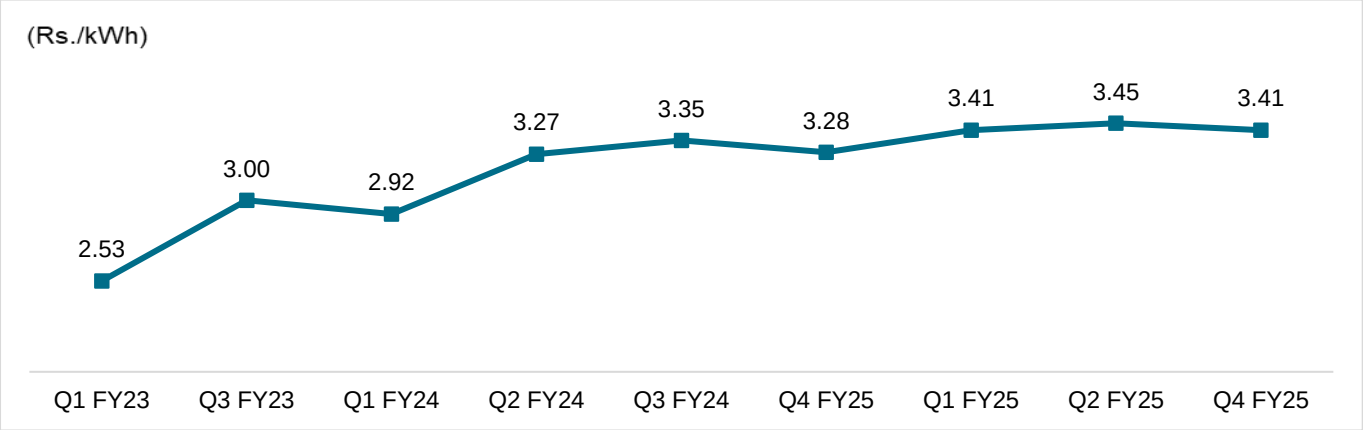
Figure 27: Weighted average solar tariff trend



Source: Crisil Intelligence

Wind-solar hybrid tariffs are affected by concurrent trends from the solar and wind sectors. Like solar, the lowest-ever WSH tariff in India, ₹ 2.41/kWh was achieved in a December 2020 allotment. The recent upturn in wind and solar tariffs has also affected WSH tariffs. Recently, the WSH tariff has stayed above the threshold of ₹ 3/kWh, lower than vanilla wind tariffs but competitive with vanilla solar tariffs.

Figure 28: Recent trend in competitively bid out wind-solar hybrid tariff (weighted average tariffs)



Source: Crisil Intelligence

4.3.2 Competitiveness of RE tariffs trends of recently concluded hybrid tenders

With a large quantum of the pipeline already in place for solar/wind-only projects, nodal authorities are now turning to issue tenders that aim to improve the quality of power supplied to off-takers. Key changes have been made to tender structures concerning the quantum of generation available from RE sources and the ability to match peak demand.

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

- Plain vanilla hybrid tenders require simple blending of solar and wind resources to achieve higher PLFs compared to those achieved on standalone basis and inject power for more hours during the day, compared to either source on standalone basis.
- Peak power tenders demand injection of renewable energy during peak periods of power demand in the day, typically four hours per day.
- Round the clock tenders are designed to enable injection of renewable power asking for higher availability from the power sources.
- FDRE tenders with multiple requirements across availability, peak timing supply and / or following of a particular load profile.

India has introduced FDRE generation tenders, including WSH tenders to strengthen clean generation combining solar, wind and storage technologies. These innovative tenders are increasingly gaining traction over plain vanilla RE projects 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. Some of the key advantages of these projects include improved land and transmission infrastructure utilization, reduced generation variability and complimentary generation profiles. Standalone solar and wind projects exhibit relatively low CUF. However, the amalgamation of these two technologies leads to a higher CUF, resulting in enhanced overall efficiency.

Consequently, tenders conducted for such projects have yielded competitive tariffs, recent bids into Solar with Storage with prices ranging from ₹3.2-3.6/kWh. The tariff trend for such tenders is expected to remain in the same range in Fiscal 2026 as well. These factors contribute to the growing allure and widespread adoption of WSH projects. Further, WSH in conjunction with FDRE can provide a reliable and stable power supply to meet the demands of utilities. FDRE projects (assured peak, load following, RTC and specific peak power supply) offer firm power supply as per demand given by utilities and a higher CUF compared to pure-play solar and wind projects. Furthermore, the expected tariff ranges have resulted in being higher than the norm of ₹2.5-2.6/kWh (for standalone solar with imported cell-based modules), approaching the range of ₹3-5/kWh (for WSH and FDRE).

So far, all these tender models have seen successful allocations, with FDRE at 11 GW and RTC at 4.8 GW, mainly driven by central entities.

4.4 Tendering activities in renewable energy

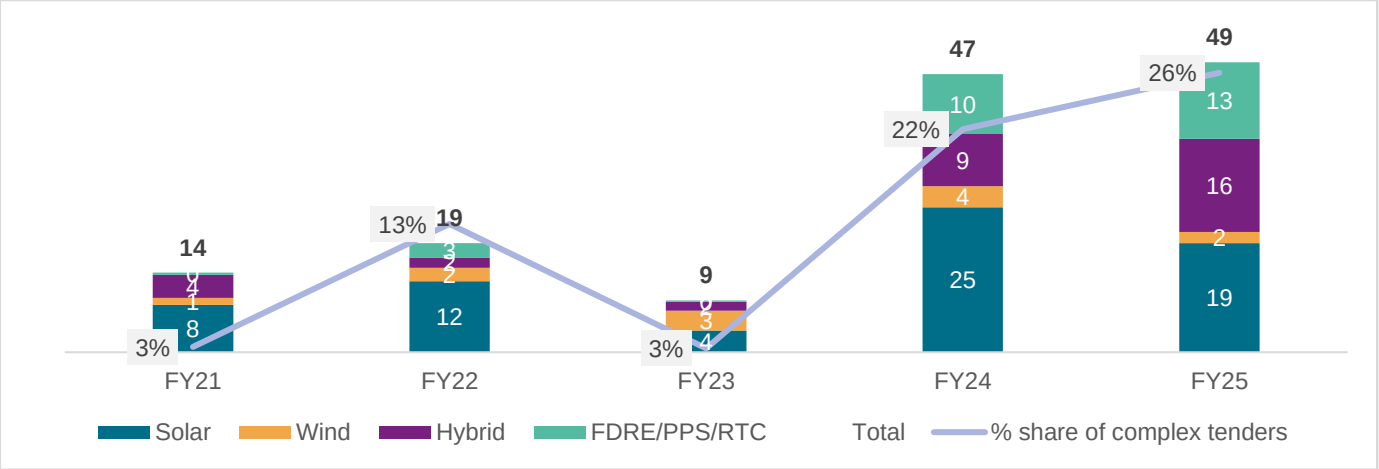
India issued over 135 GW of completed utility scale renewable energy tenders since Fiscal 2021 across all technologies including Complex tenders. The tendering activity increased about five-fold between Fiscal 2023 and 2024 due to significant increase in government targets, innovative tendering solutions, discom's shift to offtake more stable and firm power and increase in power sector investment.

The tendering activity for utility scale RE projects has outpaced the government's target of 50 GW for Fiscal 2024. The government selected SECI, NTPC, SJVN and NHPC as RE implementing agencies (REIA).

Hybrid and Complex RE tenders have shown significant growth over the years. The share of Complex RE tenders has increased from 32% in Fiscal 2021 to 59% in Fiscal 2025.

Apart from this, over 20 GW of standalone ESS tenders were also issued including pumped hydro storage. The average allocation of tenders has been above 85% of the tendered capacity in the last five years.

Figure 29: RE tendered capacity annually

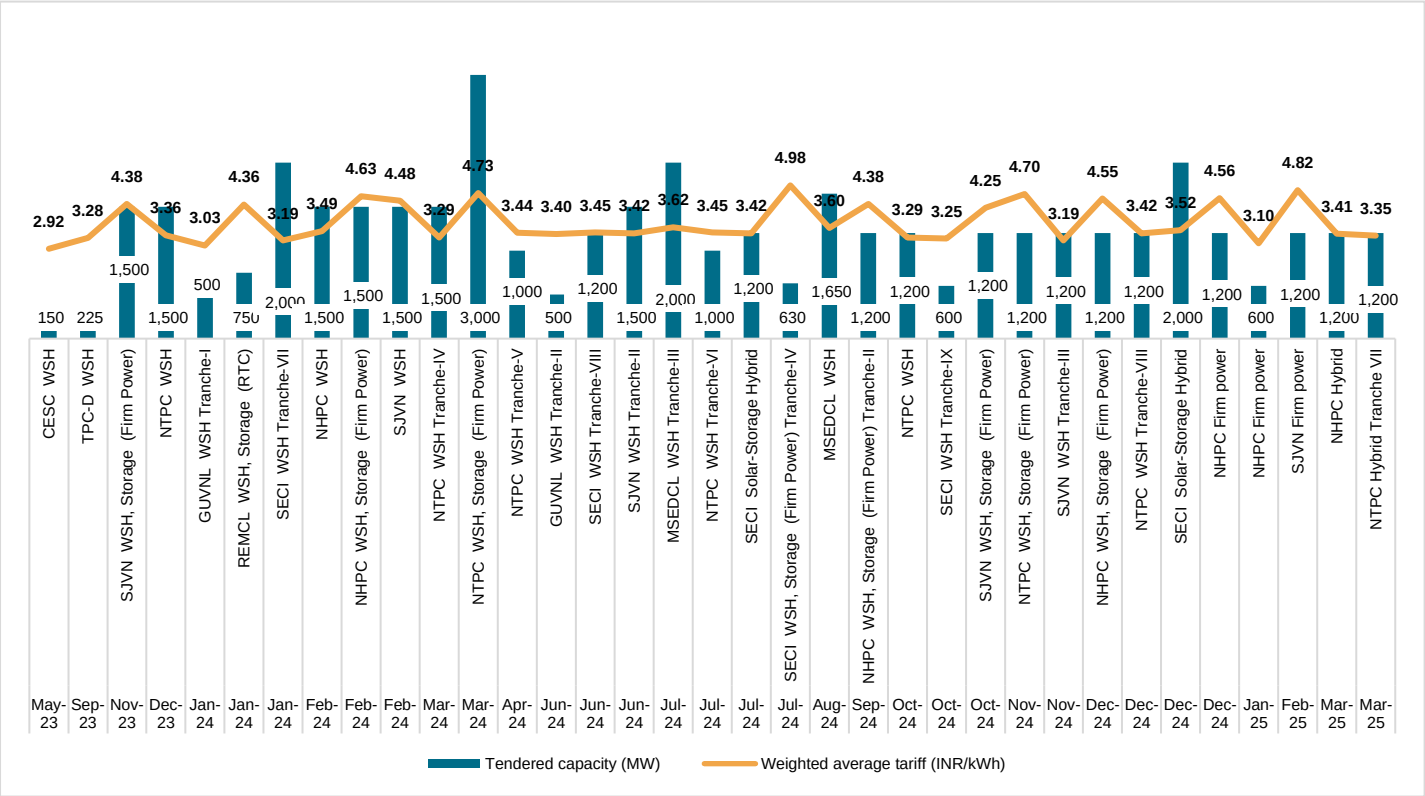


Includes only utility scale tenders concluded during the year;
Source: Central and State nodal agencies, Crisil Intelligence

Over the past year, the tariffs for FDRE, RTC and Hybrid auctions have fluctuated significantly due to their complexity and additional requirements. The lowest weighted average tariff recorded was ₹ 2.92/ kWh in a 150 MW wind-solar hybrid auction in May 2023, while the highest weighted average tariff recorded was 4.98/ kWh was seen in SECI's Tranche-IV 630 MW FDRE auction in July 2024. The weighted average tariffs for hybrid projects with storage or FDRE commitments ranged from ₹3.42/ kWh to ₹4.98/ kWh, indicating that the provision of reliable and uninterrupted power comes at a premium. This price variation is mainly driven by the complexity of integrating solar and wind energy generation with energy storage and dispatchable energy management, which requires optimization to ensure a stable power supply. As industry transitions towards hybrid solutions, RE players have enhanced their capabilities by developing robust expertise in both solar and wind projects, enabling them to effectively integrate and optimize these technologies to meet the growing demand for hybrid energy solutions.

In comparison to new coal which is at ₹ 7.47/ kWh, firm renewable power is cheaper, making it much more attractive for DISCOMs.

Figure 30: Tariff discovered in recent WSH tenders (as of March 2025)



Source: Central and State nodal agencies, Crisil Intelligence

4.4.1 Assessment of tariff discovered for utility scale energy storage tenders

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 ₹6.12/kWh) with pumped hydro storage and ReNew Power (300 MW at peak tariff of ₹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 ₹4.38/kWh.

Also, a few large-scale standalone ESS tenders were also issued by SECI, NTPC, GUVNL, MSEDCL in Fiscal 2023-24. 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. Moreover, 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.

The levelized cost of storage for DISCOMs from battery storage projects has witnessed a significant decline over the last two years, largely driven by the plummeting prices of battery packs. In fact, the effective cost of battery storage has dropped by as much as 50% since July 2022, making it comparable to the landed cost of pumped hydro storage. This decline can be attributed not only to the fall in battery pack prices but also to the increased competition in BESS tenders. As a result, the blended price of pumped storage and BESS has become cheaper than installing new coal, thereby increasing its attractiveness for offtakers.

As of January 2025, approximately 23 GW of standalone grid-scale ESS capacity has been tendered, of which about 19 GW has been awarded and are under different phases of execution.

4.5 Policy and Regulatory Framework

4.5.1 Key policies and regulations governing the renewable IPP sector

The Renewable Energy IPP business in India is shaped by several key policies and regulations aimed at accelerating clean energy adoption while ensuring grid stability and financial viability. The GoI has historically provided certain subsidies and incentives to solar and other renewable energy generators. These historical subsidies and incentives have been primarily in the form of preferential tariffs, project cost subsidies, tax incentives, tax holidays, and other incentives to end users, distributors, system integrators and manufacturers of solar energy products. However, the amount of government subsidies for solar projects has been decreasing as the cost of producing solar energy has approached grid parity.

The Electricity Act, 2003, along with policies such as the National Electricity Plan (NEP) and the Renewable Energy Tariff Regulations, provide the overarching regulatory framework for RE deployment. The Waiver on ISTS Charges for renewable projects commissioned before June 30, 2025, has been a major driver for interstate RE trade. The RPO mandates DISCOMs and industries to procure a minimum share of their electricity from renewables, driving demand for PPAs and open access projects.

Regulatory Policy/Regulations	Provisions/Implications
State RE Policies	Various states have developed their own RE Policies These State policies allow • Exemption in transmission and wheeling charges • reimbursement of state GST for rooftop solar • exemption from electricity duty and energy development cess • Development of RE park solar projects etc.
Renewable Purchase Obligations (RPOs)	• Renewable Purchase Obligation which was introduced under Electricity Act 2003 and the National Tariff Policy 2016 has now been replaced with Renewable consumption Obligation (RCO) notified under the Energy Conservation (Amendment) Act, 2022 • Target is set projected to reach 43.33% by the year 2030 from 29.91%in 2025.
Electricity (Promoting Renewable Energy Through Green Energy Open Access) Rules, 2022	• Give consumers an option to draw green energy through open access whose contract demand is 100 kW or above
Implementation of ISTS charges waiver	• Waiver of ISTS charges (but not losses) for solar and wind projects commissioned until 30 June 2025 • Projects commissioned after 30 June 2025, including solar, wind, PSP, and BESS, will face a phased reintroduction of ISTS charges
Introduction of General network access	• Non-discriminatory access to the interstate transmission network nationwide for designated interstate customers • Enables generators and drawees to plan their power requirements without needing to identify a specific source of purchase or sale
Electricity (Late Payment Surcharge and Related Matters) Rules, 2022	• LPS was introduced in June 2022 to address cash flow challenges faced mainly by generation companies and transmission companies and to promote timely payments

Regulatory Policy/Regulations	Provisions/Implications
	across the power sector. Since the notification of the LPS Rules, there has been significant progress in recovering outstanding dues, with most distribution companies now adhering to regular payment schedules, and the total unpaid bills have reduced from around ₹ 1.4 trillion in June 2022 to approximately ₹ 480 billion in February 2024. These rules provide a mechanism for settlement of outstanding dues of generation companies, ISTS Licensees and electricity trading licensees, and the rules provisioned for converting distribution companies outstanding dues to these companies into equated monthly instalments ("EMIs") for gradual liquidation of these dues
Renewable energy certificates	• REC is a market-based instrument that facilitates RPO compliance by obligated entities • International Renewable Energy Certificate (I-REC) is also an instrument which is a globally recognized standard

4.5.2 Challenges related to land acquisition, permitting, and grid connectivity

Despite India's strong commitment to clean energy and significant growth in renewable capacity, several implementation challenges hinder the pace and efficiency of renewable energy deployment. The key issues are threefold: land acquisition, permitting, and grid connectivity which impact the project timelines, costs, and bankability.

Land Acquisition Challenges

The acquisition of land for large-scale renewable energy projects is a significant hurdle in India. The process is affected by procedural inefficiencies, legal ambiguities, and fragmented land ownership, leading to delays, increased costs, and resistance from local communities. Furthermore, inconsistent land allocation and leasing norms across states, coupled with the lack of a centralized land bank, worsen these challenges. Another significant bottleneck in the development of renewable energy projects is the conversion of land classified as forest or government revenue land for non-agricultural use. This process is often plagued by delays, as it requires approval from the State Forest Department and the Ministry of Environment, Forest, and Climate Change (MoEF&CC).

Permitting and Regulatory Complexities

The permitting framework for renewable energy projects in India is complex and time-consuming, requiring multiple clearances from central and state authorities. The absence of a single-window clearance system, combined with frequent regulatory changes, creates uncertainty and delays, ultimately affecting project commissioning and investor participation.

Grid Connectivity and Evacuation Infrastructure

Reliable grid connectivity is a major challenge, particularly in high-resource zones with underdeveloped transmission infrastructure. The current lead time for obtaining central grid connectivity (under CTU) for power evacuation of a new project is 2-3 years (depending on the State as well as regional where plant is located). The development of evacuation systems often lags behind project development, resulting in stranded generation capacity, delayed revenue realization, and curtailment. Although initiatives like the Green Energy Corridor aim to address these concerns, progress is uneven, and regulatory complexities persist, hindering the efficient integration of renewable energy into the grid.

Deviation Settlement Mechanism (DSM)

The DSM presents significant operational and financial challenges for renewable energy developers due to the inherent variability of wind and solar power generation. Unlike conventional generators that can control their output, renewable generators face penalties for deviations from scheduled generation despite weather-dependent fluctuations being largely beyond their control. The regulatory environment is becoming increasingly stringent. Solar and hybrid projects must maintain deviations within 10% (tightening to 5% after April-2026), while wind generators face a 15% cap (reducing to 10% after April-2026). These limits are particularly challenging given that renewable generation depends heavily on weather forecasting capabilities, which remain imperfect despite technological advances.

Other Challenges

Solar projects are also subject to seasonal and quarterly fluctuations, especially in the winter months and monsoon season.

4.6 Outlook growth opportunities

4.6.1 Emerging trends: Trend shift in RE technologies

The Indian renewable energy landscape is undergoing a significant transformation, evolving from conventional solar and wind projects to more sophisticated hybrid models. This shift is largely driven by the Indian government's initiatives to promote Round-the-Clock and Firm and Dispatchable Renewable Energy solutions, which aim to improve grid stability, reduce variability, and increase the share of renewable energy in the overall energy mix.

The renewable energy capacity expansion has historically been driven by standalone solar and wind projects, owing to their relatively straightforward implementation and simpler value chains. Recent tendering mechanisms led by the SECI and other agencies prioritizing hybrid projects have combined wind, solar, and storage capabilities to enhance grid stability and predictability. The development and execution of these hybrid, RTC, and FDRE projects involve the complex optimization of multiple generation and storage assets, resulting in a more complex ecosystem. Consequently, the value chain has become increasingly complex, with challenges arising across various stages, including land acquisition, resource assessment, technology integration, system design, and power evacuation planning. Major hurdle in the widespread adoption of hybrid RE projects is the scarcity of developers with a proven track record of executing large-scale solar and wind projects. Although numerous companies have expertise in solar development, only a select few possess the requisite technical, operational, and financial capabilities to simultaneously manage wind development and integrate advanced BESS. As a result, the competitive landscape for hybrid tenders has become constrained, often leading to a lack of bidding interest or a concentration of awards among a limited number of large, experienced players, which can hinder the overall growth of the hybrid RE sector.

The National Wind-Solar Hybrid Policy (2018) and recent initiatives by the Solar Energy Corporation of India (SECI), such as the Hybrid and Round-the-Clock (RTC) tenders, have provided the necessary impetus for the deployment of hybrid renewable energy projects. Key factors that have facilitated the growth of hybrid projects include the waiver of ISTS charges, must-run status, customized bidding structures, and long-term power purchase agreements (PPAs) with central procurement agencies. However, several challenges persist, including the lack of standardized regulations for integrating storage systems and determining tariffs, uncertainty surrounding the viability of BESS and limited financing options for hybrid projects with storage, difficulties in co-locating sites and the absence of clear guidelines for hybridizing existing solar and wind plants, and the need for advanced scheduling and forecasting mechanisms tailored to hybrid generation patterns.

4.6.2 Role of corporate power purchase agreements

Corporate consumers are increasingly driven towards India's corporate renewable market is benefitting from strong growth drivers in the form of rising RPO target, ambitious decarbonisation agenda and attractive cost saving potential. With total corporate renewable capacity of 45.2 GW as of March 2025. The market is expected to witness rapid growth on the back of more consumers signing up for decarbonization and renewable procurement goals. The motive to reduce power bills is one of the major driving factors, especially as C&I grid tariffs have been increasing.

- **Captive demand from group companies**

The Indian renewable market has witnessed the entry of several prominent Indian corporates, including Reliance, Tata Power, JSW, Adani, Hero, Mahindra, and Serentica, among others, due to the attractive fundamentals of the RE space. This strategic move enables these companies to not only offer their services to other consumers but also to their own group companies, thereby expanding their market footprint and gaining considerable experience. This experience, in turn, enhances their competitiveness, allowing them to win more businesses and solidifying their position in the market. As an example, Serentica and Hindustan Zinc have signed a PPA for 530 MW of round-the-clock power supply from solar, wind and storage projects.

- **Group captive PPAs**

Group captive structure allows companies to use advantage of captive projects which gives exemption from cross subsidy surcharge and additional surcharge while making minimal investment of 26% of total equity invested in the project. This business model is particularly popular among corporate consumers.

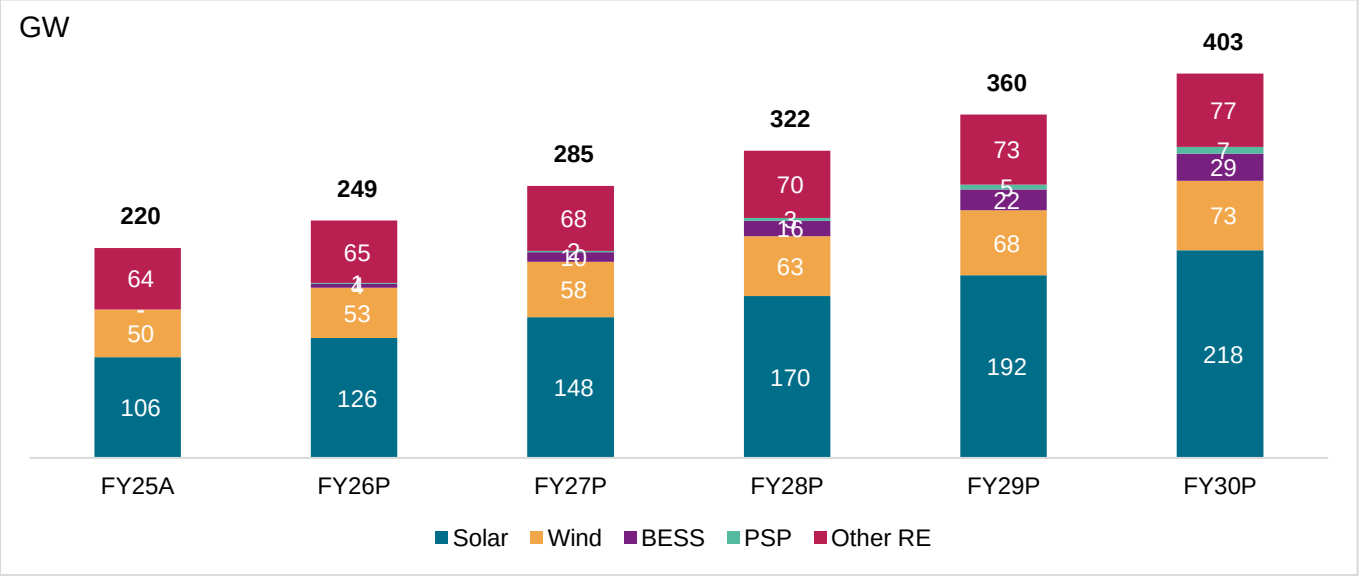
- **Third-party PPAs**

Third-party OA arrangements offer an attractive option for consumers who prefer not to make upfront investments and achieve substantial savings over grid-tariffs. Additionally, short-term, and medium-term third-party OA solutions are available, providing consumers with the flexibility to sign shorter-tenure PPAs, allowing them to benefit from reduced energy costs without long-term commitments.

4.6.3 Renewable capacity addition outlook in India for next 5 years

The share of coal in the country's energy mix is estimated to decline to 34% by FY30, due to limited thermal plant capacity additions. Hydropower capacity additions, including PSP (pumped storage) are expected to be commissioned from Fiscal 2026 to 2030, resulting in 7-9% share. 20 nuclear plants are planned to be commissioned by Fiscal 2030, resulting in capacity additions of approximately 6 GW. Renewable energy would account for the largest capacity addition of a total of approximately 138 GW till Fiscal 2030. The share of total RE is projected to reach 46% till FY30. Solar capacity is expected to increase steadily whereas wind expected to keep the share up. Share of energy storage capacities (PSP and BESS) is projected to increase from approximately 0-1% in Fiscal 2024 to approximately 5% in Fiscal 2030 to provide adequate storage capacity for sustained renewable energy capacity addition.

Figure 31: Overall RE installed capacity



Note: A – Actual; P – Projected
Source: Crisil Intelligence

4.7 Criticality of having presence across the value chain to support business growth

Supply chain integration is critical for renewable energy developers in India to ensure cost efficiency, regulatory compliance, and timely project execution. With increasing policy support for domestic manufacturing (such as PLI schemes and ALMM regulations), developers who integrate their supply chains can reduce dependency on imports, mitigate price volatility, and enhance project resilience. Moreover, streamlined procurement and logistics improve quality control, reduce delays, and support new business models like hybrid energy solutions. In a rapidly evolving market, having an integrated supply chain is a key competitive advantage for long-term sustainability and profitability.

4.7.1 Criticality of Backward Supply Chain Integration and Plans of Leading Renewable IPPs to be Fully Integrated Companies

The renewable energy sector has become increasingly competitive, with companies vying for market share and struggling to maintain profitability in a landscape of declining tariffs and rising costs. To stay ahead of the curve, integrated players have emerged as a dominant force, leveraging their control over multiple stages of the value chain to achieve significant cost advantages, maximize value from the supply chain, and hedge against market fluctuations. By owning the full value chain, these companies are able to improve project execution, improve asset performance, and navigate regulatory uncertainties, ultimately gaining a strategic advantage in the market.

The renewable energy sector in India is witnessing a fundamental shift as leading players transition from pure-play IPPs to fully integrated energy companies. This move toward vertical integration is driven by a combination of financial, operational, and strategic imperatives aimed at enhancing margins, mitigating external risks, and securing long-term competitiveness.

Initially, most players focused solely on project development under the IPP model. However, as market dynamics evolved, several companies have progressively backward-integrated establishing in-house EPC teams, as well as O&M capabilities. This strategic shift not only improves project economics by reducing dependency on third-party service providers but also safeguards proprietary performance data, a key asset for optimizing future projects and asset management strategies.

A key driver behind this transition has been the volatility in international trade, with fluctuating commodity prices, supply chain disruptions, and evolving trade policies such as tariff and non-tariff barriers on imported solar modules creating uncertainty for project developers. By internalizing critical supply chain functions, firms can de-risk their operations and maintain greater control over costs, quality, and execution timelines. Solar manufacturing business also has advantages including shorter payback time and significant cash flows. This, in turn, enables the cash flows from manufacturing to financially support the expansion of IPP business, creating a synergistic and sustainable business model.

Simultaneously, several large corporate groups with significant captive energy demand are leveraging their internal consumption requirements to enter the renewable IPP business. By developing renewable assets that cater to their own group companies, these firms are not only ensuring energy security but also establishing a foothold in the broader renewable market. India's policy landscape increasingly favoring domestic manufacturing through PLI and import restrictions on foreign modules; many players are making strategic bets on the upstream solar value chain. Investments in solar module and cell manufacturing are aimed at capitalizing on the growing demand for domestically produced components, strengthening India's renewable energy self-sufficiency while securing a competitive advantage in a rapidly expanding market. Going forward, successful players are likely to be those that effectively balance their IPP businesses with a robust, vertically integrated supply chain while leveraging favorable policy shifts and captive demand to maximize market share and long-term profitability. Integrated RE players are poised to gain a competitive edge in the upcoming years, as the solar manufacturing sector experiences rapid scaling. With numerous players vying to capitalize on this unique market opportunity, the industry is likely to face an oversupply of modules and cells. In this scenario, only integrated players with captive demand or those with established export partnerships are expected to be able to maintain their market presence and achieve long-term sustainability.

4.7.2 Criticality of having land banks and transmission connectivity for solar IPP business

In India's fast-evolving renewable energy sector, the availability and control of land and transmission infrastructure have become decisive determinants of project success, particularly for solar IPPs with large scale aspirations. Land acquisition in India remains fraught with regulatory ambiguity, fragmented ownership patterns, local-level opposition, and procedural delays that can delay projects by 12-24 months or lead to project reconfiguration. Having pre-acquired, title-cleared land banks not only accelerate project implementation but also provide strategic leverage during tenders, especially under ISTS connected schemes, where time-bound commissioning is critical for maintaining tariff viability and avoiding penalties.

Transmission connectivity is emerging as an acute constraint. Multiple states are witnessing saturation at key substations; new capacity additions are increasingly dependent on advance booking of transmission access under the General Network Access (GNA) framework. The lack of timely grid connectivity has resulted in bottlenecks and stranded generation assets in multiple zones. For IPPs, acquiring connectivity approvals from Central Transmission Utilities (CTU) and State Transmission Utilities (STU) in-parallel with land acquisition is crucial to de-risking timelines and ensuring off-take readiness. Moreover, projects with pre-secured connectivity and land are increasingly preferred by utilities, DISCOMs, and corporate buyers, as they reflect lower execution risk. The IPPs are also aggregating land in renewable energy zones and proactively investing in transmission linkages (including private pooling substations or dedicated lines) to ensure bankability and avoid grid-related curtailments. These pre-development efforts not only streamline statutory approvals (including MoEF&CC clearances, forest clearances, and revenue permissions) but also reduce dependency on EPC timelines.

5 Overview of Solar PV cell and module manufacturing sector in India

5.1 Solar PV cell and module manufacturing

5.1.1 Solar Cell manufacturing more complex than module assembly

A photovoltaic (PV) cell, commonly called a solar cell, is a nonmechanical device that converts sunlight directly into electricity via the 'photovoltaic effect.' The photovoltaic effect is a process that occurs in some semiconducting materials, such as silicon. At the most basic level, the semiconductor absorbs a photon, exciting an electron which can then be extracted into an electrical circuit by built-in and applied electric fields. It is a type of device whose electrical characteristics (such as current, voltage, or resistance) change when it is exposed to light. The primary component, solar cells are the fundamental building blocks of solar panels. The following key raw materials and components are used in the manufacturing of solar cells:

Silicon Wafers: Silicon wafers are the fundamental building blocks of solar cells. These wafers are thin slices of silicon, which is a semiconductor material essential for converting sunlight into electricity. The wafers are produced by slicing cylindrical silicon ingots derived from high-purity silicon. Solar cell performance/ efficiency is directly influenced by the quality and purity of the semiconductor materials used.

Silver Paste: In the manufacturing process of solar cells, photovoltaic silver paste is coated or printed on the surface of the cell to form a metal electrode grid. Silver paste is essential for creating conductive contacts on the front surface of solar cells. Silver has excellent electrical conductivity and can provide a good electron transport path, playing a role in electron collection and conduction in the process of converting solar energy to electrical energy in PV cells. These conductive grids of silver paste help in collecting the current and transferring it to the circuitry of the cell, thereby increasing the efficiency of the cell. Silver paste is typically screen-printed with a grid pattern on the front-side (facing the sunlight) of a silicon wafer and co-fired with the printed back-side aluminum and back-contact silver paste in order to form a circuit. This facilitates the collection and transfer of the electric current generated by the silicon wafer.

Aluminium paste: The aluminium paste is generally screen printed and dried on the perforated dielectric passivation layer on the backside of the silicon wafer. Upon firing in a furnace, it forms a back surface field that reflects electrons back into the silicon, allowing them to be collected as current. This process improves the overall efficiency of the solar cell.

Other Gases and Chemicals: Various gases and chemicals are utilized throughout the solar cell manufacturing process. The two most common doping elements used are boron and phosphorus; Boron creates p-type silicon with positive charge carriers (holes) and Phosphorus creates n-type silicon with negative charge carriers (electrons). Cleaning and etching of silicon wafers often involve sulfuric acid, hydrofluoric acid, potassium hydroxide and hydrogen peroxide to remove organic and inorganic contaminants such as silicon dioxide.

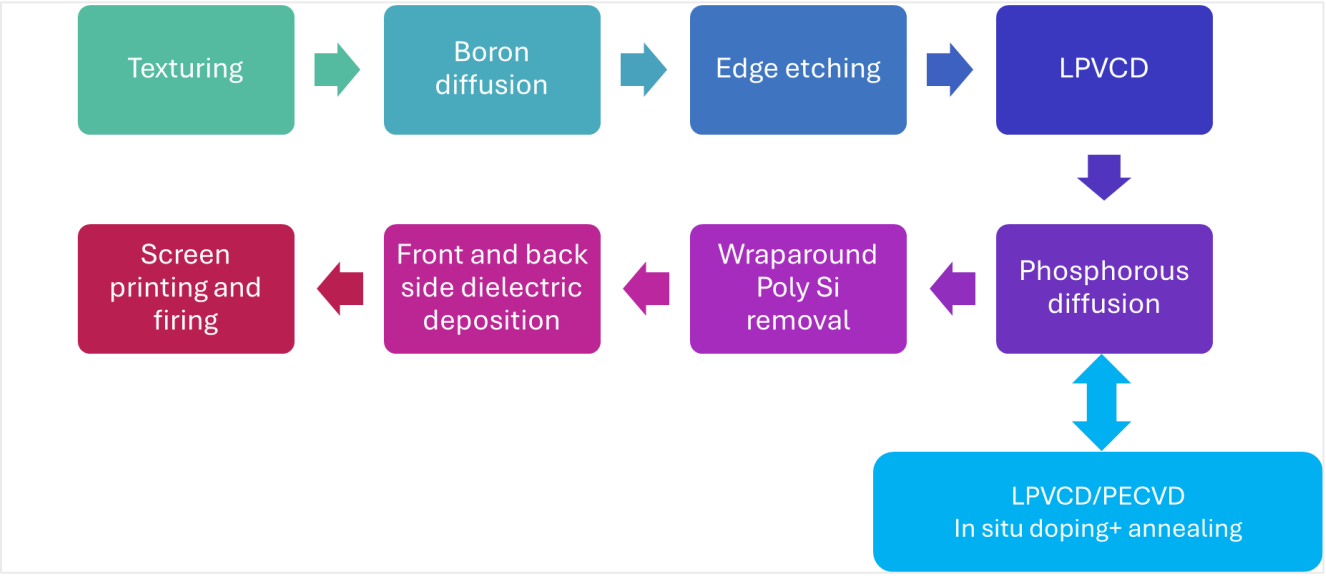
5.1.2 Solar cell manufacturing process

Making solar cells from silicon wafers involves fabrication steps such as etching the silicon, doping the wafers to create positive and negative charge areas and the depositing of conducting and non-reflecting films. When the wafers are treated with chemicals, they are rinsed at the end of the process steps, but traces of chemicals may remain. Such chemical traces can shorten the life span of the solar cells and reduce their efficiency while also impacting the next steps. Therefore, the solar cell manufacturing process begins with ultrasonic cleaning to remove grease and surface particles from the wafers. The process flow for manufacturing TOPCon cells is primarily dictated by the choice of the deposition technology to form TOPCon layers and whether the layers are in-situ doped or require an

external doping. Ultrasonic cleaning is followed by chemical cleaning and texturing carried out in wet benches, which eliminates organic and metallic contaminants.

Surface texturing is a critical step in the TOPCon solar cell manufacturing process that helps increase cell efficiency. The goal of texturing is to create micrometer-scale pyramids on the silicon wafer surface that reduce reflectivity and increase light trapping. This textured surface reduces optical loss by lowering light reflection and increasing the optical path, which enhances light absorption. The wafers are then subjected to a diffusion process, where dopants are introduced to create a p-n junction, which is essential for converting sunlight into electricity. TOPCon cells are mainly adapted on n-type wafers, thus boron diffusion is employed instead of phosphorus. The boron diffusion process in the front field is conducted for emitter formation. The process continues with high-temperature diffusion to form the p-n junction, which is the core of the solar cell responsible for separating the charge carriers generated by light. An edge isolation procedure is then employed to remove the unwanted diffusion around the edges of the solar cell and electrically isolate the front and rear surfaces. This is followed by applying an anti-reflection coating on the sun-facing side of the wafer via the deposition of a thin silicon nitride layer, further improving light absorption. Depending on the polysilicon doping mechanism, annealing may be required. Finally, metallization is carried out by screen printing metal paste onto both sides of the wafer to facilitate the flow of electrical current, which is then subjected to high-temperature co-firing in a belt furnace to create ohmic-contact electrodes. The completed solar cells are subsequently tested, sorted, and prepared for use in the solar module manufacturing process.

Figure 32: Schematic diagram of solar cell manufacturing process



Note:

LPVCD: Low Pressure Chemical Vapor Deposition; PECVD: Plasma-enhanced chemical vapor deposition

Source: Crisil Intelligence

TOPCon technology incorporates a thin tunnel oxide layer to passivate the surface of the solar cells. This passivation reduces recombination losses, which improves the conversion efficiency of solar cell. By limiting carrier recombination at the contact surface, this technology contributes to better overall solar cell performance and more efficient power output. Converting from a mono PERC solar cell to a TOPCon solar cell involves upgrading the rear side of the PERC cell with an ultra-thin tunnel oxide layer and a polysilicon film, which requires advanced equipment like Plasma-Enhanced Chemical Vapor Deposition (PECVD) or Atomic Layer Deposition (ALD) and laser doping, making it a more complex and costly process than the initial PERC manufacturing.

5.2 Policy and Regulatory Framework

5.2.1 Impact of domestic content requirements (DCR) and import duties

Under some of the current schemes of MNRE, namely CPSU Scheme Phase-II, PM-KUSUM and Grid-connected Rooftop Solar Programme Phase-II, wherein government subsidy is given, it has been mandated to source solar PV cells and modules from domestic sources as per specifications and testing requirements fixed by MNRE.

Central Public Sector Undertaking (CPSU) Scheme: A scheme for setting up 12 GW Grid- Connected Solar PV Power Projects by CPSUs with domestic cells and modules is under implementation. Under this scheme, Government has sanctioned around 8.2 GW of projects, as on 31.03.2025.

Grid-connected Rooftop Solar Programme: Targeted to achieve a cumulative installed capacity of 40 GW from Grid Connected Rooftop Solar (RTS) projects. Under the scheme, for Component A: CFA to Residential sector – 4 GW and for Component B: Incentives to DISCOMs – for initial 18 GW Capacity were provided. As of 27 June 2025, the installed capacity was 4,412.57 MW with ₹ 81.77 billion of subsidy released under the PM Surya Ghar scheme.

The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM): All three components of the scheme aim to add Solar capacity of about 34,800 MW by March 2026 with the total Central Financial support of ₹ 34,422 crores. Components B and C of PM KUSUM Scheme were mandate DCR resulting into an estimated demand of 24.8 GW for DCR. However, subsequently, MNRE waived off the DCR for solar cells under the Component C of the scheme. As on 31 May 2025, out of sanctioned 10 GW capacity, around 603 MW capacity was installed under Component A of PM KUSUM Scheme.

Introduction of ALMM List-II for Solar PV Cells

MNRE in December 2024, issued amendment to ALMM Order 2019 and introduced List II for solar PV cells under the ALMM framework. This amendment, set to take effect from 1st June 2026. From 1st June 2026, all solar PV modules used in projects – including government-backed schemes, net-metering projects, and open access renewable energy initiatives – will be required to source their solar cells from ALMM List-II, ensuring quality and reliability in solar PV cells used in India's energy infrastructure. For projects that have already been bid out but whose last date of bid submission is before the issuance of this order, an exemption will apply, allowing them to proceed without the requirement to use solar PV cells from List-II, even if their commissioning date is post-1st June 2026. However, for all future bids, the requirement to source both solar PV modules and cells from the respective ALMM lists will be mandatory, marking a decisive shift towards quality assurance and sustainability in India's solar power sector.

In March 2025, MNRE issued revised DCR norms for solar PV Cells and specified that only those based on crystalline-silicon technology and manufactured in India using an undiffused silicon wafer (black wafer) will qualify as domestically produced. These wafers fall under Customs Tariff Head 3818, and all manufacturing processes, from wafer to solar cell, must be conducted within India. Solar cells made using imported diffused silicon wafers (blue wafers) will not be eligible under MNRE's DCR-mandated programmes.

Since prices of Indian solar cells are higher than alternatives from China even with BCD, this is likely to lead to increase in the capex of the future solar plant needing a tariff hike of about 40-50 paise per unit as offset. The implementation of ALMM for solar PV cells will boost domestic cell manufacturing and reduce reliance on imports. However, with average annual demand of 40-45 GW from Fiscal 2027 to 2030, timely commissioning of solar cell projects is expected to be crucial to ensure capacity is adequate form demand. The ALMM cell mandate could also pose challenges for Companies that do not develop domestic cell manufacturing capability as they would not be complying and, thus, could face module-supply challenges that can impact their market share over the long term. Overall, the non-tariff barrier is likely to protect domestic manufacturers that are vulnerable to global supply shocks and even aid exports as the United States, a key market, continues to manufacture modules at 30-35% higher prices owing to lack of upstream components.

5.3 Assessment of module and cell manufacturing capacity in India

In 2018, India had domestic cell and module manufacturing capacities at approximately 3 GW and 8 GW, respectively. The said capacities were underutilised due to higher costs compared to imported cell & modules.

India's solar photovoltaic (PV) industry has witnessed rapid expansion in recent years, establishing itself as a significant player in the global renewable energy market. The country's solar module manufacturing capacity has grown from 21 GW in Fiscal 2022 to approximately 89 GW in Fiscal 2025. This increase has been driven by government initiatives such as the PLI scheme, the reimposition of the ALMM order, and a robust pipeline of solar projects.

The growth in domestic module manufacturing has led to a substantial rise in solar module exports. Exports surged from ₹0.6 trillion in Fiscal 2022 to ₹9.6 trillion by Fiscal 2025. A key factor behind this export boom has been the Uyghur Forced Labour Prevention Act (UFLPA), which restricted imports of Chinese solar products into the US, redirecting demand towards India and ASEAN manufacturers. However, during Fiscal 2025 due increased scrutiny of India made solar panels by U.S. authorities for potential links to forced labor practices in China exports dropped. Over 95% of India's module exports are to the US.

Additionally, solar cell manufacturing capacity has also expanded, rising from 10 GW in Fiscal 2024 to approximately 25 GW in Fiscal 2025. Despite these improvements, domestic cell production remains insufficient to meet the demand created by module manufacturing, resulting in continued reliance on imports. Despite advancements, India continues to rely heavily on imports for components in the backward integration.

India’s cumulative module manufacturing nameplate capacity has reached approximately 91 GW in as per the ALMM list updated in June 2025 and the cumulative cell manufacturing capacity is about approximately 25 GW till Fiscal 2025. The nameplate module capacity in India is expected to touch 110-120 GW by March 2026. The difference in the manufacturing capacities of solar cell and module is partly due to the lack of vertical integration of domestic solar fabs. However, the operational capacity could be less than 50% of the nameplate capacity.

While moving up the value chain, from solar modules and cells to ingots/wafers and polysilicon, India's PV manufacturing skills substantially decline. Proceeding upstream in the PV supply chain, the complexity and manufacturing capex requirements increase. Polysilicon and ingots/wafers have historically played a negligible role in India's overall PV commodities/products trade. For these components, the domestic industry has solely depended on imported products from international marketplaces. As the renewable energy industry is relatively new in India, there is a scarcity of skilled personnel with experience in the industry.

5.3.1 Advantages of fully integrated solar manufacturing

Fully integrated solar PV manufacturing refers to a production process where a single company controls and manages all stages of solar panel production, from the production of raw materials (such as silicon) to the final assembly and testing of solar panels. It includes the fabrication and assembly of materials across the solar value chain, the most obvious being solar PV panels, which include many subcomponents like wafers, cells, encapsulant, glass, backsheets, junction boxes, connectors, and frames. There are several advantages of having an integrated solar PV manufacturing.

Better quality control: Having a fully integrated solar PV manufacturing process allows the manufacturer a complete control over every stage of production allowing tighter control with reduced defects.

Improved cost management: Costs as well as overheads can be managed efficiently allowing higher profitability in a fully integrated solar PV manufacturing process.

Reduced supply chain risks: With lesser dependence on external suppliers, risk of supply chain disruptions, price volatility, and quality issues can be managed efficiently.

Increased efficiency: Having control over all stages of production, the wastages can be managed efficiently leading to better yield, increased efficiency and lower costs.

Faster response to market dynamics: Fully integrated manufacturers can respond quickly to market dynamics such as changes in market demand, technology advancements, and regulatory requirements etc.

Scalability: With fully integrated manufacturing, the manufacturers can easily scale up production to meet the growing market demand without any external partnership or acquisitions.

Competitive advantage: Companies that achieve full integration can differentiate themselves from other players in the market, establishing a leadership position in the market and attracting premium customers.

Better data management: With access to date at every stage of production, the manufacturers can collect and analyse data for making data-driven decision and process optimization.

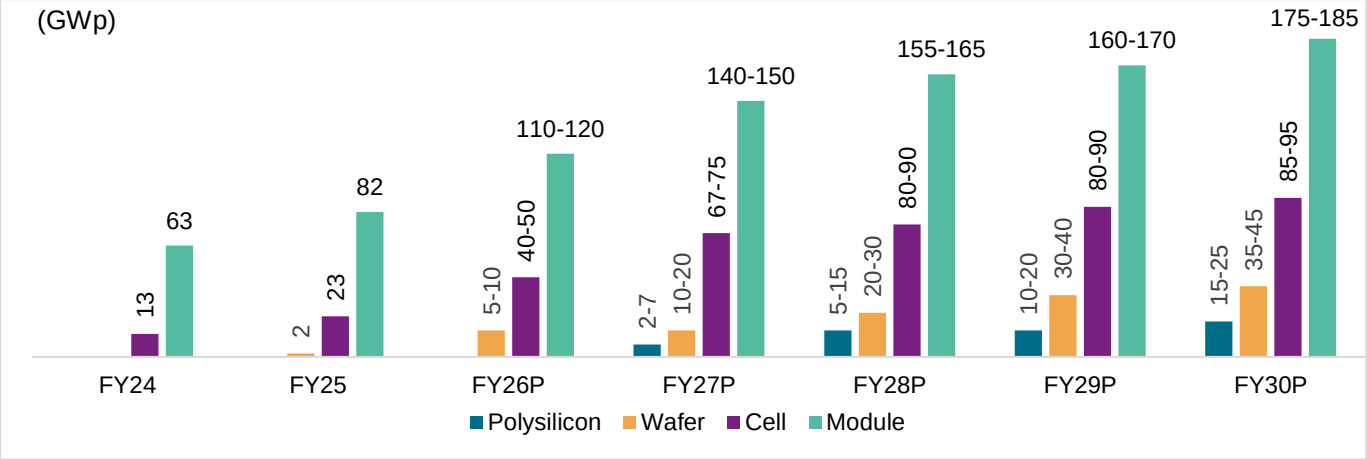
Enhanced innovation: By controlling all stages of production, manufacturers can more easily experiment with new technologies, materials, and processes, driving innovation and improving product performance.

5.4 Estimation of module and cell manufacturing capacity in India

India aims to build its presence across all stages of PV manufacturing over the next two to three years. In November 2020, the GoI introduced the PLI scheme for manufacturing high-efficiency solar PV modules with a financial outlay of ₹ 45 billion. It later enhanced the outlay by ₹ 195 billion under the Union Budget for Fiscal 2023.

Crisil Intelligence expects solar PV manufacturing Capacity to reach 175-185 GW by Fiscal 2030, with full integration from polysilicon to modules expected to account for approximately 25% of capacities, largely driven by PLIs. Achieving this is expected to require an investment of ₹ 1.20-1.30 trillion by Fiscal 2030. Crisil Intelligence expects module manufacturing capacity to grow twice by Fiscal 2030 with approximately 25% of the capacity to be fully integrated and integrated units to come only post Fiscal 2025. Gujarat is projected to be at the epicenter of additions with 55-60% additions in the next five Fiscals.

Figure 33 :India-Current and projected manufacturing capacity, GWp

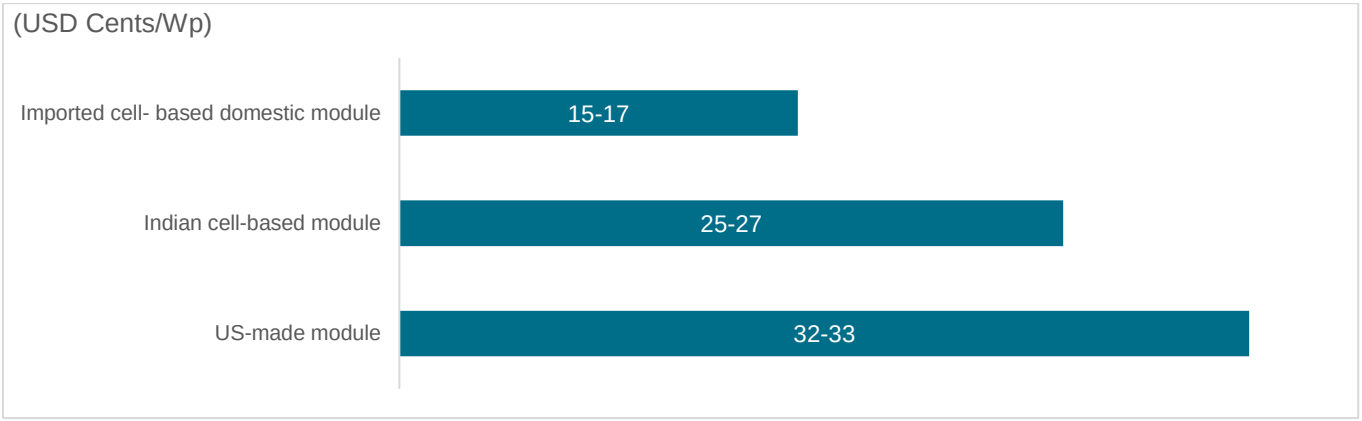


Note:

P: Projected; Source: Crisil Intelligence

Despite the high price of Indian cell-based modules, they continue to be priced 19% to 21% below US-made modules, reflecting differences in scale and cost of production.

Figure 34: Domestic cell-based modules 19% to 21% cheaper than US-made modules

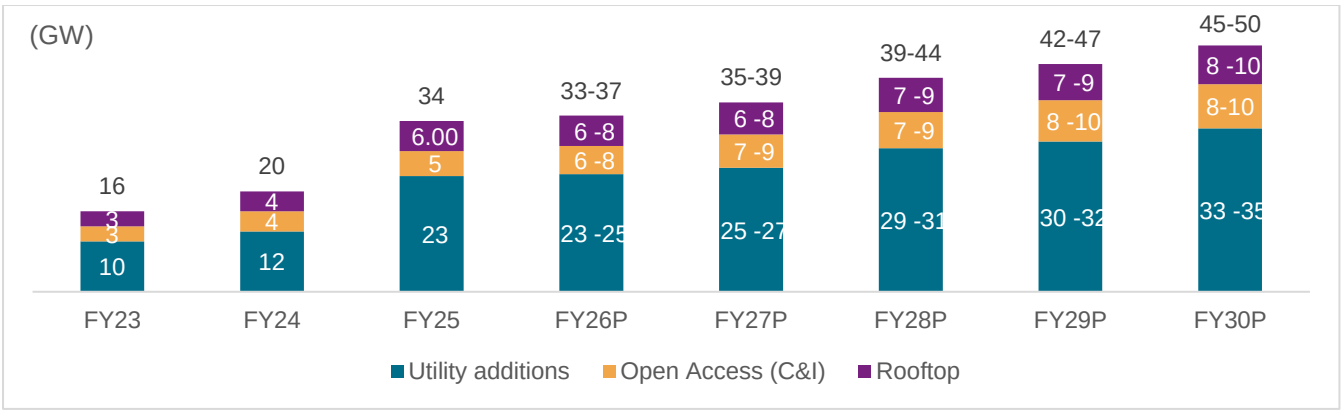


Source: Crisil Intelligence

India is expected to add 160-180 GW of solar capacity over Fiscal 2026-2030. Considering the average module price of USD 0.20/Wp, this capacity addition provides a total opportunity of USD approximately 32-36 billion over Fiscals 2026-2030.

The domestic demand for solar modules has been driven by the competitively bid utility segment at 66%, followed by the rooftop segment at 18% and open access segment at 16% between Fiscals 2019 and 2025. Fiscal 2025 witnessed a significant bump up, driven by increase in solar additions (24 GW) against Fiscal 2024 (15 GW), which along with DC overloading, resulted in a sharp increase in solar module demand to 34 GW in Fiscal 2025. The average demand per annum is expected to double between Fiscals 2026 and 2030 over Fiscal 2021 and 2025

Figure 35: India-average projected annual module demand of 38 to 43 GW between Fiscals 2026 to 2030



Note: Demand includes DC overloading

The total of ranges for the subsegments may not add to the range of the total owing to round off and range limits

Source: Crisil Intelligence

5.5 Supply chain and technology trends

5.5.1 Overview of the solar module supply chain, including raw material sourcing and logistics

Crystalline silicon (c-Si) technology is largely deployed in solar PV globally as well as in India. The technology is also expected to comprise the largest pie in India's ambitious target of 280 GW solar capacity addition by 2030. However, historically, 80-85% of the solar modules needed to be imported as domestic capacity was inadequate to meet

demand. India does not have a manufacturing base for polysilicon ingots and wafer; hence, players import these components, incurring high cost.

Figure 36: Schematic of c-Si PV module supply chain



Source: Crisil Intelligence

Table 7: Overview of PV production process

Particulars	Polysilicon	Ingot Wafer	Cell fabrication	Module
Production process	A high-purity, fine-grained crystalline silicon product manufactured using Siemens process and fluidized bed reactor	Czochralski process for production of mono-Si. Directional solidification for production of multi-Si ingot.	Wafers are cut into rectangular or hexagonal shapes and impurities are added through doping process	Multiple solar cells are interconnected in series. These strings are placed on top of a glass sheet with EVA. Junction box and frame is added to complete the module processes
Complexities	High		Medium	Low to medium
Domestic manufacturing capacity	Nil		Approximately 25 GW (as of March 24) Moderate	Approximately 91 GW (as of June 2025) Significant
Key players in India as of 2024	-		Adani, Premier, Tata Power, Rnewsys, etc	Adani, Tata, Premier, Renewsys, Saatvik, Vikram Solar, Waaree, etc.
Import dependence	High		High	Medium to High

Source: Crisil Intelligence

Solar cell manufacturing is more complex than solar module manufacturing due to the intricate processes involved in converting raw materials such as silicon wafers into functional PV cells. This complexity requires advanced equipment, precision technology and stricter quality control. In contrast, solar module manufacturing primarily involves assembling pre-made cells into panels, a process that is more straightforward and less equipment intensive. As a result, solar cell manufacturing can demand three to four times more capital expenditure compared to module assembly.

5.5.2 Assessment of technology trends

Solar technology is evolving every year, and prices of modules are decreasing, both Monofacial and bifacial modules. As a result, bifacial modules are preferred even in utility-scale projects. The global PV industry is moving towards monocrystalline cell technology from polycrystalline cells. The share of monocrystalline technology is now about 97%[1] (compared with 66% in 2019) of total crystalline silicon (c-Si) production. The performance ratio has also been improved in the 80-90% range. The c-Si segment is expected to grow substantially due to c-Si's long life and light weight. Monocrystalline solar PV panels possess high efficiency and hence preferred.

[1] Fraunhofer ISE: Photovoltaics Report, updated: 17 May 2024

Over the past decade, solar PV cells have become approximately 60% more efficient, while generation costs have seen a remarkable decline of almost 80%. These achievements have been made possible through the combination of public and private investments in research and development (R&D) efforts across the entire solar PV supply chain.

The development of new solar cell designs is essential for achieving further efficiency gains while simultaneously reducing material intensity and manufacturing costs. Multiple companies are actively working on tandem and perovskite technologies. These innovative designs hold the potential to enhance the performance of solar cells. However, additional investment in R&D will be required to bring these technologies to full commercialization.

Table 8: Existing vs upcoming technologies

Parameters	Mono PERC	TOPCon	HJT
Initial Capex	$ 31-38 mn./GW	$ 38-46 mn./GW	$ 69-75 mn./GW
Cell Efficiency	23.2% - 23.7%	24.5% - 25.2%	24.5% - 25.2%
Module Efficiency	20.0% – 21.5%	22.0% - 23.0%	22.0% - 23.0%
Bi-faciality	70% - 75%	80% - 85%	80% - 90%
Complexity	Moderately complex	Less than HJT	Most complex
Temperature Co-efficient of Power (Pmax Temperature Co-efficient)	• -0.35% / °C. • PERC cells experience a more noticeable power decline at elevated temperatures	• -0.29% / °C. • Offers a significant power improvement over PERC cell at elevated temperatures	• -0.24% to -0.26% /°C. • Lowest temperature coefficient - HJT cells experience minimal power loss even at high temperatures.
Losses and Damages	p-type Mono PERC cells are prone to LID and PID losses. Such losses are high compared to peers	PID and LID losses in TOPCon are lower compared to Mono PERC,	Not prone to PID and LID losses, since general cell construction is n-type

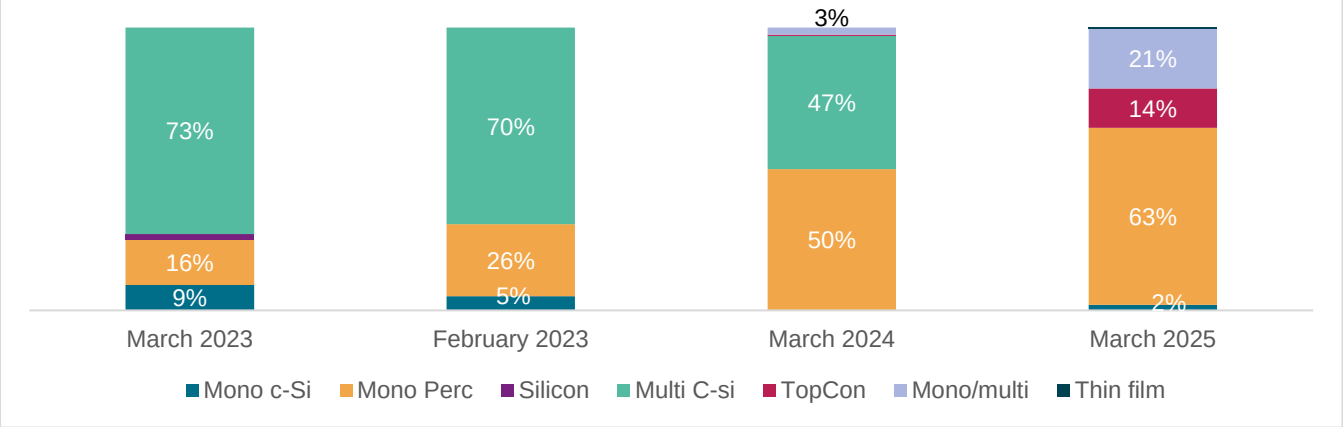
Note: Initial capex for module manufacturing lines pertains to Chinese set-ups.
Potential Induced Degradation (PID) and Light Induced Degradation (LID)
Source: Crisil Intelligence

In the coming years, it is expected that more advanced cell designs such as heterojunction (HJT), TOPCon, and back contact will gain greater market shares. These cell designs hold the potential for achieving additional efficiency gains in solar panels.

Evolution of cell technology in India

The evolution of cell technology in India has mirrored the global market. According to the module batch enlistment in the ALMMs over Fiscals 2022 to 2025, the share of Mono PERC has risen sharply from 16% in March 2022 to 63% in March 2025, with TOPCon also making notable gains to reach 14% by the end of the period. Consequently, lower efficiency cells, such as Multi C-Si, have been largely phased out, with their market share dwindling to negligible levels by March 2025, down from a dominant 73% in March 2022. The shift in technology is on account of the shift in preference of the end-user demand. Developers are increasingly adopting the TOPCon technology in solar cells due to its higher efficiency, lower cost and improved performance compared with older technologies.

Figure 37: TOPCon share inches up while Mono PERC continues to be the largest



Note: The share of technology denotes the count of module batch enlistment per technology divided by total module batch enlistment in the respective month.

MNRE has not released ALMM for March 2023 and thus ALMM for February 2023 has been used.

Source: MNRE, Crisil Intelligence

5.5.3 Backward integration into cells is critical

Backward integration into solar cell manufacturing is a strategic imperative aimed at optimising costs, reducing dependence on external suppliers, improving quality control and margins, ensuring traceability of origin (key for some export markets) and, in the Indian context, complying with local procurement policy rules. While India's module manufacturing capacity has increased rapidly to 101 GW as of June Fiscal 2026 (as per ALMM list 13th August 2025), the domestic integration of solar cell capacity has only been to the extent of 20% to 25% of module manufacturing capacity (assuming full utilisation). Raw material costs form the bulk (80% to 85%) of Indian solar cell manufacturers' operating costs. Of the raw material expenditure, the major component is also imported (wafers), exposing the solar cell manufacturers to foreign exchange risks. This can, in turn, impact project profitability. Imports are a necessity as upstream components required for cell manufacturing, i.e., polysilicon ingots and wafers, are not readily available in India.

5.5.4 Insights on Price trend of solar PV cells and modules

Low prices to prevail across the value chain

On a global scale, the global polysilicon production capacity was estimated at around 3.48 million tones by end of December 2024 in China accounted for 93.5%. Weakened demand and lower consumption coupled with oversupply, resulted in a dramatic price drop in upstream component (polysilicon) of 71% to $8 per kg in March 2024, down from $28 per kg in December 2022. Consequently, downstream components also witnessed significant price reductions, with wafer prices plummeting by 65-70% to $0.12-0.15/piece as of March 2025.

The oversupply of polysilicon also prompted the world's largest monocrystalline solar wafer supplier to cut the prices of its photovoltaic wafers twice between April and May 2023, reducing prices by 33% as cell manufacturers sought to fulfill their order requirements. Cell prices were also down approximately 76% over December 2022 levels, $0.03 per Wp in March 2025. Module prices fell by 52% to $0.11 per Wp during the same period. Module prices are expected to remain stable or decline marginally due to the supply glut in China coupled with subdued demand in international markets like the US and EU.

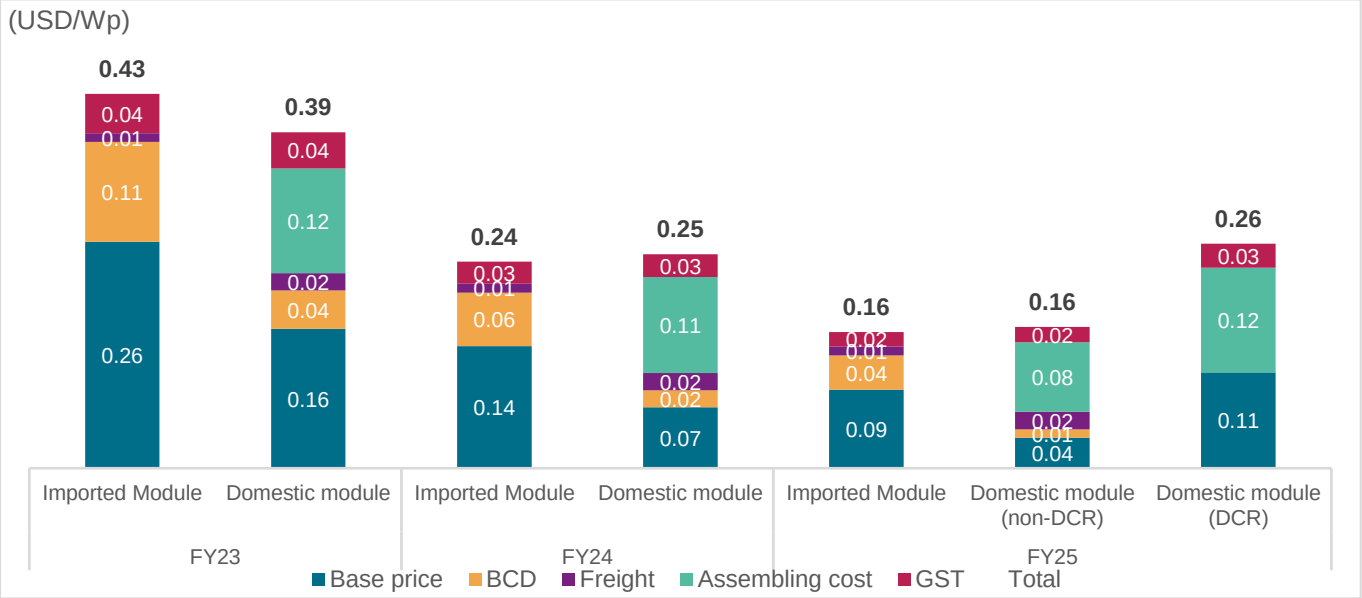
Declining module prices

Module prices experienced a remarkable surge of 22% in Fiscal 2022 and a subsequent 7% increase in Fiscal 2023. However, in Fiscal 2025, module prices remained stable, standing at $0.11 per Wp in March 2025. The sharp decline observed in previous years can be attributed mainly to the supply glut in China and low upstream components including polysilicon. Domestic module prices declined in line with China prices to $0.14 per Wp in March 2025 but

maintained a sizeable premium over China prices. As of March 2025, India had approximately 82 GW module capacity, in contrast to only around 23 GW of cell capacity.

Crisil Intelligence anticipates China module prices to remain stable or decline marginally over Fiscal 2025 due to the supply glut. Domestic module prices are expected to remain stable at $0.13-0.15 per Wp due to ALMM implementation before softening in the medium-term as domestic manufacturing becomes sufficient to meet local demand. With sufficient domestic manufacturing, the prices are going to remain at low levels; however further drop is not expected, since the demand is also increasing.

Figure 38: Cost Comparison of Imported vs Domestic module



Note:

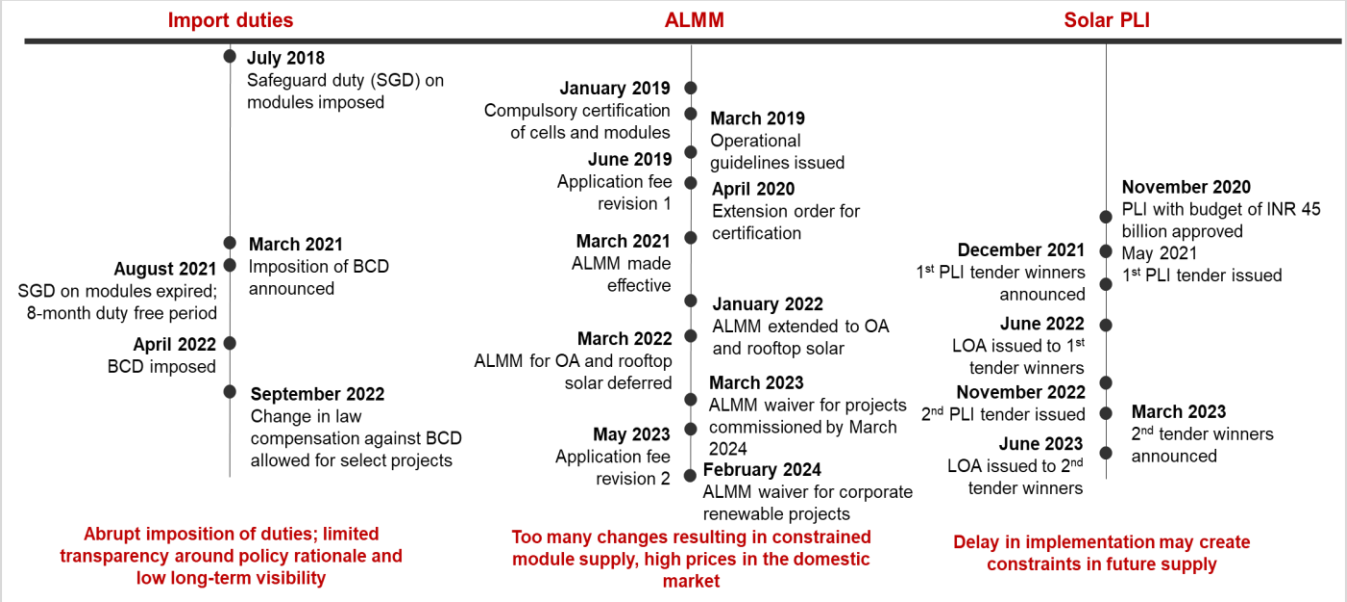
BCD here comprises BCD+AIDC

Source: Crisil Intelligence

5.6 Challenges and Risk Assessment

5.6.1 Policy and regulatory uncertainties

The solar PV manufacturing is largely dependent on government policies. Government policies play a crucial role in shaping the solar module manufacturing landscape in India. PLI outlay for high-efficiency solar PV modules, ALMM-I (Module) and ALMM-II (Cell) CPSU Scheme, PM-KUSUM and Grid-connected Rooftop Solar Programs are among a few of the major government initiative which are driving the domestic manufacturing push and better control over the supply chain by Indian solar module manufacturer. Despite a supportive government, the policy framework has been in flux with several amendments and reversals. Policy formulation and implementation is often hampered by shifting and conflicting priorities, poor design, disjointedness between different arms of the government and disregard for practical considerations. A representative example of policy flux in the PV module market is given below.



5.6.2 Supply chain vulnerabilities and dependence on imports

India's aspiration to become a self-sufficient solar manufacturing hub is hindered by its significant reliance on imports for critical upstream components, including polysilicon, wafers, silver paste, ethylene vinyl acetate (EVA), backsheets, and advanced solar cell technologies. Although the India has witnessed substantial growth in domestic module manufacturing and assembly capacity, the lack of large-scale commercial production of polysilicon and wafers within India restricts the industry's ability to achieve comprehensive backward integration. According to recent industry assessments, more than 85% of the upstream materials required for cell and module production are sourced from a concentrated group of countries, including China, South Korea, Vietnam, and Malaysia, which dominate the global value chain.

This dependence on a limited set of suppliers exposes Indian manufacturers to a multitude of risks, including fluctuations in raw material prices, foreign exchange volatility, and global supply chain disruptions triggered by geopolitical conflicts, pandemics, or trade disruptions. Furthermore, the absence of sufficient domestic supply chain capabilities leads to limited control over quality and delivery schedules, thereby reducing the competitiveness of Indian modules in both domestic and export markets. As India aims to achieve over 500 GW of non-fossil fuel capacity by 2030, the vulnerabilities in the supply chain pose a significant risk to the scalability, resilience, and bankability of solar manufacturing projects.

5.6.3 International trade issues

The global solar equipment trade landscape is becoming increasingly complex due to shifting geopolitical alliances, protectionist policies, and non-tariff barriers, which pose both challenges and opportunities for Indian solar manufacturers seeking to expand their global presence. The Indian exporters are navigating the complexities of frequently changing tariff schedules, safeguard duties, import quotas, and export restrictions imposed by various countries in response to global market trends. Bilateral trade tensions, such as those between the U.S. and China or India and China, often have a ripple effect on renewable energy trade flows, creating uncertainties around policy continuity and market access. These challenges are further compounded by administrative hurdles, including delayed customs clearances, variations in product testing requirements, and the lack of mutual recognition of certifications between countries. Such uncertainties have impacted the bankability of projects, increased working capital requirements, and deter foreign investment in Indian manufacturing.

5.6.4 Competition from low-cost international manufacturers

There are multiple players in this sector who have announced their plans to setup manufacturing facilities in India. The domestic manufacturer may face competition from these players. Currently, no foreign player is enlisted in ALMM List. However, going forward, along with the domestic players, competition may arise from the global players with established manufacturing base like China and Southeast Asia. Also, Domestic manufacturers do not enjoy economies of scale like leading Chinese suppliers. Huge supply glut in China has led to prices falling sharply across the value chain threatening competitiveness of domestic manufacturers despite high import duties.

5.6.5 Environmental and sustainability challenges

The manufacturing process involves the use of materials that can generate hazardous waste. The production process involved in solar PV manufacturing, such as etching, doping, and coating, can generate greenhouse gases, volatile organic compounds, and acid gases, which can contribute to air pollution. Some of the materials used to make solar cells, such as cadmium, lead, arsenic, and selenium, are toxic and can pose health and environmental risks if not handled properly. Water consumption is also significant, especially for the production of silicon wafers, which need to be purified, cut, and polished with large amounts of water. These challenges can impact costs, operational efficiency, and the overall feasibility of the project.

6 Company Overview

SAEL Industries Limited ("SAEL" or "the Company" or "the Group) entered the agri-processing, edible oil processing, and warehousing development and management sectors in 1999. The promoters established agri-processing and grain handling capacities and subsequently diversified into Waste-to-Energy (WtE) operations across two locations - an integrated plant in Ghazipur utilizing rice husk as the primary fuel and a 14.5 MW WtE power plant in Channu, Punjab, operating on rice husk and multiple fuels. Thereafter, the Group commissioned an agro-processing plant in Shahjahanpur, Uttar Pradesh, and developed warehousing facilities across the state between 2011 and 2014.

During this period, the promoters identified challenges faced by farmers due to the limited time available for clearing crop residue post-harvest, often resulting in crop residue burning, leading to deteriorating air quality across Delhi and Northern India. In response, the Group commenced power generation utilizing paddy straw, establishing its first 100% paddy-straw-based AgWtE plants at Ferozepur and Jaitu in Punjab. The Group's strong association with the farming community in Northern India enabled the establishment of an extensive farmer engagement network, ensuring consistent paddy straw supply and addressing a key operational challenge often encountered by other WtE plants.

Norfund, a Norwegian government's investment fund for developing countries, focused on supporting sustainable private sector growth and accelerating the energy transition through investments that create jobs and drive the shift to renewable energy, contributing to poverty reduction and avoiding emissions and the U.S. International Development Finance Corporation (DFC), sovereign backed investment fund for developing countries, focused on climate and development driven investments, have jointly invested USD 145 million in the Group as of June 30, 2025. Additionally, in January 2025, the National Development Bank (NDB), a multilateral development institution of the BRICS nations, undertook its first renewable energy financing in India through an investment in one of SAEL's renewable energy projects.

The Group diversified into solar energy in 2011 by setting up its first solar power project under the Jawaharlal Nehru National Solar Mission. A phase of focused expansion began in 2016 with the commissioning of a 30 MW plant, followed by a 50 MW plant in 2017. The Group has since significantly scaled its solar Independent Power Producer (IPP) portfolio, including the development of a 1,000 MWp solar project at Khavda, Gujarat (comprising two plants of 500 MWp each), which was completed within 16 months, reflecting its project execution capabilities. The Group has also diversified into hybrid solar and energy storage systems as part of its broader renewable energy strategy.

The Group's solar module manufacturing business further strengthens its position in the integrated renewable energy value chain. The first module manufacturing facility, commissioned in Ferozepur, Punjab, comprised a 225 MW line utilizing Poly and Mono technologies and was upgraded in 2024 to produce TOPCon bifacial modules. Subsequently, the Group commissioned a 2,000 MW TOPCon solar module manufacturing facility in Kishangarh, Rajasthan, in 2024, which was expanded to 3,400 MW in 2025.

Renewable energy capacities for SAEL are summarized below:

KPIs	September 30, 2025		June 30, 2025		March 31, 2025		March 31, 2024		March 31, 2023	
	MW	MWp	MW	MWp	MW	MWp	MW	MWp	MW	MWp
Total Capacity (A+B+C+D)	**5,765.70**	**8,464.40**	**5,165.70**	**7,356.40**	**4,415.70**	**6,181.40**	**2,485.70**	**3,412.40**	**485.70**	**614.40**
Solar	4,850.80	6,916.50	4,850.80	6,916.50	4,250.80	6,016.50	2,320.80	3,247.50	320.80	449.50
Solar +ESS	750.00	1,383.00	150.00	275.00	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-	-	-
Agri Waste to Energy	164.90	164.90	164.90	164.90	164.90	164.90	164.90	164.90	164.90	164.90
Operational Capacity (A)	**870.80**	**1,152.50**	**470.80**	**599.50**	**441.00**	**569.70**	**286.30**	**362.70**	**286.30**	**362.70**
Solar	720.80	1,002.50	320.80	449.50	320.80	449.50	220.80	297.20	220.80	297.20
Solar +ESS	-	-	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-	-	-
Agri Waste to Energy	150.00	150.00	150.00	150.00	120.20	120.20	65.50	65.50	65.50	65.50
Completed and pending COD capacity (B)	**1,200.00**	**1,519.00**	**800.00**	**1,000.00**	**-**	**-**	**-**	**-**	**-**	**-**
Solar	1,200.00	1,519.00	800.00	1,000.00	-	-	-	-	-	-
Solar +ESS	-	-	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-	-	-
Agri Waste to Energy	-	-	-	-	-	-	-	-	-	-
Under Construction Contracted Capacity (C)	**2,344.90**	**3,509.90**	**2,944.90**	**4,281.90**	**2,044.70**	**2,716.70**	**1,799.40**	**2,323.70**	**149.40**	**174.70**
Solar	2,330.00	3,495.00	2,930.00	4,267.00	2,000.00	2,672.00	1,700.00	2,224.30	50.00	75.30
Solar +ESS	-	-	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-	-	-
Agri Waste to Energy	14.90	14.90	14.90	14.90	44.70	44.70	99.40	99.40	99.40	99.40
Awarded Capacity (D)	**1,350.00**	**2,283.00**	**950.00**	**1,475.00**	**1,930.00**	**2,895.00**	**400.00**	**726.00**	**50.00**	**77.00**
Solar	600.00	900.00	800.00	1,200.00	1,930.00	2,895.00	400.00	726.00	50.00	77.00
Solar +ESS	750.00	1,383.00	150.00	275.00	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-	-	-
Agri Waste to Energy	-	-	-	-	-	-	-	-	-	-

Source: The Company

Table 9: Rating wise break up of capacities of SAEL

Description	FY 2023	%	FY 2024	%	FY 2025	%	Sep-25	%
AA	20.00	4.12%	1,820.00	73.22%	3,750.00	84.92%	4,700.00	81.52%
A+	132.00	27.18%	132.00	5.31%	132.00	2.99%	132.00	2.29%
Below A+	193.00	39.74%	393.00	15.81%	482.40	10.92%	482.40	8.37%
Unrated	140.70	28.97%	140.70	5.66%	51.30	1.16%	451.30	7.83%
Total	**485.70**	**100.00%**	**2,485.70**	**100.00%**	**4,415.70**	**100.00%**	**5,765.70**	**100.00%**

Source: The Company

The Company's total contracted and awarded AC capacity has grown at a CAGR of 201.52% to 4,415.70 MW (6,181.40 MWp) as of March 31, 2025 from 485.70 MW (614.40 MWp) as of March 31, 2023. Offtaker profile of AA rated and above have shown significant jump from 4.12% of total contracted and awarded AC capacity on March 31, 2023 to 84.92% on March 31, 2025. Company continues to benefit from a strong off-taker profile, as of September 30, 2025, 81.52% of total contracted & awarded capacity is with offtakers with credit ratings of AA and above.

Table 10: Offtaker wise break up of SAEL operational capacity (as of September 30, 2025)

Off-taker	AC Capacity (MW)	DC Capacity (MWp)	% of AC Capacity	% of DC Capacity	Average. Receivable Days of IPPs
Central	2,820.00	4,358.97	48.91%	51.50%	
SECI	1,470.00	2,075.97	25.50%	24.53%	13
NHPC	600.00	1,108.00	10.41%	13.09%	NA
SJVN	450.00	725.00	7.80%	8.57%	66
NTPC	300.00	450.00	5.20%	5.32%	67
State	1,880.00	2,620.00	32.61%	30.95%	
GUVNL	1,880.00	2,620.00	32.61%	30.95%	29
Capacity Contracted with AA rated and above Off-takers	4,700.00	6,978.97	81.52%	82.45%	
Capacity Contracted with A rated and below (including unrated) Off-takers	1,065.70	1,485.40	18.48%	17.55%	
Total	**5,765.70**	**8,464.41**	**100.00%**	**100.00%**	

Source: The Company

Following table summarises the module manufacturing capacities for SAEL

Table 11: Summary of module manufacturing capacities for SAEL

FY	Particulars	Rajasthan Facility	Punjab Facility	Total
FY23	**Installed Capacity (MW)**	-	225.00	**225.00**
	Effective Installed Capacity (MW)	-	92.08	**92.08**
	Production (MW)	-	1.65	**1.65**
	Capacity Utilisation (%)	-	1.79%	**1.79%**
FY24	**Installed Capacity (MW)**	-	225	**225**
	Effective Installed Capacity (MW)	-	190.96	**190.96**
	Production (MW)	-	47.48	**47.48**
	Capacity Utilisation (%)	-	24.86%	**24.86%**
FY25	**Installed Capacity (MW)**	2,000.00	225.00	**2,225.00**
	Effective Installed Capacity (MW)	1,322.10	190.96	**1,513.06**
	Production (MW)	775.00	115.89	**890.89**
	Capacity Utilisation (%)	58.62%	60.69%	**58.88%**
Q1FY26	**Installed Capacity (MW)**	3,400.00	225.00	**3,625.00**
	Effective Installed Capacity (MW)	672.72	47.74	**720.47**
	Production (MW)	503.00	36.21	**539.21**
	Capacity Utilisation (%)	74.77%	75.85%	**74.84%**

Source: The Company

7 Competitive positioning

Competitive mapping covers the details of companies, their products and services within a given market to understand competitive intensity. Some of the key independent power producers include ACME Solar Holdings Limited, NTPC Green Energy Limited, ReNew Energy Global PLC, Tata Power Renewable Energy Limited, Adani Green Energy Limited. Solar module manufacturers include Premier Energies Limited, Waaree Energies Limited, Emmvee Photovoltaic Power Pvt. Ltd., Rayzon Solar, Vikram Solar Limited. These players also have a sizeable quantum of capacity under consideration/development. SAEL competes with renewable energy project developers on the basis of a number of differentiating factors in the industry, including site selection, access to vendors, access to project land, efficiency and reliability in project development and operation, and auction bid terms.

In addition, the company also competes with both conventional and renewable energy companies for the financing needed to develop and construct projects. The Company also competes with other conventional and renewable energy companies for a limited pool of personnel with requisite industry knowledge and experience, as well as equipment supplies, permits and land to develop new projects.

Table 12: Brief profile of IPP peers

Name	Listed / Unlisted	Brief profile
SAEL Industries Limited	• Unlisted	• Part of SAEL Group formed in 1999 • Primarily engaged in waste-to-energy power generation, agricultural processing & exports, solar power generation, Solar Module Manufacturing, and warehousing. • Agriculture business of the group has been demerged and now SIL is the renewable energy development company of the group • The Group has experience in operating and maintaining large power stations efficiently • Leading renewable energy power producer in India that is integrated and diversified, and is well positioned to capitalize industry tailwinds, with in-house EPC and O&M strengths to drive innovation and efficiency.
Adani Green Energy Limited	• Listed	• Part of Adani Group, a diversified conglomerate • The Adani Group has presence across diverse businesses • The Adani Group has successful incubation track record • The Adani Group has healthy balance sheet and provides need based support to its subsidiaries • The Adani Group has experience in operating and maintaining large power stations efficiently • AGEL is one of the leading RE companies enabling the clean energy transition
ReNew Energy Group PLC	• Listed	• The ReNew Group's large and diversified portfolio provides economies of scale and operating advantages, mitigating concentration risk

Name	Listed / Unlisted	Brief profile
		• Provides end to end solutions for decarbonisation • The ReNew Group has strong financial flexibility on account of CPPIB being the majority shareholder • The ReNew Group has diversified portfolio in terms of technology and geography • ReNew Energy a global RE Company offering clean & green energy including Wind, Solar, Hybrid Power
Acme Solar Holdings Limited	• Listed	• One of the early entrants in the solar IPP business in India • ACME is one of the established players in Solar business • ACME has adequate financial flexibility as seen from its track record of fundraising. • Above average financial risk profile, supported by large and diverse portfolio of assets
Tata Power Renewable Energy Limited	• Unlisted	• The TATA power Company Limited (TPCL) is an Indian electric utility and electricity generation company • TATA Group started its power generation in 1910 • TPCL operates thermal, hydro, renewable energy projects across various countries • TPCL has strong financial flexibility, driven by stable and healthy cash accrual from the existing businesses and adequate liquidity. • TPREL is an RE IPP which offers clean & green energy solutions via wind & solar projects including hybrid and complex projects.
NTPC Green Energy Limited	• Listed	• NTPC Limited, India's largest power company (in terms of installed capacity as well as generation) • NTPC Limited is a Central Public Sector Enterprise (CPSE) under Ministry of Power • NTPC Limited provides support, vision, resources, and experience • NTPC Limited has experience in operating and maintaining power stations efficiently and in acquiring land for large power projects throughout India • NGEL an umbrella company for the green business initiatives of NTPC and undertakes projects through organic and inorganic routes
Juniper Green Energy	• Unlisted (IPO under progress)	• Arvind Tiku, Hemant Tikoo, Niharika Tiku, Juniper Renewable Holdings Pte. Ltd., and AT Holdings Pte. Ltd. are the Promoters • AT Group's asset portfolio spans across diverse sectors; main focus areas are in Real Estate, Renewable Energy, Private & Structured Credit and Public Markets • Juniper Green Energy a RE IPP with experience in building, and developing RE assets including solar, wind, WSH and FDRE projects

Source: Company websites, Investor presentations, regulatory filings before SEBI, Crisil Intelligence

Table 13: Experience and offerings of IPP peers (As of June 2025)

Name	Yrs of Exp in RE	Presence across no. of States / Union Territories	IPP Total operational capacity	Module Manufacturing Operational capacity (GW)	IPP	EPC	O&M	Solar PV module manufacturing
SAEL Industries Limited	16 yrs#	11	10.02 GW_{DC}*	3.62	Y	Y	Y	Y
Adani Green Energy Limited	10 yrs	12	21.65 GW_{DC}	4.00	Y	Y	Y	Y
ReNew Energy Group PLC	15 yrs	9	11.14 GW_{AC}	6.40	Y	Y	Y	Y
Acme Solar Holdings Limited	15 yrs	11	2.89 GW_{AC}	1.20	Y	Y	Y	Y
Tata Power Renewable Energy Limited	18 yrs	15	5.64 GW_{AC}	4.90	Y	Y	Y	Y
NTPC Green Energy Limited	3 yrs	9	6.80 GW_{AC}	-	Y	Y	Y	N
Juniper Green Energy	5 yrs	4	NA	-	Y	Y	Y	N

Note:

** Including completed but awaiting COD, NA: Not Available as not available or reported for the particular period; Module manufacturing capabilities of group company (ies) considered*

 # SAEL Industries Ltd was incorporated in 2022; however, the group has been in the Renewable Energy Industry as an IPP since 2009

Source: Company websites, Investor presentations, regulatory filings before SEBI, Crisil Intelligence.

- Based on the table above:
    - The Company is amongst the top 5 Indian renewable energy IPPs which are vertically integrated and equipped with in-house solar module manufacturing based on operational capacity as on June 30, 2025.
    - The Group benefits from a diversified and strong off-taker profile including central and state government off-takers, which provides it with a long-term and stable revenue profile during the term of PPAs.

Table 14: Profile of off taker and technology mix for IPP peers (As of June-2025)

Name	Total IPP Capacity (GW)	Operational IPP Capacity (GW)	Off Taker			Technology Mix (operational)			
			Central Off Taker (%)	GUVNL (%)	Other States (%)	Solar (%)	Wind (%)	WSH (%)	Other (FDRE/ RTC (incl. Solar with ESS, AgWtE) (%)
SAEL Industries Limited	5.76 (8.46 GW_{DC})	1.27** (1.15 GW_{DC})	49.30%	32.60%	18.10%	84.13%	-	-	15.87%
Adani Green Energy Limited	NA	15.82	59.14%	1.88%	38.87%	70.54%	12.56%	16.91%	NA
ReNew Energy Group PLC	18.23	11.14	55.00%	4.00%	41.00%	50.10%	38.10%	-	11.80%
Acme Solar Holdings Limited	6.97	2.89	83.43%	2.37%	14.2%	98.27%	1.73%	-	-
Tata Power Renewable Energy Ltd.	11.32	5.6	NA	NA	NA	81.68%	18.32%	-	-
NTPC Green Energy Limited	32.28	6.8	NA	NA	NA	90.71%	9.29%	-	-
Juniper Green Energy	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

NA: Not Available as not available or reported for the particular period

*** This includes project completed and awaited COD of 800 MW (1000 MWp)*

Source: Company websites, Investor presentations, regulatory filings before SEBI, Crisil Intelligence.

Table 15: Performance of IPP peers (As of June-2025)

Name	PLF	Plant availability
SAEL Industries Limited	S:23.80% WtE: 89.80%	S: 99.74% WtE: 90.50%
Adani Green Energy Limited	S: 28.00% W: 42.30% H: 43.90%	S: 99.30% W: 95.50% H: 98.60%
ReNew Energy Group PLC	S: 25.00% W: 34.00%	NA

Name	PLF	Plant availability
Acme Solar Holdings Limited	S: 28.50%	S:99.40%
Tata Power Renewable Energy Limited	S: 24.00% W: 27.00%	S: 100.00% W: 98.00%
NTPC Green Energy Limited	S:25.00% W:33.00%	NA
Juniper Green Energy	NA	NA

Note:

NA: Not Available as not available or reported for the particular period

Source: Company websites, Investor presentations, regulatory filings before SEBI, Crisil Intelligence.

- The Company is one of the leading Indian renewable power producers by total capacity as of June 30, 2025.
- One of the marquee projects of the Company includes 21 MW_{DC} project in Mizoram, which, was the first and the largest Solar IPP project in the Northeast India at the time of commissioning.
- The Company has commissioned India's largest rooftop solar project across a metro network (at the time of commissioning), spanning 21 stations, 1 depot, and parking with Noida Metro Rail Corporation.
- The Company has commissioned one of the largest Canal Top projects in India, covering 4.5 km of Ghaggar Link canal.

Table 16: Brief profile of module manufacturing peers

Name	Listed / Unlisted	Brief profile
SAEL Industries Ltd.	• Unlisted	• Part of SAEL Group formed in 1999 • Primarily engaged in waste-to-energy power generation, agricultural processing & exports, solar power generation, solar module manufacturing and warehousing. • Agriculture business of the group has been demerged and now SIL is the renewable energy development company of the group • The Group has experience in operating and maintaining large power stations efficiently
Waaree Energies Ltd.	• Listed	• Part of Waaree Group; primarily engaged in manufacturing solar PV cells and modules • An established player in the solar module manufacturing industry with track record of over 15 years. • It has healthy balance with gearing less than unity • It also provides EPC services for solar power plants, and trades in other solar-related products such as solar water heaters and solar water pumps.

Name	Listed / Unlisted	Brief profile
Premier Energies Ltd.	• Listed	• Has Integrated (solar cell and module) manufacturing facilities • The Company has established market position and longstanding experience of the promoter in the solar industry: • At the group level, capacity increased to approximately 2 GW for cells and approximately 4.1 GW for modules in March 2025 • The Company derives a small portion of revenue from the solar EPC business.
Vikram Solar Ltd.	• Listed	• Established player with operational capabilities in solar module manufacturing • Consistent revenue growth with steady margins • Sells solar modules domestically and undertakes exports, along with EPC contracts to set up solar power plants.
Rayzon Solar	• Unlisted (IPO under progress)	• It manufactures solar PV modules and also provides solar EPC (engineering, procurement, and construction) services through group companies. • It has significant growth in scale of operations and healthy operating efficiency • The Company has shown improvement in capital structure which is getting reflected in moderation in gearing
Saatvik Solar	• Listed	• Saatvik manufactures solar PV modules; engaged in providing solar energy solutions, specialising in EPC services for solar power projects. • Significant ramp up in capacity, from 0.6 GW in Fiscal 2023 to 1.8 GW as of April 2024, and 3.8 GW as of December 2024 • It has debt: equity ratio of 0.37 for Fiscal 2025, indicating low leveraged company.
Emmvee Photovoltaic Power Pvt. Ltd.	• Unlisted (IPO under progress)	• Engaged in the manufacturing of solar PV cells and solar PV modules. • The group has been in the solar equipment industry, encompassing solar water heating systems and solar modules, for over 30 years. • Successful commissioning of integrated cell and module capacity of 1.5 GW in September 2024, followed by commissioning of 1.5 GW of module capacity in January 2025.
Goldi Solar Pvt. Ltd.	• Unlisted	• Goldi Group is an established player and among the leading companies in the Indian solar module manufacturing sector • Also provides EPC services, IPP and deals in solar inverters • The Group's manufacturing capacity is expected to increase further to 14.7 GW in FY2026 from 10.7 GW as of March 2025.

Note:

NA: Not Available as not available or reported for the particular period

Source: Company websites, Investor presentations, regulatory filings before SEBI, Crisil Intelligence.

Table 17: Experience and offerings of module manufacturing peers

Name	Manufacturing presence	TOP-Con	Mono PERC	Bi-facial module	EPC -Roof-Top	EPC- IPP	O&M
SAEL Industries Limited	2 States	Y	N	Y	Y	Y	Y
Waaree Energies Ltd.	1 State	Y	Y	Y	Y	Y	Y
Premier Energies Ltd.	1 State	Y	Y	Y	Y	Y	Y
Vikram Solar Ltd.	2 States	Y	Y	Y	Y	Y	Y
Rayzon Solar	1 State	Y	Y	Y	Y	Y	Y
Saatvik Solar	1 State	Y	Y	Y	Y	Y	Y
Emmvee Photovoltaic Power Pvt. Ltd.	1 State	Y	Y	Y	Y	Y	Y
Goldi Solar Pvt. Ltd.	1 State	Y	Y	Y	Y	Y	Y

Note:

Y: Present in the segment, N: Not present in the segment

Source: Company websites, Investor presentations, regulatory filings before SEBI, Crisil Intelligence.

Table 18: Module capacity details of module manufacturing peers

Name	Operational capacity (GW)	Under-Construction/ Planned (GW)	Total Capacity (GW)	Cell capacity Planned (GW)
SAEL Industries Limited	3.60	5.00	8.60	5.00
Waaree Energies Ltd.	15.00	10.00	25.00	10.00
Premier Energies Ltd.	5.13	3.00	9.13	6.40
Vikram Solar Ltd.	4.50	16.00	20.50	12.00
Rayzon Solar	6.00	2.00	8.00	3.50
Saatvik Solar	3.70	5.00	8.70	4.80

Name	Operational capacity (GW)	Under-Construction/ Planned (GW)	Total Capacity (GW)	Cell capacity Planned (GW)
Emmvee Photovoltaic Power Pvt. Ltd.	7.80	8.50	16.30	6.00
Goldi Solar Pvt. Ltd.	10.70	4.00	14.70	4.00

Note:

NA: Not Available as not available or reported for the particular period

Source: ALMM List (August 2025), Company websites, Investor presentations, regulatory filings before SEBI, Crisil Intelligence.

- The Company is one of the leading module manufacturers for TOPCon modules based on operating capacity as on June 30, 2025.
- The Company was one of the first few Indian companies to manufacture large solar panels with 630 Wp and with efficiency of 22.95% or above.
- The module manufacturing business of the Company produces bifacial modules which are more efficient as they generate energy from both sides of modules, which has the capability to increase the PLF up to 10% (subject to Albedo factor; natural ability of the ground to reflect light) with a low average degradation of 0.4%.
- The Company provides guarantee for power output for 25 years and a material and workmanship warranty for 12 years for its modules.
- The Company has extensive presence across the value chain, allowing it to leverage its in-house strengths to drive innovation and efficiency.
- The Company has developed in-house solar module manufacturing and assembly infrastructure, and they are one of the few Indian renewable energy firms with such capabilities.
- The Company has technologically advanced solar module assembly capacity on TOPCon bifacial modules technology with an installed capacity of 3,525 MW as of September 30, 2025.

The WtE sector is characterized by numerous small- to medium-sized players, including private companies and public-private partnerships, rather than a few large, listed corporations. The limited information and lack of major listed players in India's waste to energy sector steam from fragmented market, data collection and reporting and a focus on smaller decentralized projects. The industry is growing driven by government support and large potential for energy recovery from growing waste streams. However, smaller project sizes, remote locations, lack of stringent regulatory oversight leads to insufficient data collection, reporting, and public access to reliable information on the sector's performance and players. Following table summarises the list of key players in AgWtE sector based on publicly available information.

Table 19: Waste to energy peer comparison

Particulars	SAEL Industries	Kalpataru Projects*	Green Planet Energy	Janati Bio Power Pvt. Ltd.
Group	• SAEL	• Kalpataru	• SPV by Kamala Mills Ltd, Darashaw & Co. and MPPL Renewable Energy Pvt Ltd	• SVL Ltd. (Orient Green Power Ltd. sold its Biomass power plants to Janati Bio Power Private Limited in 2017)
Years in business	• 16 Years#	• 22 Years	• 13 Years	• 19 Years
Total capacity of power plants	• 164.9MW	• 15.8 MW	• 100 MW (awarded by PEDA)	• 106 MW
Project details	• 60.5 MW in Punjab • 15 MW in Haryana • 89.4 in Rajasthan	• 15.8 MW in Rajasthan	• 30 MW projects in Punjab	• 32.5 MW in Tamil Nadu • 34 MW in Rajasthan • 22 MW in Maharashtra • 10 MW in Madhya Pradesh • 7.5 MW in Telangana
Feedstock used	• Paddy straw, Agricultural residues, Wheat husk, Millet husk, Barley husk, Jawar husk etc.	• Agricultural crop residues & forestry wastes	• Agricultural crop residues	• Agri - residues and waste from agriculture crops, forestry, and related industries
PPA with	• Punjab Discom • Haryana Discoms • Rajasthan Discoms	• Rajasthan Discoms	• Punjab Discom	• NA

Notes:

**For FY24-25, Kalpataru Projects had approximately 2.7% revenue from Others which mainly included revenue from toll collection, sale of electricity and real estate units.*

NA: Not Available as not available or reported for the particular period

Source: Company websites, Investor presentations, Crisil Intelligence.

 # SAEL Industries Ltd was incorporated in 2022, however, the group has been in the Renewable Energy Industry as an IPP since 2009

- The Company is a pioneer in the Indian Agri Waste-to-energy (AgWtE) industry and the largest AgWtE operator in India based on operational capacity as on June 30, 2025.
- The Company is the largest AgWtE power producer in India, with a total capacity of 150 MW as of March 31, 2025
- The AgWtE plants of Company are known for their efficiency and scalability with the best available technology from Burmeister & Wain Energy and wide fuel flexibility.
- The Company is one of the largest industrial offtaker of paddy stubble in India as on June 30, 2025, which acts as a feedstock for their power plants, helping them contribute towards both energy transition and pollution mitigation.

- The Company has partnered with global technology suppliers, such as Burmeister & Wain Energy (BWE), which provide industry best equipment and specializes in high-efficiency biomass boilers which are capable of utilizing agricultural biomass like paddy straw amongst other fuel
- The Company's strength in the AgWtE sector is demonstrated by its experience, which allows it to get robust PLF and PA higher than the industry average.
- The Company has successfully executed waste-to-energy projects in the climates of western Rajasthan, which is prone to sandstorms and extreme climatic vagaries.
- The AgWtE plants operated by Company are equipped with advanced technologies, and the Company is among the early entrants as AgWTE power producers based on paddy straw in India,
- AgWtE plants operated by the Company are known for their efficiency and scalability, with an average generation PLF of 90.9% and PA of 89.35%as on March 2025.
- Some of the AgWtE plants operated by the Company are also equipped with air-cooled condensers (more water efficient) , instead of the more common water-cooled condensers.
- The company has established a PLF performance which is higher than the peers.

Table 20: Key parameters for Q1FY26

As on June 30, 2025	Units	SAEL Industries Ltd	Adani Green Energy Limited#	Renew Energy Global PLC#	ACME Solar Holdings Ltd.	Tata Power Renewable Energy Ltd.	NTPC Green Energy Limited	Juniper Green Energy Limited	Waaree Energies Limited	Premier Energies Limited	Vikram Solar Limited
Operational Parameter - Module Manufacturing											
Installed Capacity	MW	3,625.00	4,000.00	6,400.00 #	1,200.00	4,900.00#	NA	NA	15,000.00	5,100.00	4,500.00
Effective Installed Capacity	MW	720.47	NA	NA	NA	NA	NA	NA	NA	NA	NA
Production	MW	539.21	NA	NA	NA	949.00	NA	NA	NA	NA	949
Capacity Utilisation	%	74.84%	NA	NA	NA	NA	NA	NA	NA	77.00%	NA
Operational Parameter - IPP											
Total Capacity (A+B+C+D)	MW	**5,165.70**	**36,500^^**	**18,231.60**	**6,970.00**	**11,319.00**	**23,202.00**	**NA**	**NA**	**NA**	**NA**
Solar	MW	4,850.80	NA	7,586.00	3,440.00	4,764.00	17,136.00	NA	NA	NA	NA
Solar + ESS	MW	150.00	NA	NA	NA	NA	1,170.00	NA	NA	NA	NA
Other*	MW	-	NA	10,645.60@	3,530.00	6,555.00	4,896.00	NA	NA	NA	NA
Agri Waste to Energy	MW	164.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
Operational Capacity (A)	MW	**470.80**	**15,816.00**	**11,139.20**	**2,890.00**	**5,644.00**	**6,802.00**	NA	**NA**	**NA**	**NA**
Solar	MW	320.80	11,156.00	5,376.00	2,840.00	4,085.00	6,170.00	NA	NA	NA	NA
Solar + ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other*	MW	-	4,660.00	5,763.50@	50.00	1,559.00	632.00	NA	NA	NA	NA
Agri Waste to Energy	MW	150.00	NA	NA	NA	NA	NA	NA	NA	NA	NA

As on June 30, 2025	Units	SAEL Industries Ltd	Adani Green Energy Limited#	Renew Energy Global PLC#	ACME Solar Holdings Ltd.	Tata Power Renewable Energy Ltd.	NTPC Green Energy Limited	Juniper Green Energy Limited	Waaree Energies Limited	Premier Energies Limited	Vikram Solar Limited
Completed and pending COD capacity (B)	MW	**800.00**	**NA**	**NA**	**NA**	**NA**	**NA**	NA	NA	NA	NA
Solar	MW	800.00	NA	NA	NA	NA	NA	NA	NA	NA	NA
Solar + ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other*	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Agri Waste to Energy	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Under Construction Contracted Capacity (C)	MW	**2,944.90**	**15,700.00^^**	**7,092.10**	**2,240.00**	**5,675.00**	**16,400.00**	NA	NA	NA	NA
Solar	MW	2,930.00	NA	2,210.00	NA	679.00	10,966.00	NA	NA	NA	NA
Solar +ESS	MW	-	NA	NA	NA	NA	1,170.00	NA	NA	NA	NA
Other*	MW	-	NA	4,882.10@	2,240.00	4,996.00	4,264.00	NA	NA	NA	NA
Agri Waste to Energy	MW	14.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
Awarded Capacity (D)	MW	**950.00**	**5,000.00^^**	**NA**	**1,840.00**	**NA**	**NA**	NA	NA	NA	NA
Solar	MW	800.00	NA	NA	600.00	NA	NA	NA	NA	NA	NA
Solar +ESS	MW	150.00	NA	NA		NA	NA	NA	NA	NA	NA
Other*	MW	-	NA	NA	1,240.00	NA	NA	NA	NA	NA	NA
Agri Waste to Energy	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average Capacity Utilization Factor											
Solar, Wind, Hybrid (as applicable)	%	23.80%	S: 28.00% W: 42.30% H: 43.90%	S: 25.00% W: 34%	S: 28.50%	S: 24.40% W: 27.10%	S:25.00% W:33.00%	NA	NA	NA	NA
AgWTE (Generation)	%	89.69%	NA	NA	NA	NA	NA	NA	NA	NA	NA
AgWTE (Export)	%	79.62%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average Plant Availability											
Solar, Wind, Hybrid (as applicable)	%	99.74%	S: 99.30% W: 95.50% H: 98.60%	NA	S:99.40%	NA	NA	NA	NA	NA	NA
AgWTE	%	90.35%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average External Grid Availability											
Solar, Wind, Hybrid (as applicable)	%	97.09%	NA	NA	NA	S: 100.00% W: 98.00%	NA	NA	NA	NA	NA
AgWTE	%	98.27%	NA	NA	NA		NA	NA	NA	NA	NA
Financial Parameter											
Revenue from operations	₹ million	2,607.78	38,000.00	39,189.00	5,109.84	NA	6,802.10	NA	44,258.30	18,207.42	11,335.77
Total Income	₹ million	2,763.13	40,060.00	41,182.00	5,839.90	NA	7,516.90	NA	45,971.80	18,695.20	11,377.79
EBITDA	₹ million	1,336.32	33,480.00	28,231.00	5,149.07	NA	6,929.90	NA	11,686.70	5,973.04	2,463.88
EBITDA Margin	%	48.36%	83.57%	68.55%	88.17%	NA	92.19%	NA	25.42%	31.95%	21.66%
Adjusted EBITDA	₹ million	1,501.01	32,480.00	28,233.00	5,308.18	NA	6,750.30	NA	11,686.70	5,970.62	2,463.88

As on June 30, 2025	Units	SAEL Industries Ltd	Adani Green Energy Limited#	Renew Energy Global PLC#	ACME Solar Holdings Ltd.	Tata Power Renewable Energy Ltd.	NTPC Green Energy Limited	Juniper Green Energy Limited	Waaree Energies Limited	Premier Energies Limited	Vikram Solar Limited
Adjusted EBITDA Margin	%	54.32%	81.08%	68.56%	90.90%	NA	89.80%	NA	25.42%	31.94%	21.66%
Profit (Loss) for the period/year after tax ("**PAT**")	₹ million	(583.11)	8,240.00	5,131.00	1,308.24	NA	2,204.80	NA	7,728.90	3,077.93	1,333.64
Net Debt	₹ million	90,192.77	NA	NA	NA	NA	NA	NA	NA	NA	NA
Adjusted Total Equity	₹ million	11,287.83	NA	NA	NA	NA	NA	NA	NA	NA	NA
Net Debt to Adjusted Total Equity	(x)	7.99	NA	NA	NA	NA	NA	NA	NA	NA	NA
Days of Receivable Outstanding	(Days)	34.50	NA	NA	NA	NA	NA	NA	NA	NA	NA
Adjusted EBIDTA ROCE	(%)	4.89%	4.98%	4.70%	5.15%	NA	4.92%	NA	690.13%	42.56%	20.21%

Notes:
*Other includes wind, FDRE/RTC/PPS etc. #includes capacity of group company @Includes merchant projects (if any); ^^ Approximate figure

NA: Not Available as not available or reported for the particular period

Source: The Company, Company websites, Investor presentations, regulatory filings before SEBI, Crisil Intelligence.

The Company had lowest days of receivable outstanding amongst the listed peers (23 days) as on March 31, 2025.

Table 21: Key parameters for FY25

As on March 31, 2025	Units	SAEL Industries Ltd	Adani Green Energy Limited	Renew Energy Global PLC	ACME Solar Holdings Ltd.	Tata Power Renewable Energy Ltd.	NTPC Green Energy Limited	Juniper Green Energy Limited	Waaree Energies Limited	Premier Energies Limited	Vikram Solar Limited
Operational Parameter - Module Manufacturing											
Installed Capacity	MW	2,225.00	4,000.00#	6,400.00#	1,200.00	4,900.00#	NA	NA	15,000.00	5,100.00	4,500.00
Effective Installed Capacity	MW	1,513.06	NA	NA	NA	NA	NA	NA	NA	NA	1,646.29
Production	MW	890.89	NA	NA	NA	3,291.00	NA	NA	NA	NA	1,286.10
Capacity Utilisation	%	58.88%	NA	NA	NA	NA	NA	NA	NA	NA	78.12%
Operational Parameter - IPP											
Total Capacity (A+B+C+D)	MW	***4,415.70***	***33,000.00^^***	***18,455.20***	***7,015.00***	***10,960.00***	**23,179.00**	***NA***	***NA***	***NA***	***NA***
Solar	MW	4,250.80	NA	7,635.90	3,485.00	4,711.00	18,944.00	NA	NA	NA	NA
Solar +ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other*	MW	-	NA	10,819.30@	3,530.00	6,249.00	4,235.00	NA	NA	NA	NA

As on March 31, 2025	Units	SAEL Industries Ltd	Adani Green Energy Limited	Renew Energy Global PLC	ACME Solar Holdings Ltd.	Tata Power Renewable Energy Ltd.	NTPC Green Energy Limited	Juniper Green Energy Limited	Waaree Energies Limited	Premier Energies Limited	Vikram Solar Limited
Agri Waste to Energy	MW	164.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
Operational Capacity (A)	MW	**441.00**	**14,243.00**	**11,167.20**	**2,750.00**	**5,550.00**	**5,902.00**	**NA**	**NA**	**NA**	**NA**
Solar	MW	320.80	10,103.00	5,271.10	2,750.00	3,991.00	5,419.00	NA	NA	NA	NA
Solar +ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other*	MW	-	4,140.00	5,896.10@	NA	1,559.00	483.00	NA	NA	NA	NA
Agri Waste to Energy	MW	120.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
Completed and pending Capacity COD (B)	MW	**-**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Solar	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Solar + ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other*	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Agri Waste to Energy	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Under Construction Contracted Capacity (C)	MW	**2,044.70**	**15,407.00^^**	**7,288.00**	**2,175.00**	**5,410.00**	**17,277.00**	**NA**	**NA**	**NA**	**NA**
Solar	MW	2,000.00	NA	2,365.00	135.00	720.00	13,525.00	NA	NA	NA	NA
Solar +ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other	MW	-	NA	4,923.00@	2,040.00	4,690.00	3,752.00	NA	NA	NA	NA
Agri Waste to Energy	MW	44.70	NA	NA	NA	NA	NA	NA	NA	NA	NA
Awarded Capacity (D)	MW	**1,930.00**	**3,350.00^^**	**NA**	**2,090.00**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Solar	MW	1,930.00	NA	NA	600.00	NA	NA	NA	NA	NA	NA
Solar +ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other	MW	-	NA	NA	1,490.00	NA	NA	NA	NA	NA	NA
Agri Waste to Energy	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average Capacity Utilization Factor											
Solar, Wind, Hybrid (as applicable)	%	21.98%	S: 24.80% W: 27.20% H: 39.50%	S: 25.00% W: 26.00%	S:23.70%	S: 22.90% W: 19.40%	NA	NA	NA	NA	NA
AgWTE (Generation)	%	90.99%	NA	NA	NA	NA	NA	NA	NA	NA	NA

As on March 31, 2025	Units	SAEL Industries Ltd	Adani Green Energy Limited	Renew Energy Global PLC	ACME Solar Holdings Ltd.	Tata Power Renewable Energy Ltd.	NTPC Green Energy Limited	Juniper Green Energy Limited	Waaree Energies Limited	Premier Energies Limited	Vikram Solar Limited
AgWTE (Export)	%	81.31%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average Plant Availability											
Solar, Wind, Hybrid (as applicable)	%	99.82%	S: 99.50% W: 95.90% H: 99.60%	NA	S:99.60%	S: 100.00% W: 98.00%	NA	NA	NA	NA	NA
AgWTE	%	89.35%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average External Grid Availability											
Solar, Wind, Hybrid (as applicable)	%	99.34%	NA	NA	NA	NA	NA	NA	NA	NA	NA
AgWTE	%	97.18%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Financial Parameter											
Revenue from operations	₹ million	6,647.69	1,12,120.00	97,513.33	14,051.31	98,762.70	22,096.40	NA	1,44,445.00	65,187.45	34,234.53
Total Income	₹ million	7,305.19	1,24,220.00	1,09,071.44	15,752.41	100,460.20	24,657.00	NA	1,48,460.60	66,520.86	34,595.27
EBITDA	₹ million	1,419.15	1,02,050.00	83,056.56	13,845.56	40,334.50	21,715.60	NA	31,191.80	19,149.32	5,280.85
EBITDA Margin	%	19.43%	82.15%	76.15%	87.89%	40.15%	88.07%	NA	21.01%	28.79%	15.26%
Adjusted EBITDA	₹ million	3,589.28	1,00,870.00	82,483.45	14,055.40	43,174.50	21,727.90	NA	31,232.00	19,142.16	5,280.85
Adjusted EBITDA Margin	%	49.13%	81.20%	75.62%	89.23%	42.98%	88.12%	NA	21.04%	28.78%	15.26%
Profit (Loss) for the period/year after tax ("**PAT**")	₹ million	(2,809.48)	20,010.00	4,592.23	2,508.21	6,723.00	4,741.20	NA	19,281.30	9,371.32	1,398.31
Net Debt	₹ million	71,167.22	691,910.000	639,803.91	74,453.17	275,837.80	1,44,547.70	NA	(72,301.20)	(9,791.80)	417.02
Adjusted Total Equity	₹ million	11,342.01	1,21,370.00	1,12,601.62	45,105.80	134,778.00	1,84,403.40	NA	94,792.00	28,221.06	12,419.89
Net Debt to Adjusted Total Equity	(x)	6.27	5.71	5.68	1.65	2.05	0.78	NA	(0.76)	(0.35)	0.03
Days of Receivable Outstanding	(Days)	23.12	27.58	65.29	51.58	82.70	47.37	NA	29.70	44.26	89.65
Adjusted EBIDTA ROCE	(%)	22.35%	18.66%	16.32%	22.38%	19.08%	21.17%	NA	-264.48%	123.37%	48.52%

#Module manufacturing capacity for the group company, @Includes merchant projects (if any); ^^ Approximate figure

Table 22: Key parameters for FY24

As on March 31, 2024	Units	SAEL Industries Ltd	Adani Green Energy Limited	Renew Energy Global PLC	ACME Solar Holdings Ltd.	Tata Power Renewable Energy Ltd.	NTPC Green Energy Limited	Juniper Green Energy Limited	Waaree Energies Limited	Premier Energies Limited	Vikram Solar Limited
Operational Parameter - Module Manufacturing											
Installed Capacity	*MW*	225.00	4,000.00#	6,400.00#	NA	682.00#	NA	NA	12,000.00	3,360.00	3,500.00
Effective Installed Capacity	*MW*	190.96	NA	NA	NA	NA	NA	NA	11,010.00	1,670.00	1,779.50
Production	*MW*	47.48	NA	NA	NA	130	NA	NA	4,780.00	1,006.87	855.70
Capacity Utilisation	*%*	24.86%	NA	NA	NA	NA	NA	NA	43.37%	60.29%	48.09%
Operational Parameter - IPP											
Total Capacity (A+B+C+D)	*MW*	***2,485.70***	***21,953.00***	***15,643.30***	***5,350.00***	**10,030.00**	***14,496.00***	***2,439.30***	***NA***	***NA***	***NA***
Solar	*MW*	*2,320.80*	*16,802.00*	*7,564.40*	*3,120.00*	4,293.00	*12,396.00*	*735.00*	*NA*	*NA*	*NA*
Solar +ESS	*MW*	-	*NA*	*NA*	*NA*	NA	*NA*	*NA*	*NA*	*NA*	*NA*
Other	*MW*	-	*5,151.00*	*8,078.90@*	*2,230.00*	5,737.00	*2,100.00*	*1,704.30*	*NA*	*NA*	*NA*
Agri Waste to Energy	*MW*	*164.90*	*NA*	*NA*	*NA*	NA	*NA*	*NA*	*NA*	*NA*	*NA*
Operational Capacity (A)	*MW*	***286.30***	***10,934.00***	***9,521.40***	***1,320.00***	***4,524.00***	***2,925.00***	***660.20***	***NA***	***NA***	***NA***
Solar	*MW*	*220.80*	*7,393.00*	*4,159.40*	*1320.00*	*3,265.00*	*2,825.00*	*635.00*	*NA*	*NA*	*NA*
Solar +ESS	*MW*	-	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Other	*MW*	-	*3,541.00*	*5,362.00@*	*NA*	*1,259.00*	*100.00*	*25.20*	*NA*	*NA*	*NA*
Agri Waste to Energy	*MW*	*65.50*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Completed and pending COD capacity (B)	*MW*	***-***	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***
Solar	*MW*	-	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Solar +ESS	*MW*	-	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
*Other**	*MW*	-	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Agri Waste to Energy	*MW*	-	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Under Construction Contracted Capacity (C)	*MW*	***1,799.40***	***11,019.00***	***6,121.90***	***1,650.00***	***5,506.00***	***11,571.00***	***339.10***	***NA***	***NA***	***NA***
Solar	*MW*	*1,700.00*	*9,409.00*	*3,405.00*	*1,500.00*	*1,028.00*	*9,571.00*	*100.00*	*NA*	*NA*	*NA*
Solar +ESS	*MW*	-	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
*Other**	*MW*	-	*1,610.00*	*2,716.90@*	*150.00*	*4,478.00*	*2,000.00*	*239.10*	*NA*	*NA*	*NA*
Agri Waste to Energy	*MW*	*99.40*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Awarded Capacity (D)	*MW*	***400.00***	***NA***	***NA***	***2,380.00***	***NA***	***NA***	***1,440.00***	***NA***	***NA***	***NA***
Solar	*MW*	*400.00*	*NA*	*NA*	*300.00*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Solar +ESS	*MW*	-	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
*Other**	*MW*	-	*NA*	*NA*	*2,080.00*	*NA*	*NA*	*1,440.00*	*NA*	*NA*	*NA*
Agri Waste to Energy	*MW*	-	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*

As on March 31, 2024	Units	SAEL Industries Ltd	Adani Green Energy Limited	Renew Energy Global PLC	ACME Solar Holdings Ltd.	Tata Power Renewable Energy Ltd.	NTPC Green Energy Limited	Juniper Green Energy Limited	Waaree Energies Limited	Premier Energies Limited	Vikram Solar Limited
Average Capacity Utilization Factor											
Solar, Wind, Hybrid (as applicable)	%	20.90%	S: 24.50% W: 29.40% H: 40.70%	S: 25.00% W: 28.00%	S:24.59%	S: 22.70% W:20.20%	S: 19.78% W: 23.97%	S:25.83%	NA	NA	NA
AgWTE (Generation)	%	89.00%	NA	NA	NA	NA	NA	NA	NA	NA	NA
AgWTE (Export)	%	79.79%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average Plant Availability											
Solar, Wind, Hybrid (as applicable)	%	99.90%	S: 99.70% W: 95.50% H: 99.50%	NA	S:99.41%	S: 100.00% W:98.00%	NA	S: 98.57%	NA	NA	NA
AgWTE	%	87.18%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average External Grid Availability											
Solar, Wind, Hybrid (as applicable)	%	99.28%	NA	NA	NA	NA	NA	NA	NA	NA	NA
AgWTE	%	99.63%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Financial Parameter											
Revenue from operations	₹ million	5,584.66	92,200.00	81,947.46	13,192.50	101,751.90	19,626.00	3,915.60	1,13,976.09	31,437.93	25,109.90
Total Income	₹ million	5,870.12	1,05,210.00	96,531.33	14,662.67	104,001.80	20,376.60	4,244.57	1,16,327.63	31,713.11	25,239.62
EBITD	₹ million	970.78	86,620.00	73,230.96	19,848.56	33,207.50	18,190.30	3,708.45	21,509.19	5,066.41	3,999.07
EBITDA Margin	%	16.54%	82.33%	75.86%	135.37%	31.93%	89.27%	87.37%	18.49%	15.98%	15.84%
Adjusted EBITDA	₹ million	1,979.14	86,190.00	72,834.63	12,361.65	34,216.00	18,190.30	3,708.45	18,095.77	5,053.18	4,115.51
Adjusted EBITDA Margin	%	33.72%	81.92%	75.45%	84.31%	32.90%	89.27%	87.37%	15.56%	15.93%	16.31%
Profit (Loss) for the period/year after tax ("**PAT**")	₹ million	(2,671.41)	12,600.00	4,147.32	6,977.81	7,478.70	3,428.60	400.66	12,743.77	2,313.25	797.18
Net Debt	₹ million	17,710.04	506,860.00	565,200.93	67,527.73	182,324.20	1,23,246.00	17,112.94	(36,200.90)	9,668.13	6,880.98
Adjusted Total Equity	₹ million	8,939.90	1,06,420.00	1,05,217.44	25,908.69	128,968.40	62,321.40	17,316.79	40,878.10	6,468.51	4,454.17
Net Debt to Adjusted Total Equity	(x)	1.98	4.76	5.37	2.61	1.41	1.98	0.99	(0.89)	1.49	1.54
Days of Receivable Outstanding	(Days)	47.59	27.37	69.32	84.97	115.10	99.51	23.06	30.76	70.10	116.24
Adjusted EBIDTA ROCE	(%)	16.33%	17.64%	16.76%	18.10%	16.41%	24.43%	13.81%	-396.05%	99.34%	42.36%

Table 23: Key parameters for FY23

As on March 31, 2023	Units	SAEL Industries Ltd	Adani Green Energy Limited	Renew Energy Global PLC	ACME Solar Holdings Ltd.	Tata Power Renewable Energy Ltd.	NTPC Green Energy Limited	Juniper Green Energy Limited	Waaree Energies Limited	Premier Energies Limited	Vikram Solar Limited
Operational Parameter - Module Manufacturing											
Installed Capacity	MW	225.00	4,000.00#	NA	NA	670.00#	NA	NA	9,000.00	1,370.00	3,500.00
Effective Installed Capacity	MW	92.08	NA	NA	NA	NA	NA	NA	6,500.00	1,140.00	1,079.00
Production	MW	1.65	NA	NA	NA	NA	NA	NA	2,630.00	488.02	426.30
Capacity Utilisation	%	1.79%	NA	NA	NA	NA	NA	NA	40.46%	42.81%	39.51%
Operational Parameter - IPP											
Total Capacity (A+B+C+D)	MW	**485.70**	**20,434.00**	**13,726.20**	**3,359.00**	**6,596.00**	**8,861.00**	**704.30**	NA	NA	NA
Solar	MW	320.80	15,543.00	6,572.40	3,309.00	4,254.00	8,311.00	635.00	NA	NA	NA
Solar + ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other*	MW	-	4,891.00	7,153.80@	50.00	2,342.00	550.00	69.30	NA	NA	NA
Agri Waste to Energy	MW	164.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
Operational Capacity (A)	MW	**286.30**	**8,086.00**	**8,012.80**	**1,459.00**	**3,927.00**	**2,611.00**	**560.00**	NA	NA	NA
Solar	MW	220.80	4,975.00	3,765.00	1,459.00	2,995.00	2,561.00	560.00	NA	NA	NA
Solar + ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other*	MW	-	3,111.00	4,247.80@	NA	932.00	50.00	NA	NA	NA	NA
Agri Waste to Energy	MW	65.50	NA	NA	NA	NA	NA	NA	NA	NA	NA
Completed and Pending COD (B)	MW	**-**	**NA**	**NA**	**NA**	**NA**	**NA**	NA	NA	NA	NA
Solar	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Solar + ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other*	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Agri Waste to Energy	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Under Construction Contracted Capacity (C)	MW	**149.40**	**10,449.00**	**5,713.40**	**1,800.00**	**2,669.00**	**6,250.00**	**69.30**	NA	NA	NA
Solar	MW	50.00	8,669.00	2,807.40	1,750.00	1,259.00	5,750.00	NA	NA	NA	NA
Solar + ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other*	MW	-	1,780.00	2,906.00@	50.00	1,410.00	500.00	69.30	NA	NA	NA
Agri Waste to Energy	MW	99.40	NA	NA	NA	NA	NA	NA	NA	NA	NA
Awarded Capacity (D)	MW	**50.00**	**1,899.00**	**NA**	**100.00**	**NA**	**NA**	**75.00**	**NA**	**NA**	**NA**
Solar	MW	50.00	1,899.00	NA	100.00	NA	NA	75.00	NA	NA	NA
Solar + ESS	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other*	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Agri Waste to Energy	MW	-	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average Capacity Utilization Factor											
Solar, Wind, Hybrid (as applicable)	%	20.48%	S: 24.70% W: 25.20% H: 35.50%	S: 25.00% W: 27.00%	S:22.08%	S: 21.80% W:19.10%	S: 16.48% W: 27.17%	S:25.36%	NA	NA	NA

As on March 31, 2023	Units	SAEL Industries Ltd	Adani Green Energy Limited	Renew Energy Global PLC	ACME Solar Holdings Ltd.	Tata Power Renewable Energy Ltd.	NTPC Green Energy Limited	Juniper Green Energy Limited	Waaree Energies Limited	Premier Energies Limited	Vikram Solar Limited
AgWTE (Generation)	%	76.94%	NA	NA	NA	NA	NA	NA	NA	NA	NA
AgWTE (Export)	%	68.57%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average Plant Availability											
Solar, Wind, Hybrid (as applicable)	%	99.81%	S: 99.60% W: 94.30% H: 99.10%	NA	S:99.23%	S: 100% W:98%	NA	S:99.21%	NA	NA	NA
AgWTE	%	81.12%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average External Grid Availability											
Solar, Wind, Hybrid (as applicable)	%	99.44%	NA	NA	NA	NA	NA	NA	NA	NA	NA
AgWTE	%	99.41%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Financial Parameter											
Revenue from operations	₹ million	3,889.33	77,760.00	79,328.05	12,949.04	81,969.30	1,696.90	3,313.07	67,508.73	14,285.34	20,732.30
Total Income	₹ million	3,981.23	86,170.00	89,309.26	13,613.73	84,833.30	1,706.40	3,624.86	68,603.64	14,632.12	20,919.11
EBITDA	₹ million	1,302.24	56,370.00	64,396.37	12,784.98	32,027.50	1,548.10	2,982.87	9,235.54	1,141.00	2,048.59
EBITDA Margin	%	32.71%	65.42%	72.10%	93.91%	37.75%	90.72%	82.29%	13.46%	7.80%	9.79%
Adjusted EBITDA	₹ million	1,365.04	57,720.00	62,947.64	12,390.62	32,027.50	1,548.10	2,982.87	9,441.34	1,128.81	2,048.59
Adjusted EBITDA Margin	%	34.29%	66.98%	70.48%	91.02%	37.75%	90.72%	82.29%	13.76%	7.71%	9.79%
Profit (Loss) for the period/year after tax ("**PAT**")	₹ million	(846.14)	9,730.00	(5,029.03)	(31.74)	7,299.10	1,730.80	(120.58)	5,002.77	(133.36)	144.91
Net Debt	₹ million	9,826.56	4,72,760.00	4,52,925.42	72,652.06	115,274.70	53,451.00	19,215.63	(16,470.78)	5,037.02	6,290.80
Adjusted Total Equity	₹ million	4,622.67	73,040.00	1,06,852.76	19,005.63	122,197.50	48,892.90	7,829.73	18,384.09	4,112.15	3,651.95
Net Debt to Adjusted Total Equity	(x)	2.13	6.47	4.24	3.82	0.94	1.09	2.45	(0.90)	1.22	1.72
Days of Receivable Outstanding	(Days)	47.82	76.10	116.89	166.11	124.53	1,190.41	19.89	16.45	13.93	116.34
Adjusted EBIDTA ROCE	(%)	11.26%	18.99%	16.05%	18.54%	17.51%	NA	19.95%	15926.69%	36.76%	22.73%

Notes:

- **Other includes wind, FDRE/RTC/PPS etc. #includes capacity of group company, @Includes merchant projects (if any)*
- *NA: Not Available for the particular period*
- *Module manufacturing related parameters for the Company have been considered as provided by the Company.*
- *Total contracted & awarded capacity is sum of all Operational Capacity, Completed & Pending COD Capacity, Under Construction Contracted Capacity and Awarded capacity of all technology i.e. Solar, Solar+ESS, others and Waste to Energy.*
- *Operational Capacity represents the aggregate megawatt rated capacity of renewable power plants which have achieved commercial operational date ("COD") and obtained a commissioning certificate from a regulatory authority.*

- *Completed & Pending COD capacities is defined as capacity for projects which have completed EPC of the project, but for which commercial operations have not commenced and are pending final grid connectivity or first time charging (FTC) approvals*
- *Under Construction Contracted Capacity represents projects for which power purchase agreement has been signed but the project has not achieved its commercial operation date.*
- *Awarded capacity is defined as capacity for projects which Group has received a letter of award from the tendering body but which a PPA has not been signed.*
- *Capacity Utilization Factor ("CUF") or Average Plant Load Factor ("PLF") is the ratio of quantum of energy the plant is able to generate compared to its maximum possible generation capacity during its operational time. Average CUF or PLF for the assets refers to the weighted average of CUF/PLF of installed capacity in the portfolio as on the given financial year/period. In case where any project is commissioned in multiple phases/during the month, the period considered for calculation for such project is taken on a prorated basis, based on the number of operational days for the asset in the reporting period. Following formula is used for calculation of each segment*
    - *Capacity Utilization Factor ("CUF") for Solar IPP is the ratio of quantum of energy output of the plant compared to its maximum possible generation of AC capacity during its operational time.*
    - *Generation Plant Load Factor ("PLF (Generation)") for Waste to Energy is the ratio of quantum of energy the plant is able to generate compared to its maximum possible generation during its operational time.*
    - *Plant Load Factor ("PLF (Export)") is the ratio of quantum of energy, the Waste to Energy plant is able to export compared to its maximum possible export during its operational time. This is power exported to grid post deduction of auxiliary consumption of the plant from the generated power.*
- *Grid availability refers to the percentage of time that the electrical grid is available to accept and distribute the electricity generated by the power plant. Average Grid Availability for the assets held as on last date of the financial year/period refers to the weighted average of grid availability of the installed capacity in the portfolio as on the given financial year/period. In case where any project is commissioned in multiple phases/during the month, the period considered for Grid Availability calculation for such project is taken on a prorated basis, based on the number of operational days for the asset in the reporting period.*
- *Plant availability refers to the percentage of time that the power plant is capable of producing electricity as designed. It is a measure of the operational readiness of the plant's equipment and systems. Average Plant Availability for the assets held as on last date of the financial year/period refers to the weighted average of plant availability of the installed capacity in the portfolio as on given financial year/period. In case where any project is commissioned in multiple phases/during the month, the period considered for Plant Availability calculation for such project is taken on a prorated basis, based on the number of operational days for the asset in the reporting period.*

Source: The Company, Company websites, Annual Reports, Investor presentations, regulatory filings before SEBI, Crisil Intelligence.

Formulae used:

1. *Revenue from operation is the income earned in the usual course of business of the entity through sale of electricity (net off rebate) and sale modules, project management fees, O&M Services, EPC services etc.*
2. *Total Income is calculated as sum of Revenue from operations and other income.*
3. *EBITDA is calculated as profit or loss before Tax plus finance cost, depreciation, and amortization expense.*
4. *EBITDA Margin is computed as EBITDA divided by Total Income.*
5. *Adjusted EBITDA is calculated as profit or loss before Share of Profit of Associate and Joint Venture, Exceptional Item and Tax plus finance cost, depreciation and amortization expense, fair value adjustments of financial instruments (CCPS).*
6. *Adjusted EBITDA Margin is computed as Adjusted EBITDA divided by Total Income.*
7. *PAT- Loss/Profit for the year/period from continuing operations.*

8. *Net Debt is calculated as the sum of total borrowings (current and non-current), less cash and cash equivalents, bank balances other than cash equivalents, bank deposits with remaining maturity more than 12 months, bank deposits with remaining maturity less than 12 months and current investments.*
9. *Adjusted Total Equity is the aggregate of the Company's share capital, compulsorily convertible preference shares, reserves and surplus (including retained earnings), and other equity components, after deducting accumulated losses and items directly adjusted against equity.*
10. *Net Debt to Adjusted Total Equity ratio is calculated as Net Debt divided by Adjusted Total Equity*
11. *Days of Receivables Outstanding is calculated as closing trade receivables (excluding unbilled revenue) divided by billed revenue (revenue from operations plus opening unbilled revenue minus closing unbilled revenue) multiplied by 365 for yearly or 91 for the three months period ended June 30, 2025. Trade Receivables includes both current and non-current trade receivables.*
12. *Adjusted EBITDA ROCE is calculated as Adjusted EBITDA divided by opening capital employed and Opening Capital Employed is calculated as Adjusted total equity add total borrowings (current and non-current) less capital work in progress, capital advances, cash and cash equivalents, bank balances other than cash equivalents, bank deposits with remaining maturity more than 12 months, bank deposits with remaining maturity less than 12 months, current investments and non-current investments.*

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